ESL-TR-91/08-01

TEXAS LOANSTAR
MONITORING AND ANALYSIS PROGRAM

REPORT TO

THE MONITORING ADVISORY AND REVIEW COMMITTEE

VOLUME ONE

Presentations

August 19-20, 1991
Austin, Texas

Presentations by:

W. D. Turner
David E. Claridge
Aamer Athar
Kelly Kissock
Agami Reddy
David Ruch
Jeff Haberl
Srinivas Katipamula
Dean Willis
Robert López
Robert Sparks
John Bryant
Dennis O'Neal
Warren M. Heffington
Merwin Brown

ENERGY SYSTEMS LABORATORY
Department of Mechanical Engineering
Texas Engineering Experiment Station
Texas A&M University
College Station, Texas 77843

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VOLUME 1 - PRESENTATIONS

Table of Contents

Preface

The LoanSTAR program has now completed its second prototype year. This report is Volume I of a two volume set that documents the progress since the January 1991 MARC meeting.

This first volume contains photocopies of the material presented at the Monitoring and Advisory Review Committee (MARC) meeting held in Austin, Texas, on August 19-20, 1991.

The second volume contains papers and supporting material prepared by the LoanSTAR staff and faculty at Texas A&M University, as well as other supporting material.

This material is intended to be for discussion purposes only.

Final Agenda

MARC Meeting - August 19-20, 1991

Monday, August 19, 1991

REVIEW OF MONITORING AND ANALYSIS PROGRESS

8:00 - 8:30 a.m.	**Continental Breakfast**
8:30 - 8:40 a.m.	Welcome - Dan Turner
8:40 - 8:55 a.m.	Governor's Energy Office Overview - Carol Tombari
8:55 - 9:05 a.m.	Discussion of LoanSTAR Program - Mel Roberts
9:05 - 9:30 a.m.	LoanSTAR MAP Overview - Dan Turner
9:30 - 10:20 a.m.	Task 5 - Overview Analysis and Reporting - David Claridge --Reporting the Data - David Claridge --Agency Contact - Aamer Athar
10:20 - 10:35 a.m.	**Coffee Break**
10:35 - 12:15 p.m.	Task 5 - Continued --Preliminary Savings Analysis - Kelly Kissock --Uncertainty in Savings Analysis - Agami Reddy --NAC for Linear and Change-Point Models - David Ruch --DOE-2 Calibration Procedures - Jeff Haberl --Simplified Systems Modeling for Savings Analysis - Srinivas Katipamula --Summary of Analysis Developments and Results - David Claridge
12:15 - 1:15 p.m.	**Lunch**
1:15 - 1:35 p.m.	HC PRISM - Cathy Reynolds, Princeton University
1:35 - 2:35 p.m.	Task 4 and Tech Support --Systems Support - Dean Willis --Data Base - Robert Lopez --Programming and Test Bench - Robert Sparks --Communications and Data Summary - Jeff Haberl
2:35 - 2:55 p.m.	Task 2 - Summary of Installation Progress - John Bryant

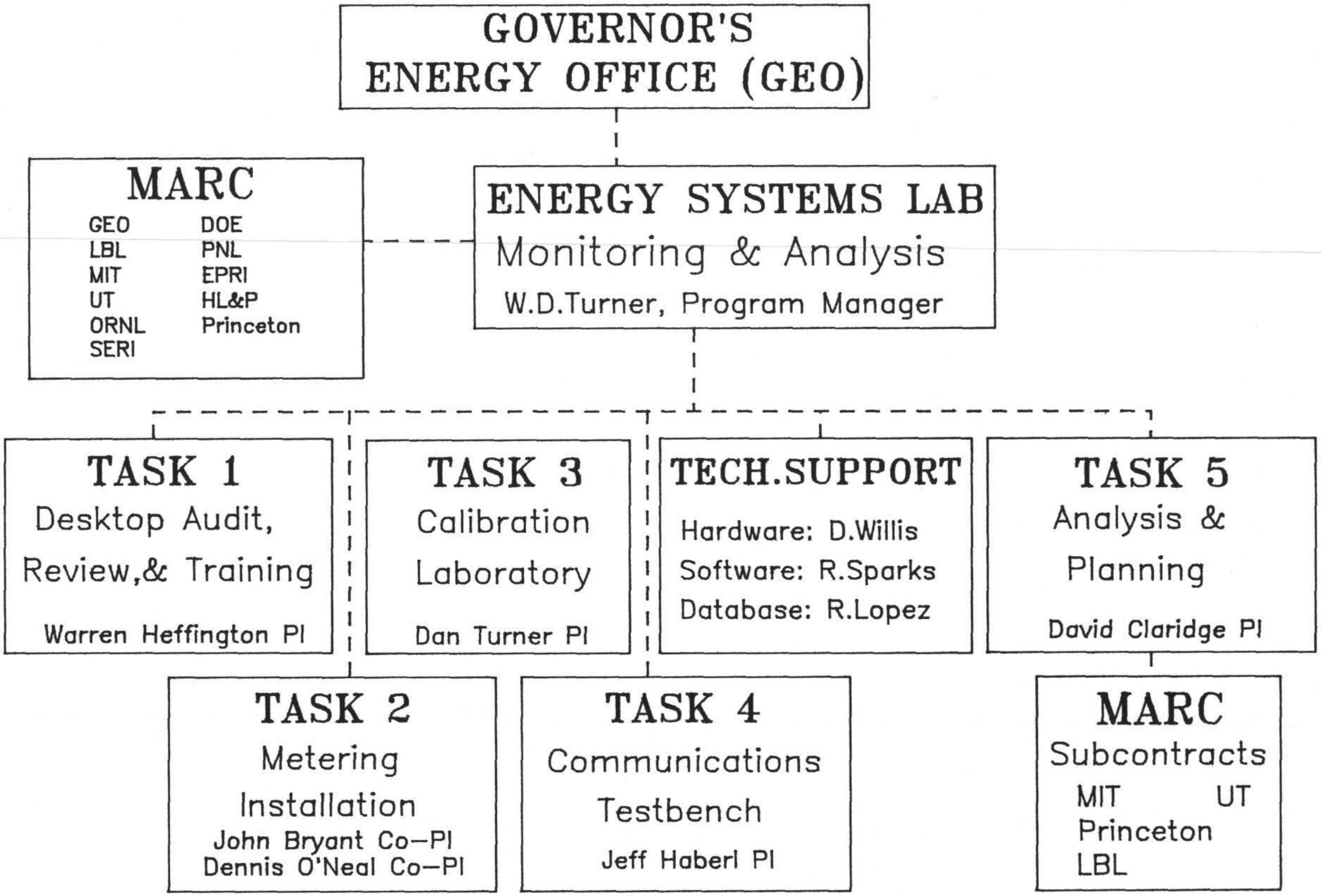
2:55 - 3:10 p.m.	**Coffee Break**
3:10 - 4:05 p.m.	Task 2 - Continued --Building Monitoring - Lessons Learned - Dennis O'Neal
4:05 - 4:50 p.m.	Task 3 - Calibration Laboratory - W. D. Turner --Flowmeter Calibration - Jeff Haberl
4:50 - 5:35 p.m.	Task 1 - Audit Progress and Reviews - Warren Heffington
6:30 p.m.	**Dinner - Iron Works Barbeque**

Tuesday, August 20, 1991

7:30 - 8:00 a.m.	**Continental Breakfast**
8:00 - 8:05 a.m.	Opening Remarks - Dan Turner
8:05 - 8:30 a.m.	U.S. Department of Energy - DOE/HUD Initiative - Ernie Freeman
8:30 - 8:55 a.m.	Electric Power Research Institute - EPRI Programs - Larry Carmichael
8:55 - 9:35 a.m.	Pacific Gas and Electric - ACT^2 Program - Merwin Brown
10:00 - 10:15 a.m.	**Coffee Break**
10:15 - 10:40 a.m.	Battelle - Dipstick Audits - Todd Taylor
10:40 - 11:05 a.m.	ORNL - Monitoring Programs - Bill Mixon
11:05 - 11:30 a.m.	SERI - Update on SERI Monitoring - Jay Burch
11:30 - 11:55 a.m.	MIT - Air Handler Measurements and Office Equipment - Les Norford
11:55 - 12:20 p.m.	UT-Austin - DOE-2 Calibration/Capitol Extension Analysis - Bruce Hunn
12:20 - 1:15 p.m.	**Lunch**

FUTURE PLANS

1:15 - 1:35 p.m.	Task 1 - Desk Top Audit Review
1:35 - 1:55 p.m.	Task 2 - Metering Equipment Installation and Subcontractor
1:55 - 2:20 p.m.	Task 3 - Calibration Laboratory
2:20 - 2:40 p.m.	Task 4 - Test Bench and Communications Testing
2:40 - 3:05 p.m.	Task 5 - Monitoring Analysis
3:05 - 3:30 p.m.	Task 6 - Improved Energy Audit Process
3:30 p.m.	**Adjourn**
4:00 p.m.	(Optional) Tour of Perry Casteneda Library LoanSTAR Installation at UT-Austin - J. Von Wolske


GOVERNOR'S ENERGY OFFICE (GEO)
MARC
GEO
DOE
LBL
PNL
MIT
EPRI
UT
HL&P
ORNL
Princeton
SERI
ENERGY SYSTEMS LAB
Monitoring & Analysis
W.D.Turner, Program Manager
TASK 1
Desktop Audit, Review,& Training
Warren Heffington PI
TASK 3
Calibration Laboratory
Dan Turner PI
TECH.SUPPORT
Hardware: D.Willis
Software: R.Sparks
Database: R.Lopez
TASK 5
Analysis & Planning
David Claridge PI
TASK 2
Metering Installation
John Bryant Co-PI
Dennis O'Neal Co-PI
TASK 4
Communications Testbench
Jeff Haberl PI
MARC
Subcontracts
MIT
UT
Princeton
LBL

TASK 5

ANALYSIS AND REPORTING

PROGRESS PRESENTATION

David E. Claridge, P.I.
Jeff S. Haberl
Srinivas Katipamula
Dennis L. O'Neal
Agami Reddy*
Mohsen Farzad
Robert Sparks
Robert Lopez
Aamer Athar
David Ruch*
Kelly Kissock*
Jianxun Wu*
Mustafa Abbas
Naveen Balakrishnan*
Doug Bronson
Amitava Dhar*
Jinrong Wang

***Funded/Partially Funded by ERAP**

August 1991

OUTLINE

* Task Responsibilities

* Overview of Buildings, Retrofits and Data

* Building Indices

* Results

  - Monthly Reports
  - Agency Contact/O&Ms
  - Savings Measured

* Analysis Approach and Development

  - Uncertainty in Savings
  - Normalized Annual Consumption Measures
  - DOE-2 Calibration
  - Calibrated Symplified Systems Models

* Summary and Conclusions

TASK RESPONSIBILITIES:

- -- **Coordinate preparation of monitoring and analysis plan**
- -- **Select and develop analysis techniques**
- -- **Develop analysis software**
- -- **Analyze collected Data**

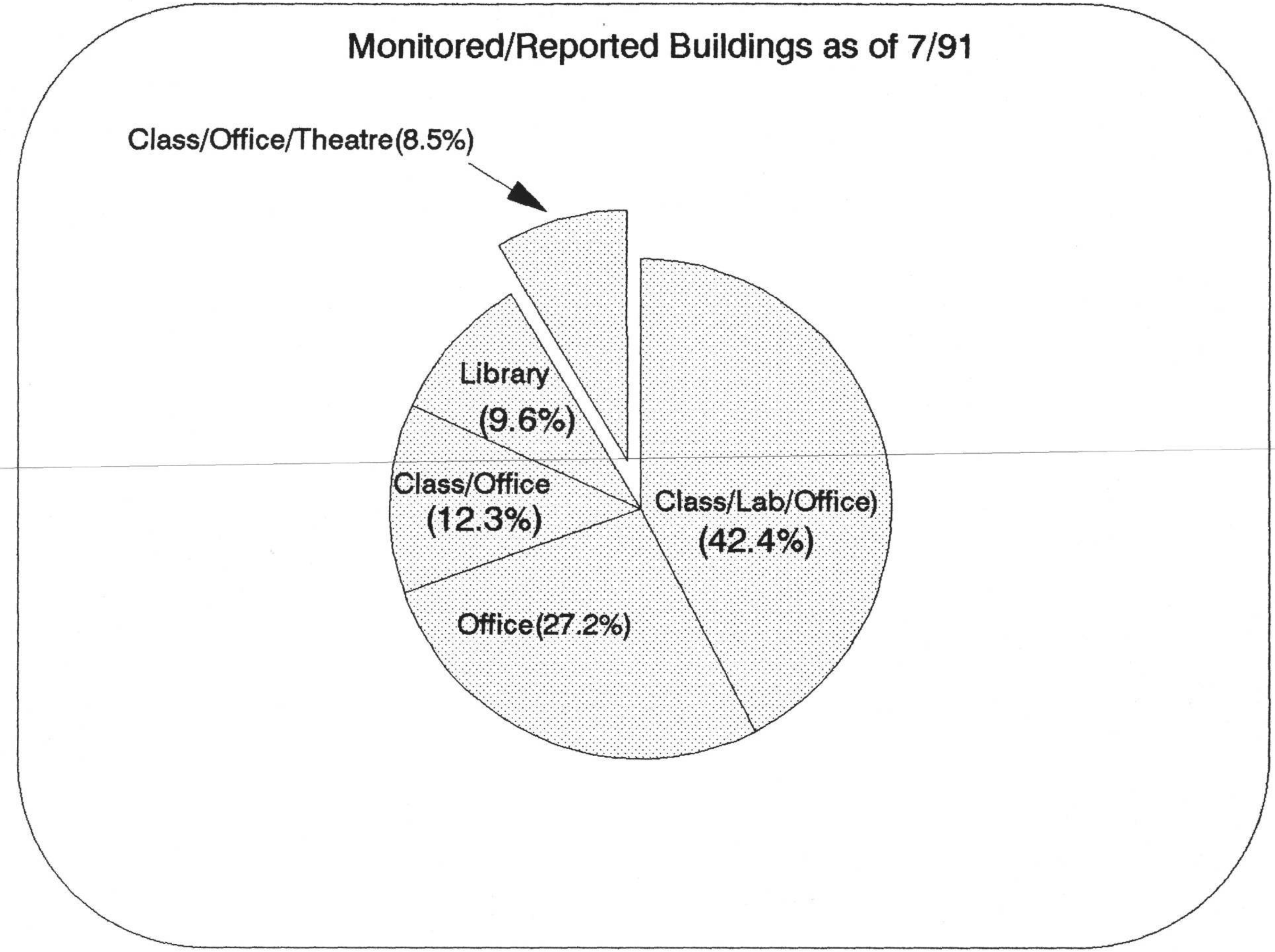
TO:

1. **Determine retrofit savings**
2. **Identify O&M opportunities**
3. **Determine individual measure savings when feasible**
4. **Initiate end-use database**

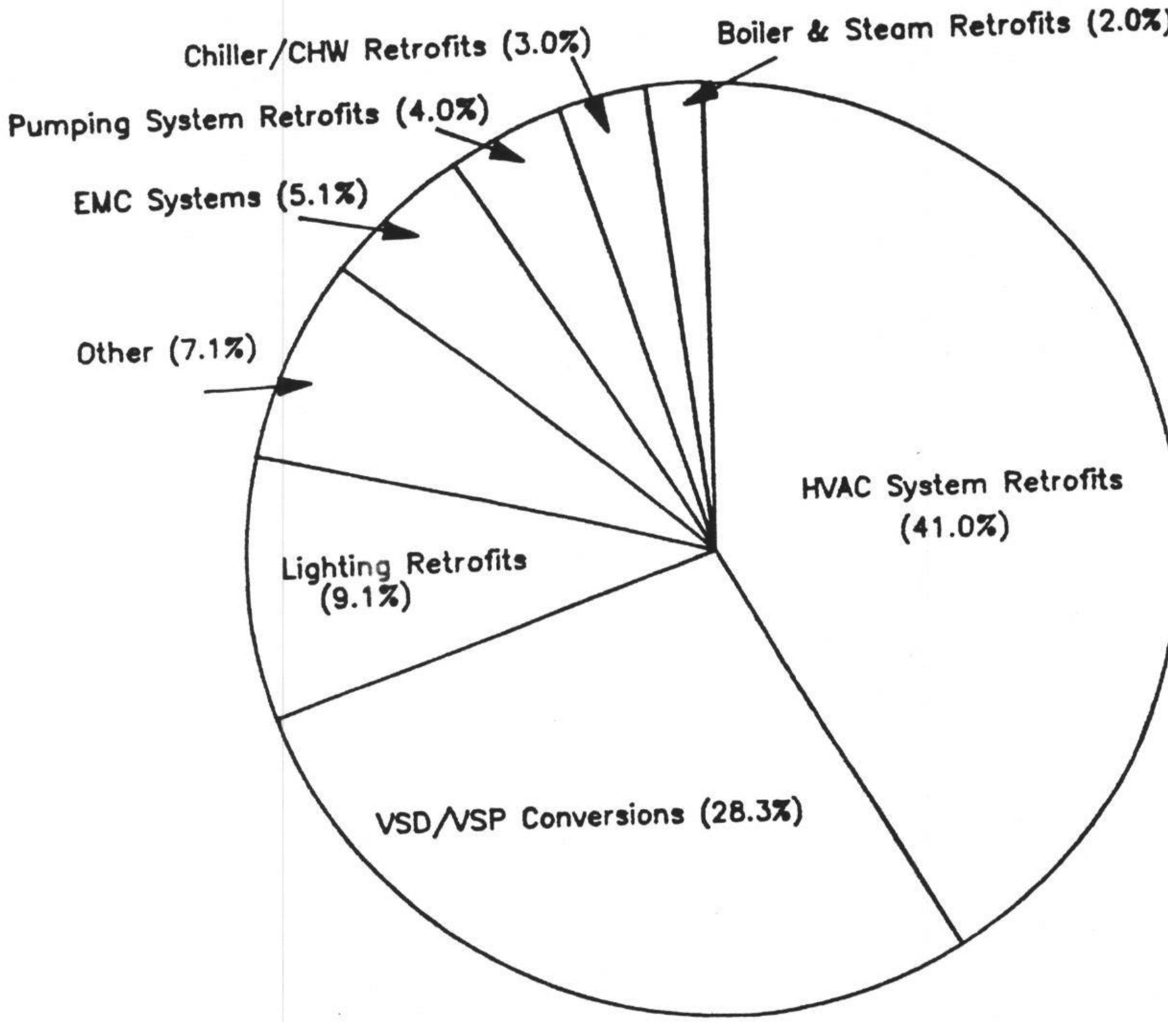
LoanSTAR Buildings with Monthly Reporting - 7/91

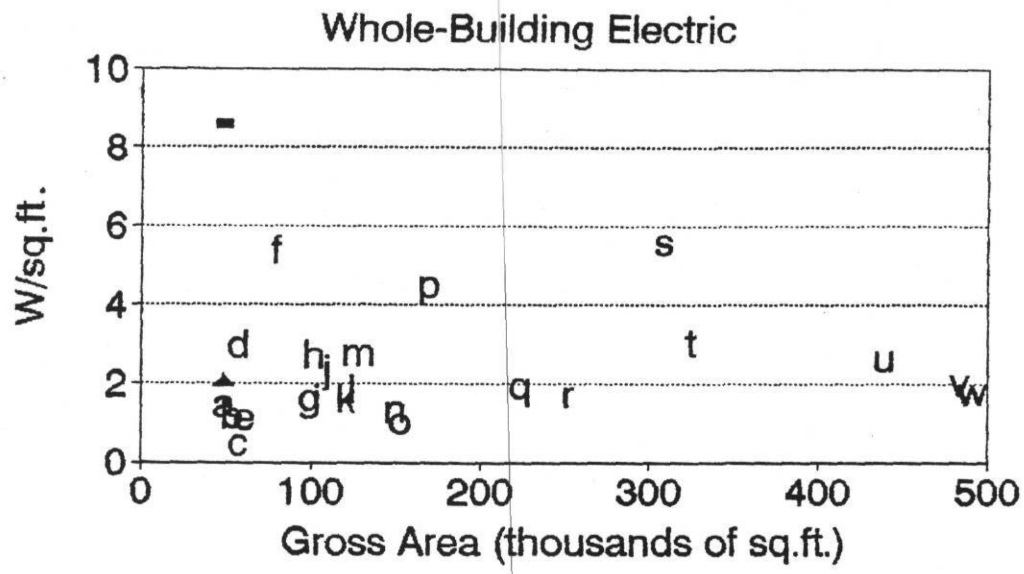
	Gross Area (ft^2)	Building Use
Texas A&M University		
Zachry Engineering Center	324,400	Class/Lab/Office
University of Texas		
Education Building	251,161	Class/Office
University Teaching Center	152,690	Class
P. C. Library	483,895	Library
Garrison Building	54,069	Class/Office/Auditorium
Gearing Building	61,041	Class/Office/Lab
Waggener Hall	57,598	Class/Office/Lab
Welch Building	439,540	Class/Office/Lab
Burdine Building	103,441	Class/Office/Auditorium
Nursing Building	99,815	Class/Lecture/Lounge
Winship Building	109,064	Class/Office/Theatre
R. A. Steindam Building	56,849	Class/Office/Lab
Painter Building	128,409	Class/Office/Lab
W. C. Hogg Building	48,905	Class/Office/Auditorium
	2,046,477	
University of Texas at Arlington		
University Hall	123,450	Class/Office/Lecture
Business Building	149,000	Class/Lecture
Fine Arts Building	223,000	Class/Office/Theatre
	495,450	
Texas Capitol Complex		
J. H. Reagan	169,746	Office
J. E. Rudder	80,000	Office/Computer
Insurance Building	102,000	Office
Insurance Annex	62,000	Office
Archives	120,000	Library/Office
W. B. Travis	491,000	Office
L. B. Johnson	308,080	Office
Winters	503,000	Office/Computer
	1,835,826	
UT Health Science Center - Houston		
School of Public Health	233,738	Lab/Class/Office
Texas Department of Health	484,019	Office/Lab
UT Health Science Center - San Antonio		
Dental School	606,097	Class/Office/Lab
Medical School	284,000	Class/Office/Lab
	890,097	

TOTAL - 6,310,007

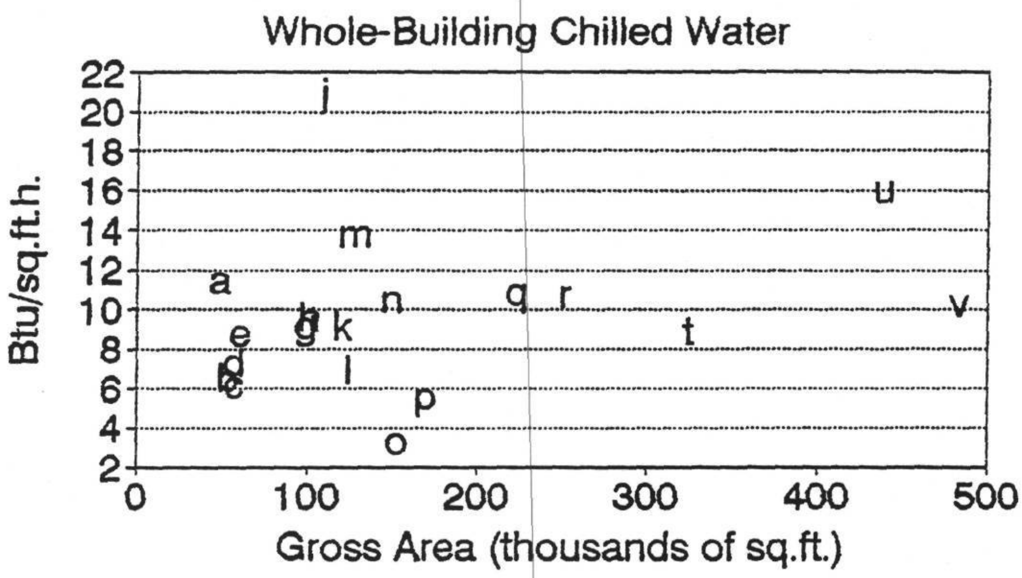

Monitored/Reported Buildings as of 7/91
Class/Office/Theatre(8.5%)
Library
(9.6%)
Class/Office
(12.3%)
Class/Lab/Office)
(42.4%)
Office(27.2%)

Summary of ECRMs for Buildings Being Monitored

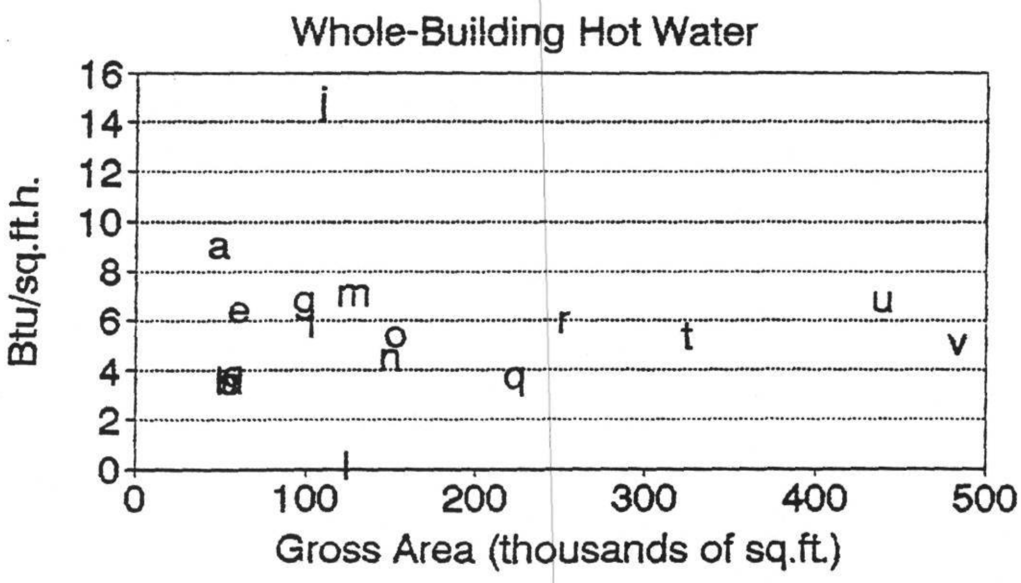




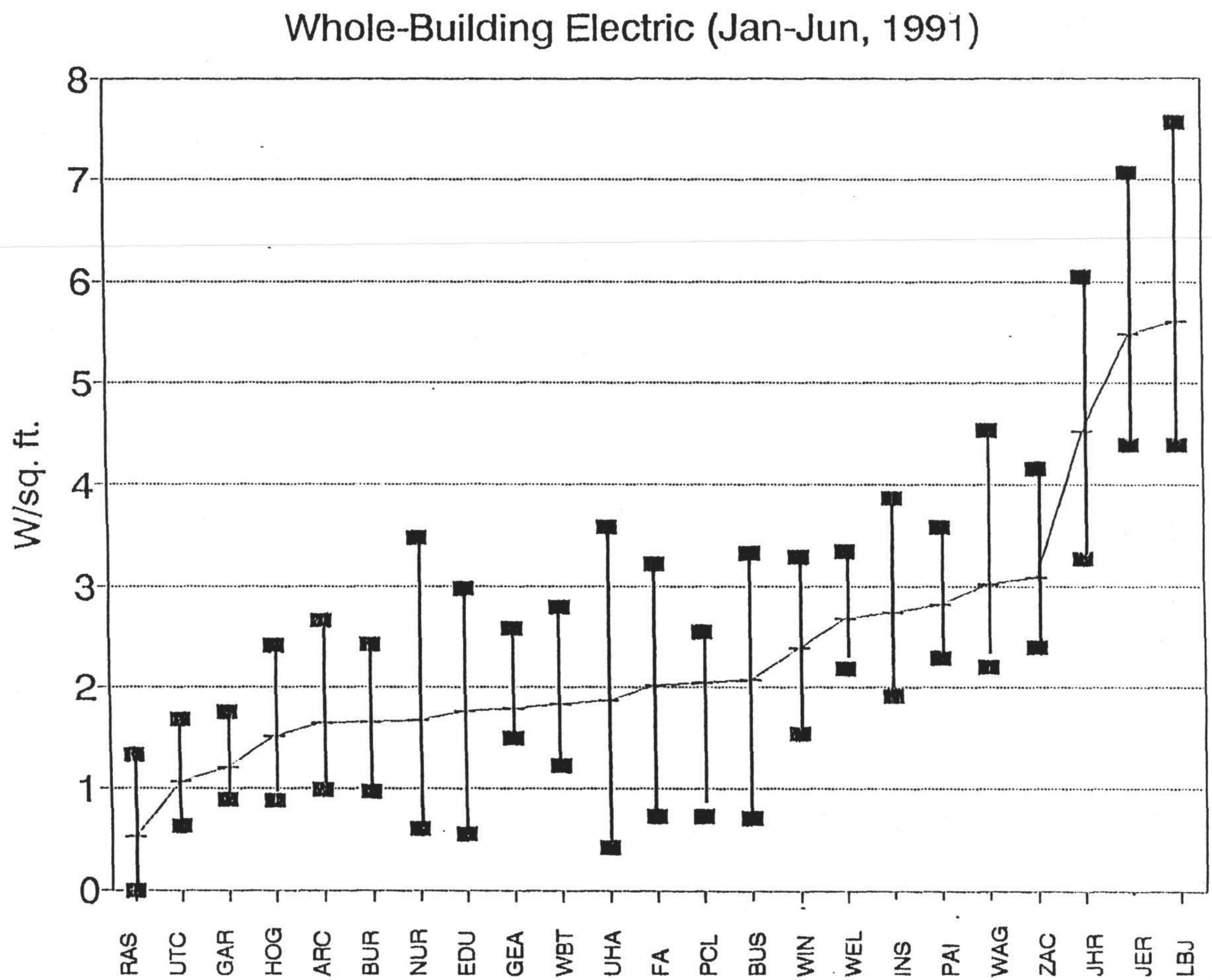
Whole-Building Electric
W/sq.ft.
Gross Area (thousands of sq.ft.)



Whole-Building Chilled Water
Btu/sq.ft.h.
Gross Area (thousands of sq.ft.)

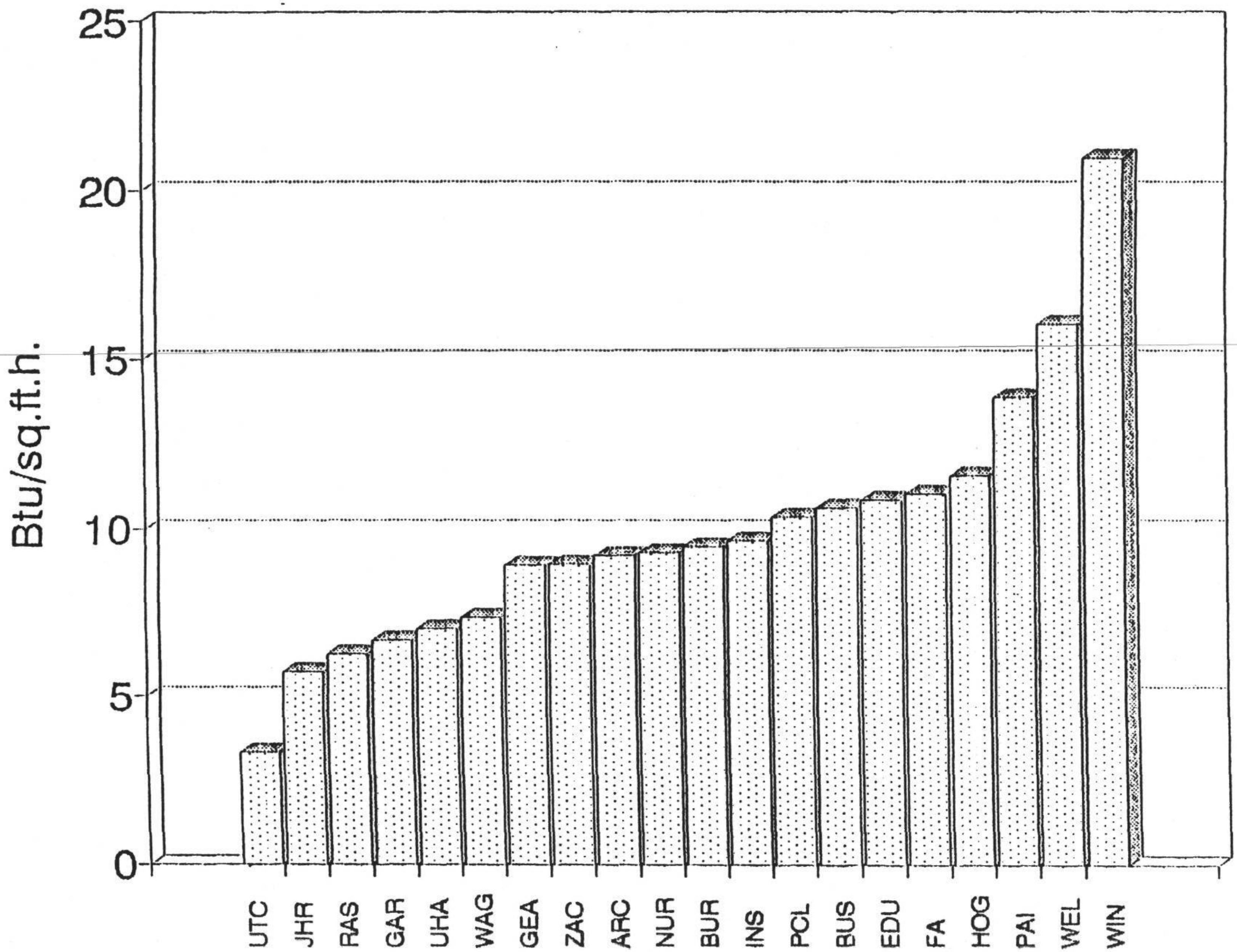


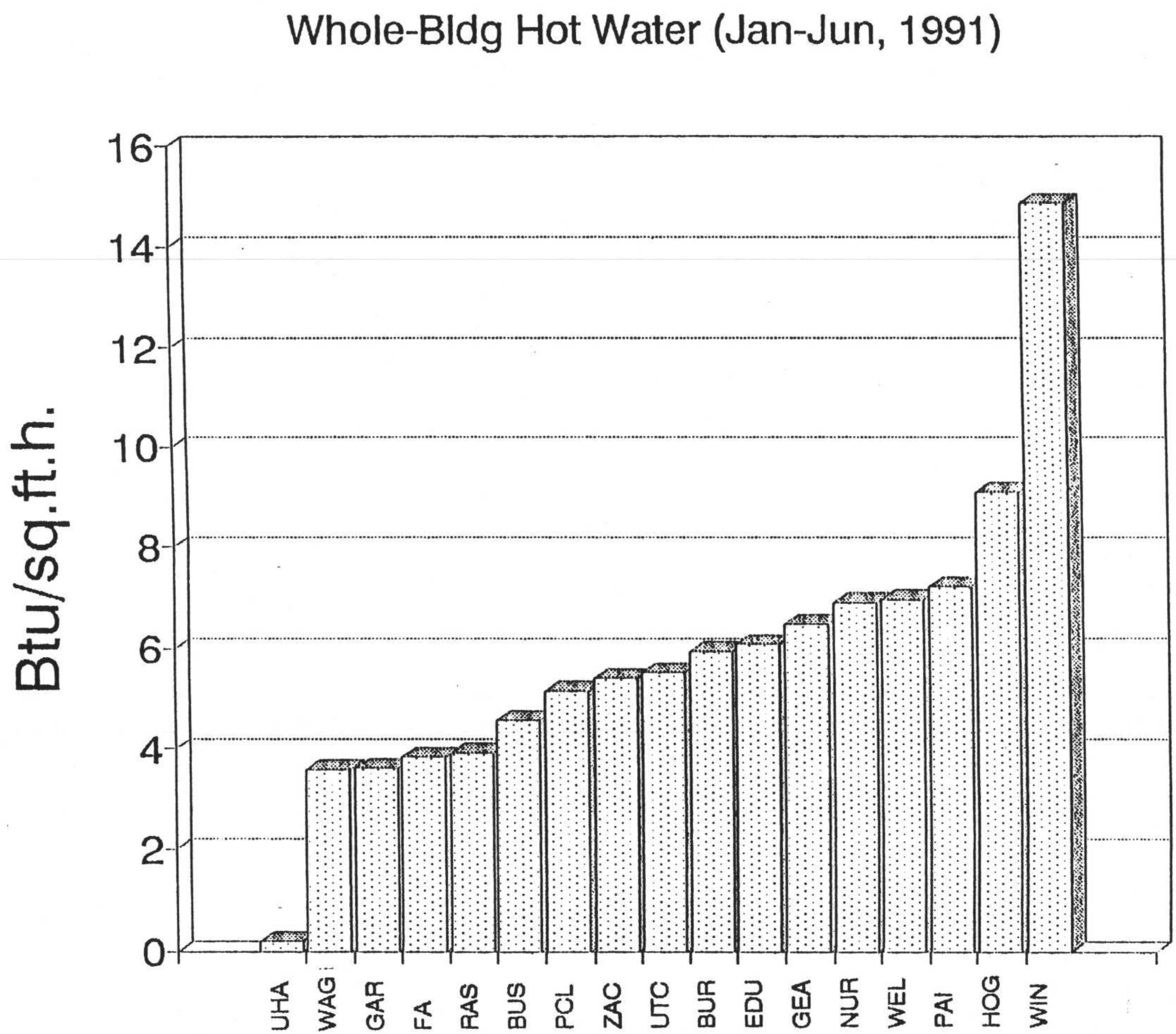
Whole-Building Hot Water
Btu/sq.ft.h.
Gross Area (thousands of sq.ft.)



Whole-Building Electric (Jan-Jun, 1991)
W/sq. ft.
0
1
2
3
4
5
6
7
8
RAS
UTC
GAR
HOG
ARC
BUR
NUR
EDU
GEA
WBT
UHA
FA
PCL
BUS
WIN
WEL
INS
PAI
WAG
ZAC
JHR
JER
LBJ

Whole-Bldg Chilled Water (Jan-Jun,1991)




Whole-Bldg Hot Water (Jan-Jun, 1991)
Btu/sq.ft.h.
16
14
12
10
8
6
4
2
0
UHA
WAG
GAR
FA
RAS
BUS
PCL
ZAC
UTC
BUR
EDU
GEA
NUR
WEL
PAI
HOG
WIN

Codes	3-Letter Code	Building's Name	Gross Area (sq.ft)	Agency	Location
a	HOG	W.C.HOGG	48,905	U.T.Austin	Austin
b	GAR	GARRISON	54,069	U.T.Austin	Austin
c	RAS	R.A.STEINDAM	56,849	U.T.Austin	Austin
d	WAG	WAGGENER	57,598	U.T.Austin	Austin
e	GEA	GEARING	61,041	U.T.Austin	Austin
f	JER	J.E.RUDDER	80,000	SP&GSC	Austin
g	NUR	NURSING	99,815	U.T.Austin	Austin
h	INS	INSURANCE	102,000	SP&GSC	Austin
i	BUR	BURDINE	103,441	U.T.Austin	Austin
j	WIN	WINSHIP	109,064	U.T.Austin	Austin
k	ARC	ARCHIVES	120,000	SP&GSC	Austin
l	UHA	UNIVERSITY HALL	123,450	U.T.Arlington	Arlington
m	PAI	PAINTER HALL	128,409	U.T.Austin	Austin
n	BUS	BUSINESS	149,900	U.T.Arlington	Arlington
o	UTC	UNIV TEACHING CENTER	152,690	U.T.Austin	Austin
p	JHR	J.H.REAGAN	169,746	SP&GSC	Austin
q	FA	FINE ARTS	223,000	U.T.Arlington	Arlington
r	EDU	EDUCATION	251,161	U.T.Austin	Austin
s	LBJ	L.B.JOHNSON	308,080	SP&GSC	Austin
t	ZAC	ZACHRY ENGG CENTER	324,400	Texas A&M	College Station
u	WEL	WELCH HALL	439,540	U.T.Austin	Austin
v	PCL	P.CASTANEDA LIBRARY	483,895	U.T.Austin	Austin
w	WBT	W.B.TRAVIS	491,000	SP&GSC	Austin
[illegible]	INS X	INSURANCE ANNEX	62,000	SP&GSC	Austin

OUTLINE

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* **Overview of Buildings, Retrofits and Data**
* **Building Indices**

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- **Monthly Reports**
- **Agency Contact/O&Ms**
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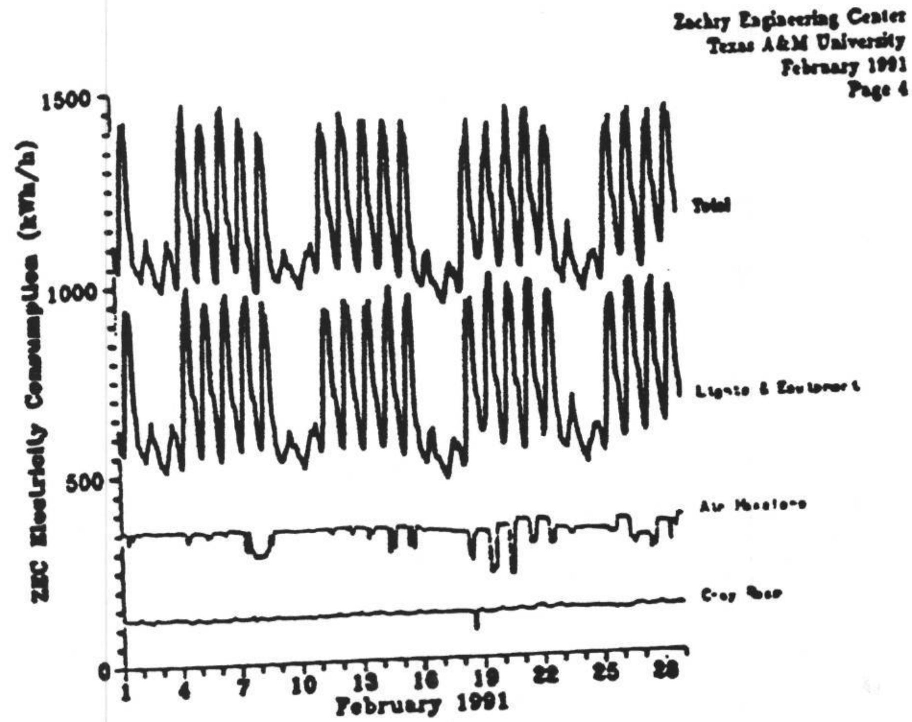
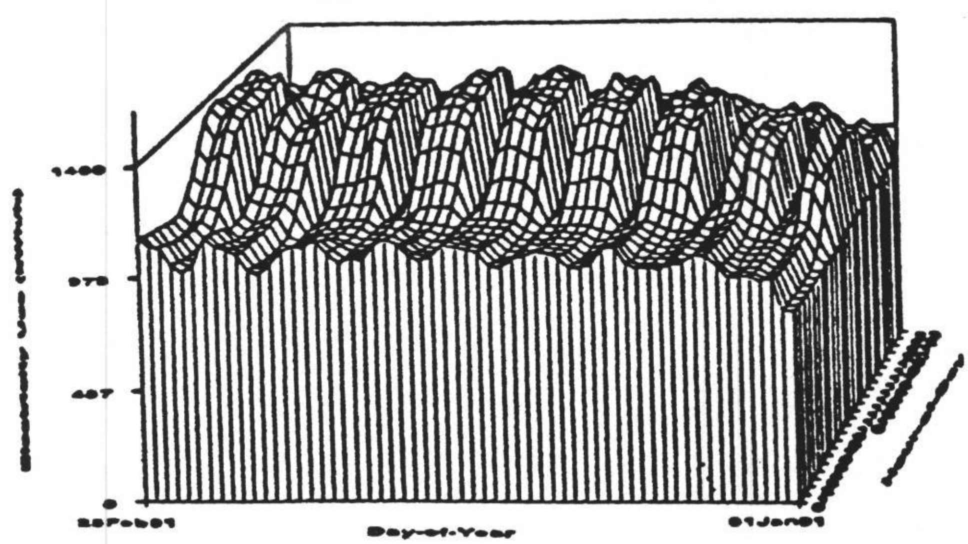
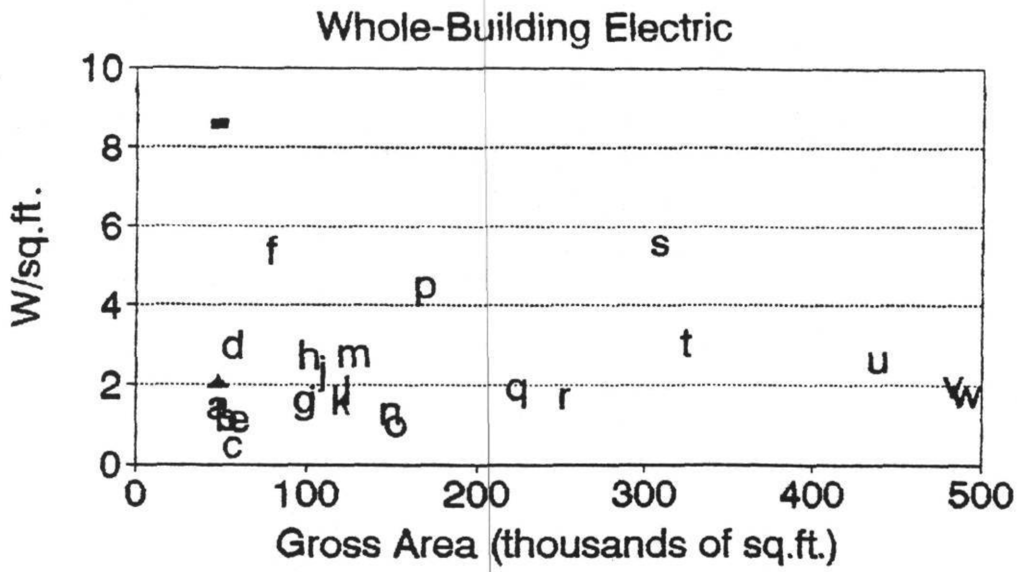
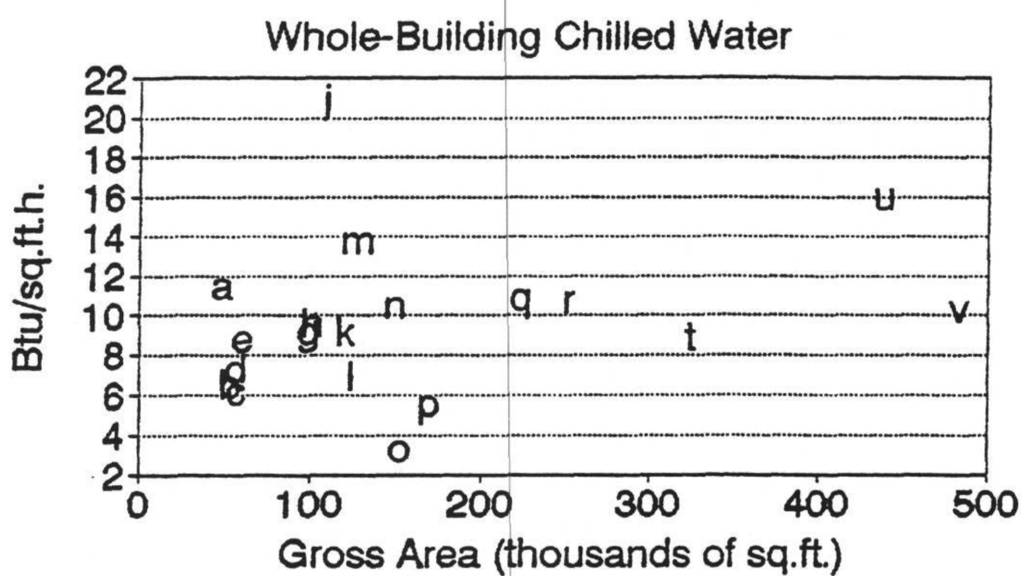
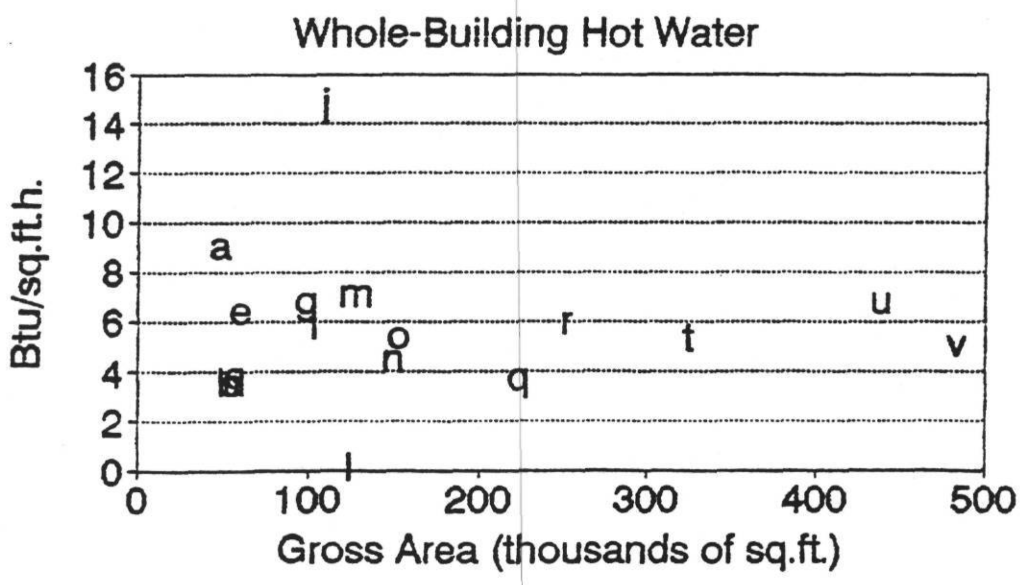
Excerpts from Typical Monthly Energy Consumption Report





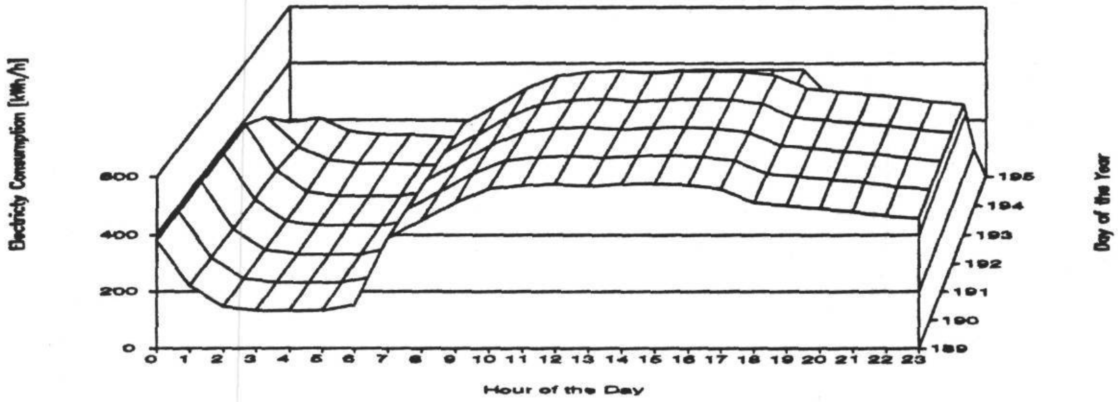

Whole-Building Electric
W/sq.ft.
Gross Area (thousands of sq.ft.)


Whole-Building Chilled Water
Btu/sq.ft.h.
Gross Area (thousands of sq.ft.)

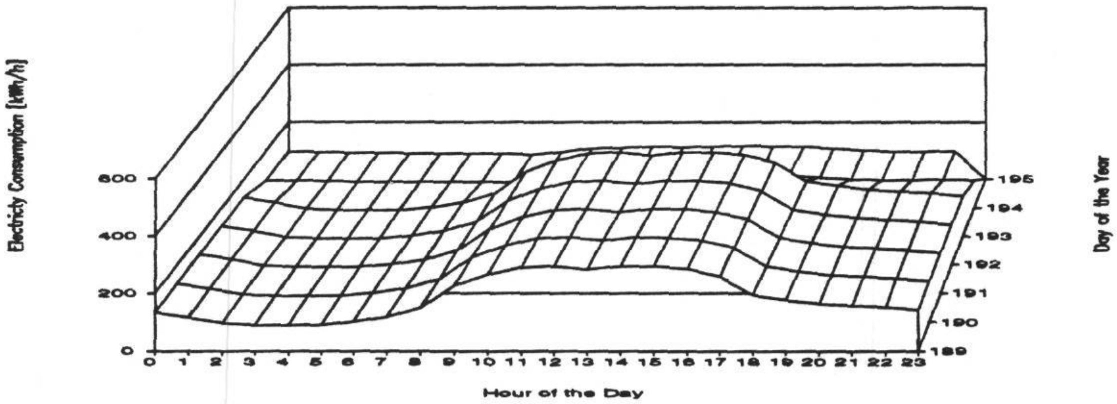

Whole-Building Hot Water
Btu/sq.ft.h.
Gross Area (thousands of sq.ft.)

Method for Determining Energy Savings for Non-Weather Dependent Loads

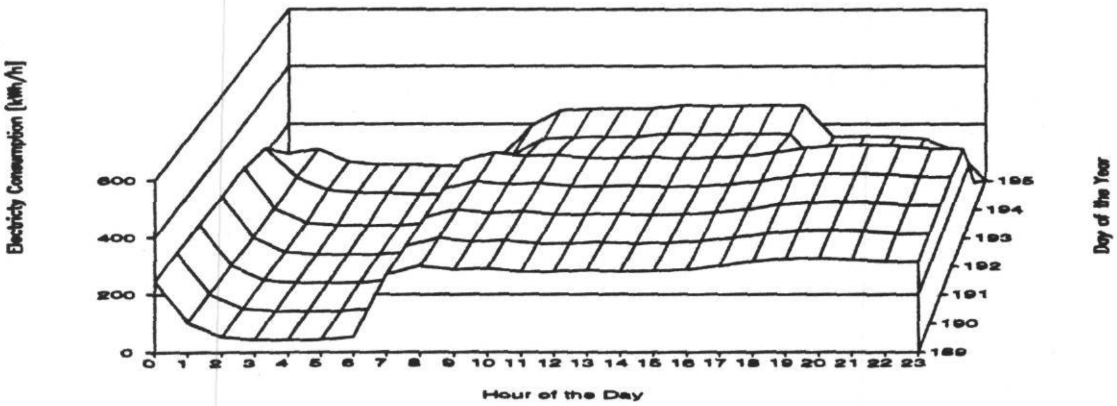
Pre-retrofit Lights and Equipment for Education Building for Typical Week



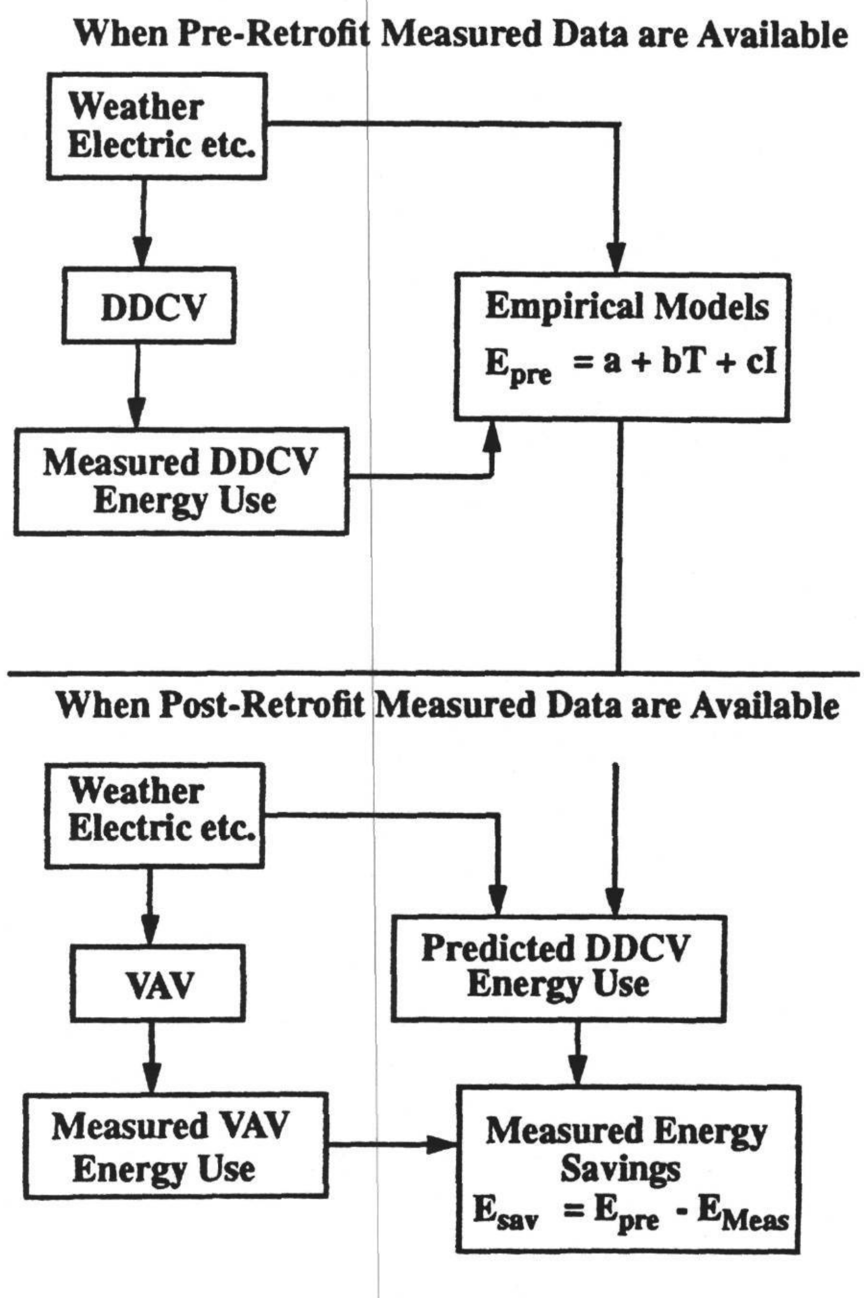
Post-retrofit Lights and Equipment for Education Building for Typical Week



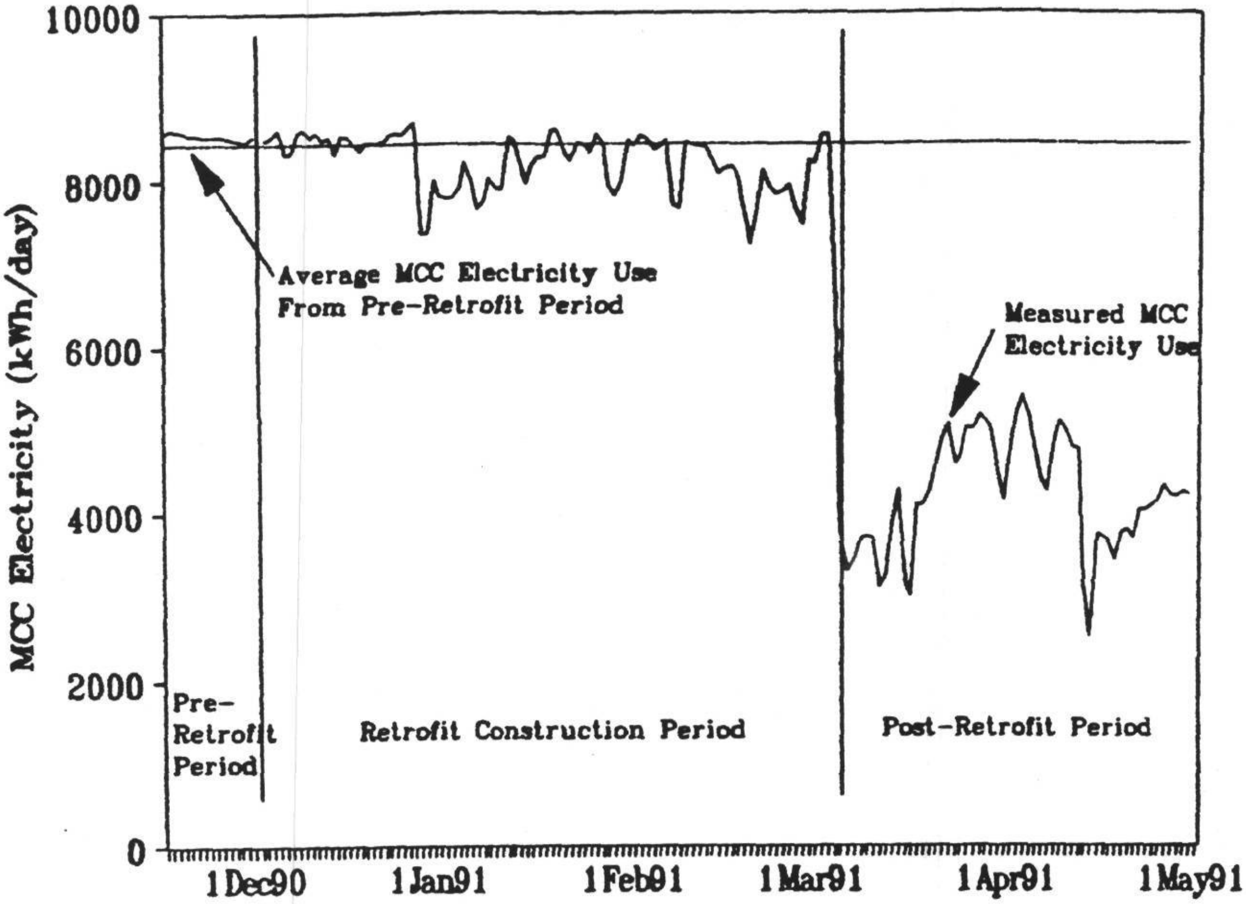
Savings Post-retrofit Lights and Equipment for Education Building - Typical Week



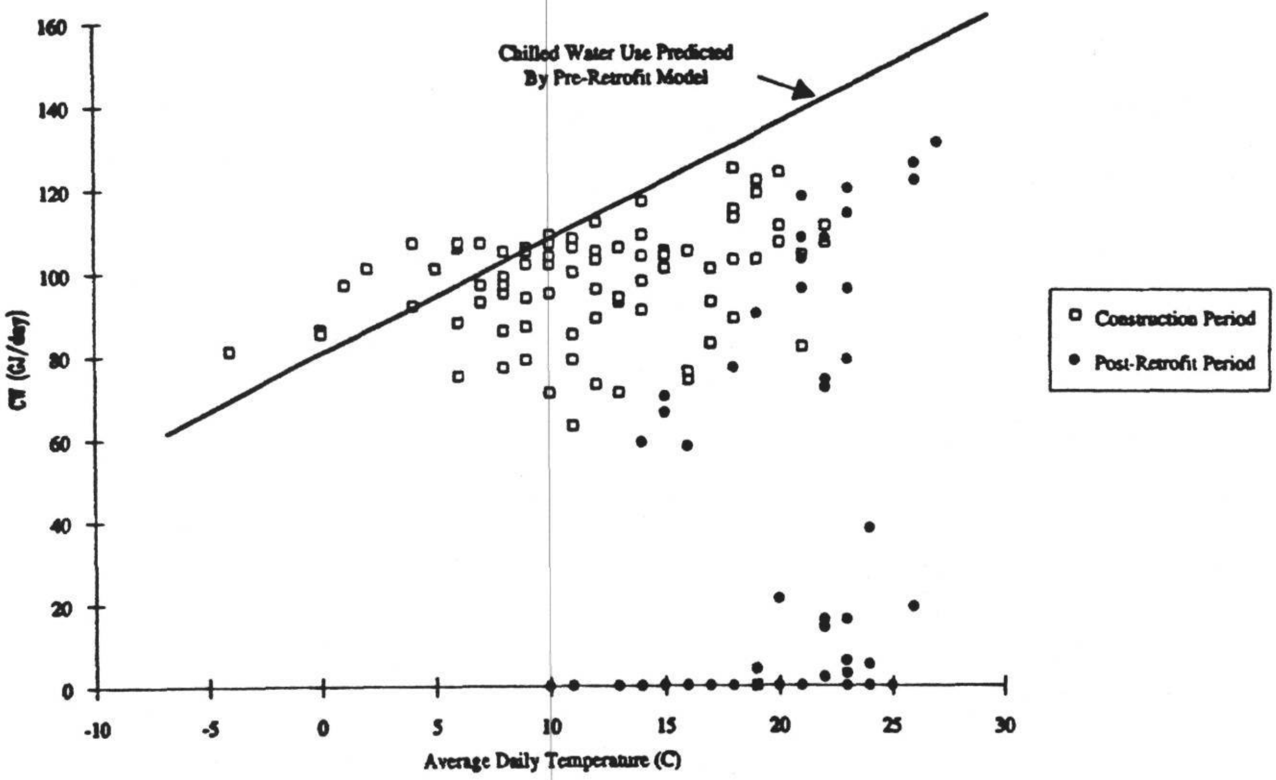
Method for Determining Energy Savings for Weather Dependent Loads



Motor Control Center electricity use which is almost exclusively air handler use is shown for November 14, 1990 - April 30, 1991. The horizontal dotted lines shows average pre-retrofit MCC use.



Chilled water consumption plotted as a function of average daily ambient temperature. The model for pre-retrofit consumption is shown with triangles while measured consumption during construction and post-retrofit consumption for March-April, 1991 are shown as squares and circles respectively.



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    - Normalized Annual Consumption Measures
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    - Calibrated Symplified Systems Models
* Summary and Conclusions

MONITORED COMMERCIAL BUILDING ENERGY DATA: REPORTING THE RESULTS

David Claridge, Jeff Haberl, Robert Sparks, Rob Lopez, Kelly Kissock, Aamer Athar

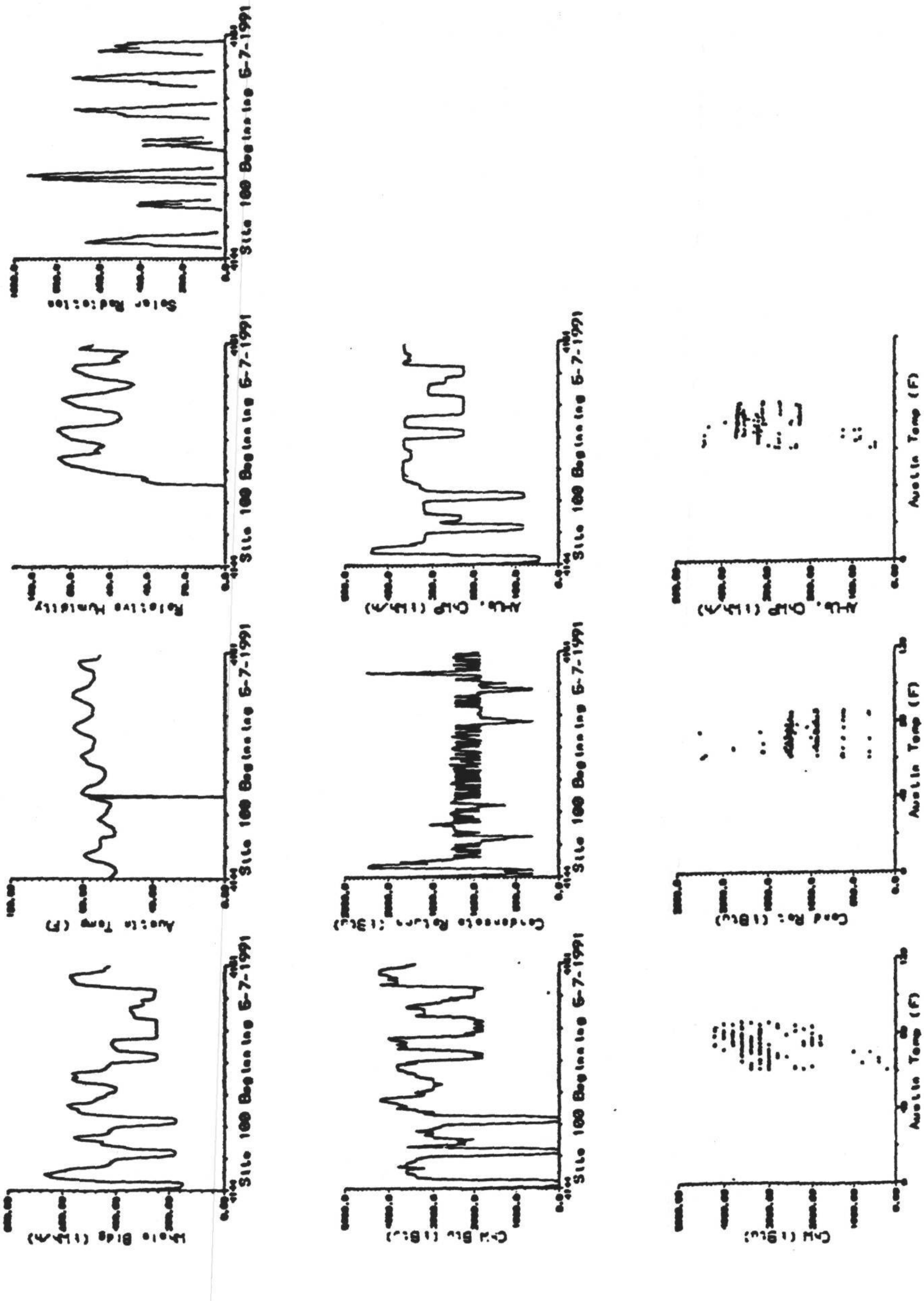
August 1991

Three Major Reporting Forms Used

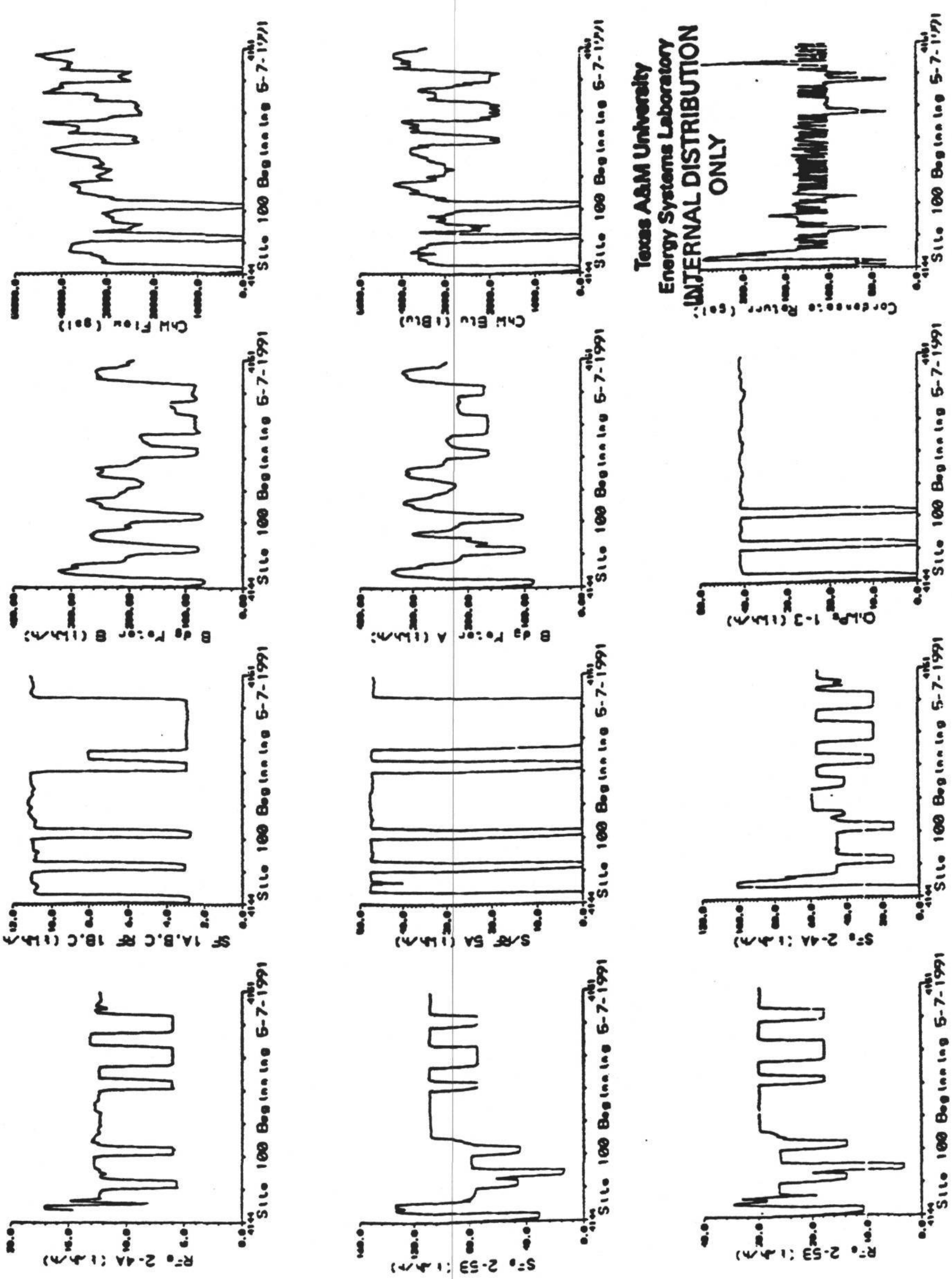
- **Weekly Inspection Plots**
- **Computer Files with Browsing Software**
- **Monthly Energy Consumption Reports**

WEEKLY INSPECTION PLOTS

Inspection plot summary sheet showing data for the UT-Austin Education Building for the week May 7-13, 1991.

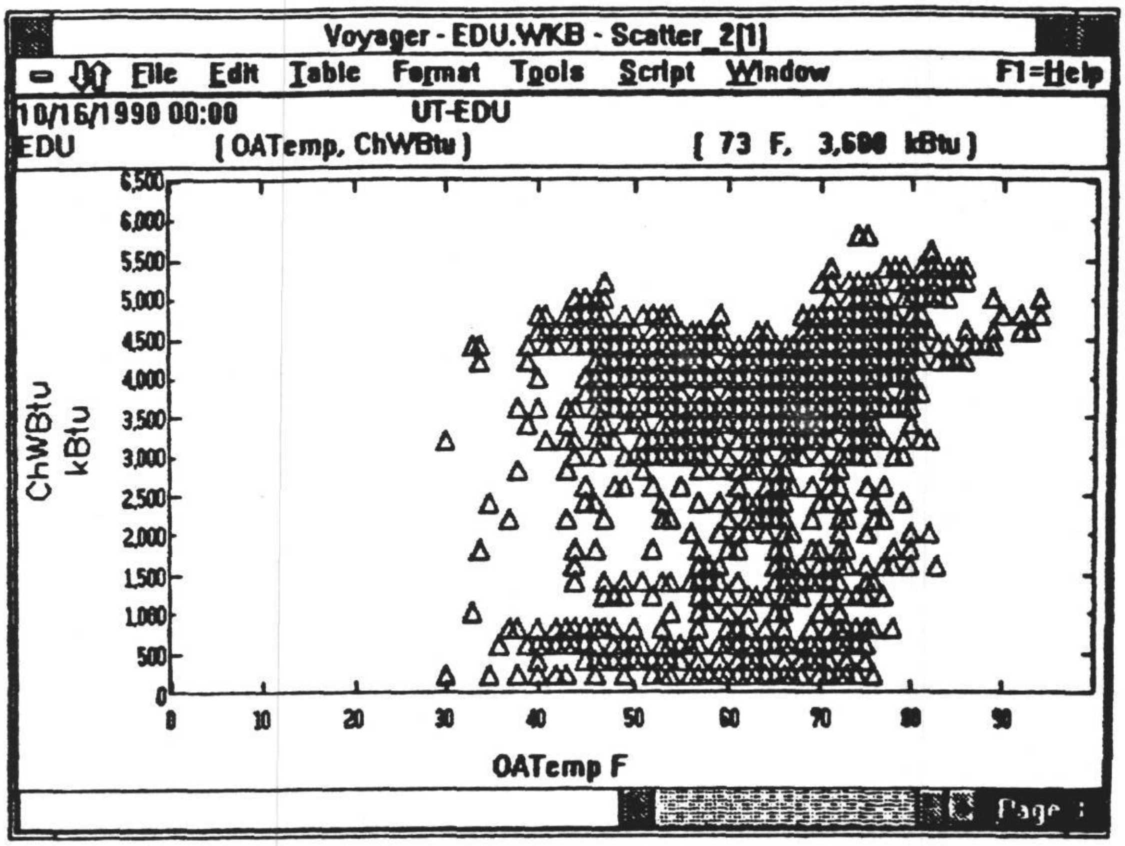


Inspection plots showing individual channels for the UT-Austin Education Building for the week May 7-13, 1991.

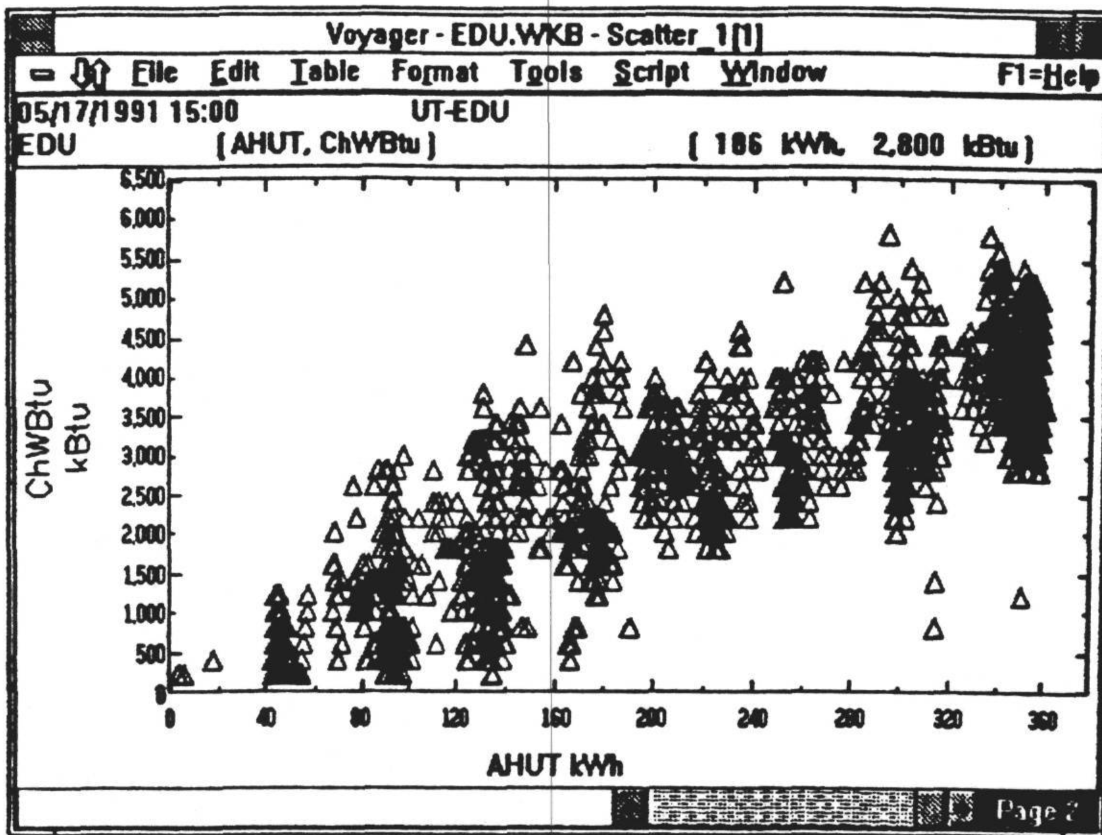


COMPUTER FILES WITH BROWSING SOFTWARE

January - April, 1991 chilled water consumption for the Education Building plotted as a function of ambient dry-bulb temperature using data exploration software.



January - April chilled water consumption for the Education Building plotted as a function of air handler electricity use by the data exploration software.



MONTHLY ENERGY CONSUMPTION REPORTS

Zachry Engineering Center

Texas A&M University
324,400 square feet

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

LoanSTAR Contact
Mohsen Farsad or Aamer Athar
053 WERC
Texas A&M University
College Station, TX 77842-3123
(409)-845-9213

Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	702476 kWh	99.9	-	-
Peak 60 Minute Demand	1312 kW	99.9	-	-
Chilled Water	1590.7 MMBtu	99.9	-	-
Hot Water	439.4 MMBtu	99.9	-	-

Peak 60 minute demand was recorded at 1500 Wednesday 4/3/91.
There were 720 hours in this month.

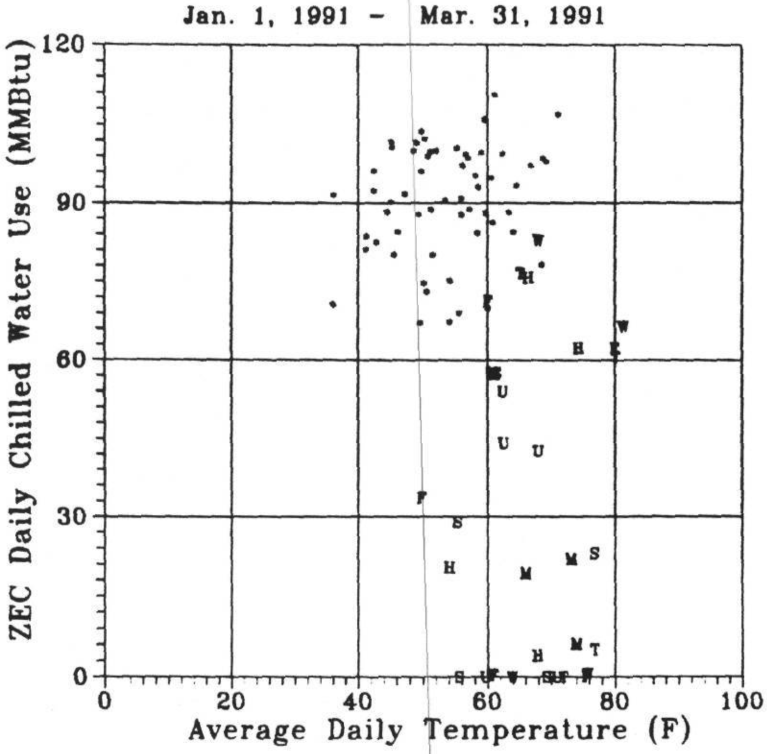
Measured Monthly Savings

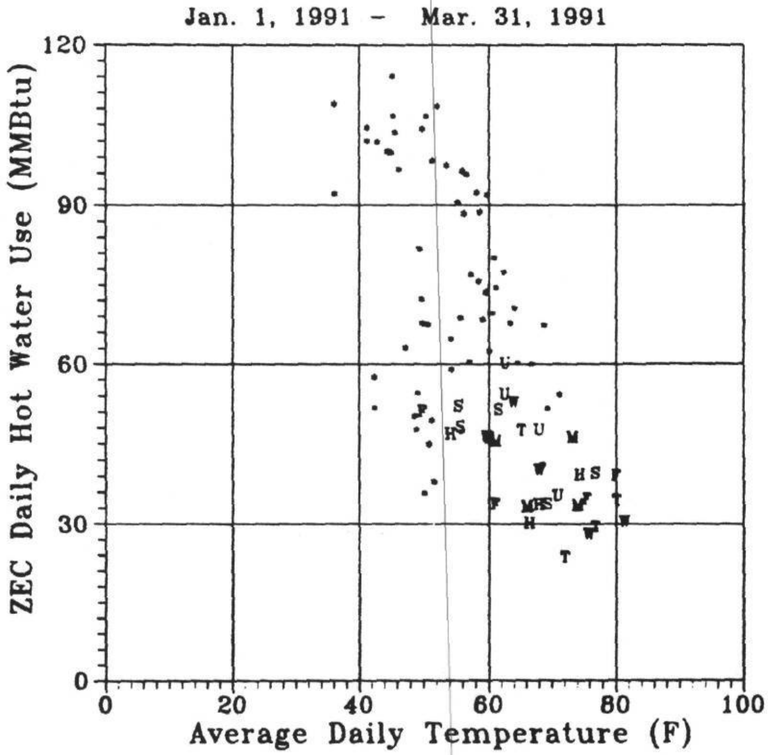
Actual	Predicted
$26,966	$24,915

Comments

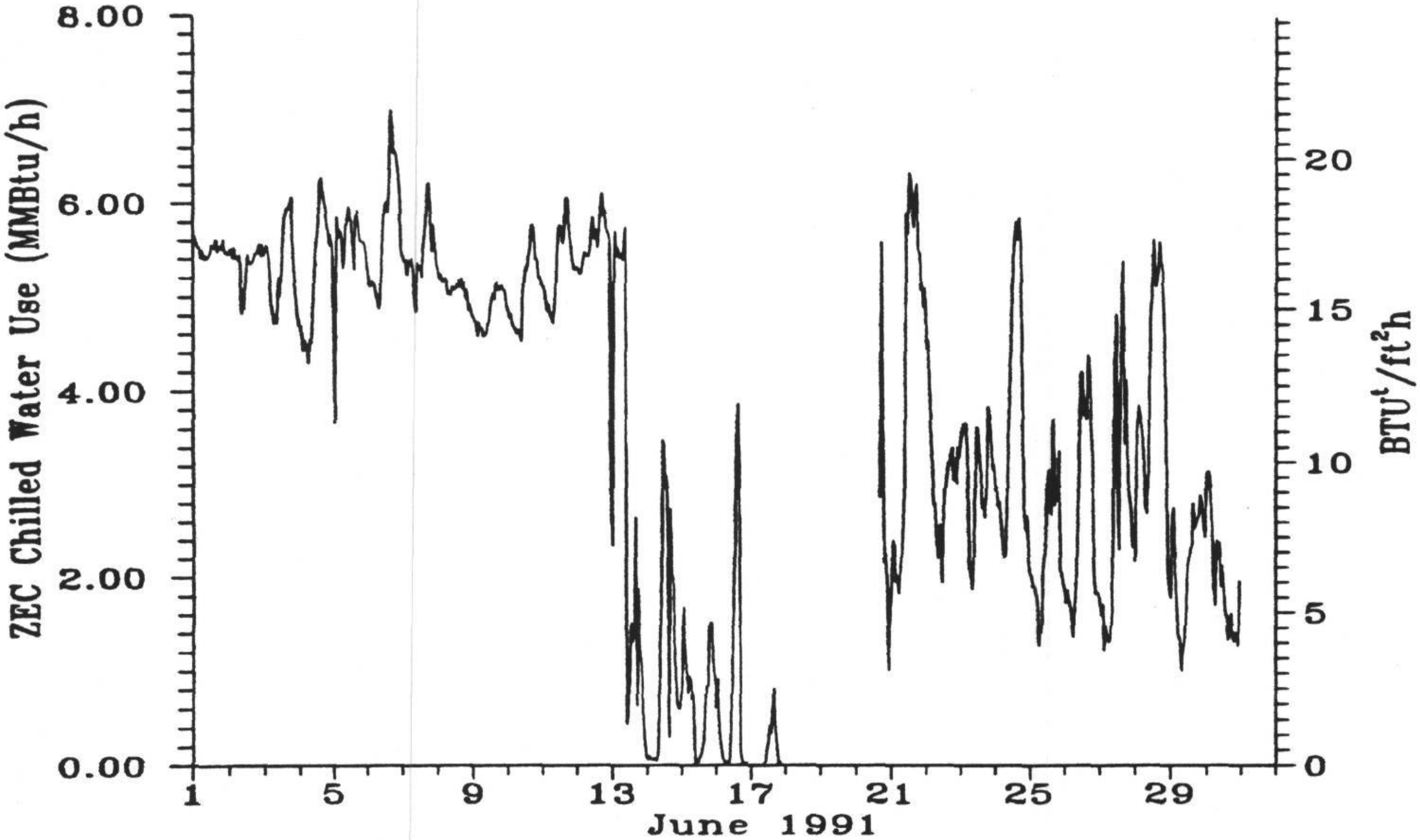
★ **Total savings to date including those measured during construction are $83,694. Savings are calculated with the 1988 costs used for loan payback estimates. Savings estimates are preliminary and subject to adjustment.**

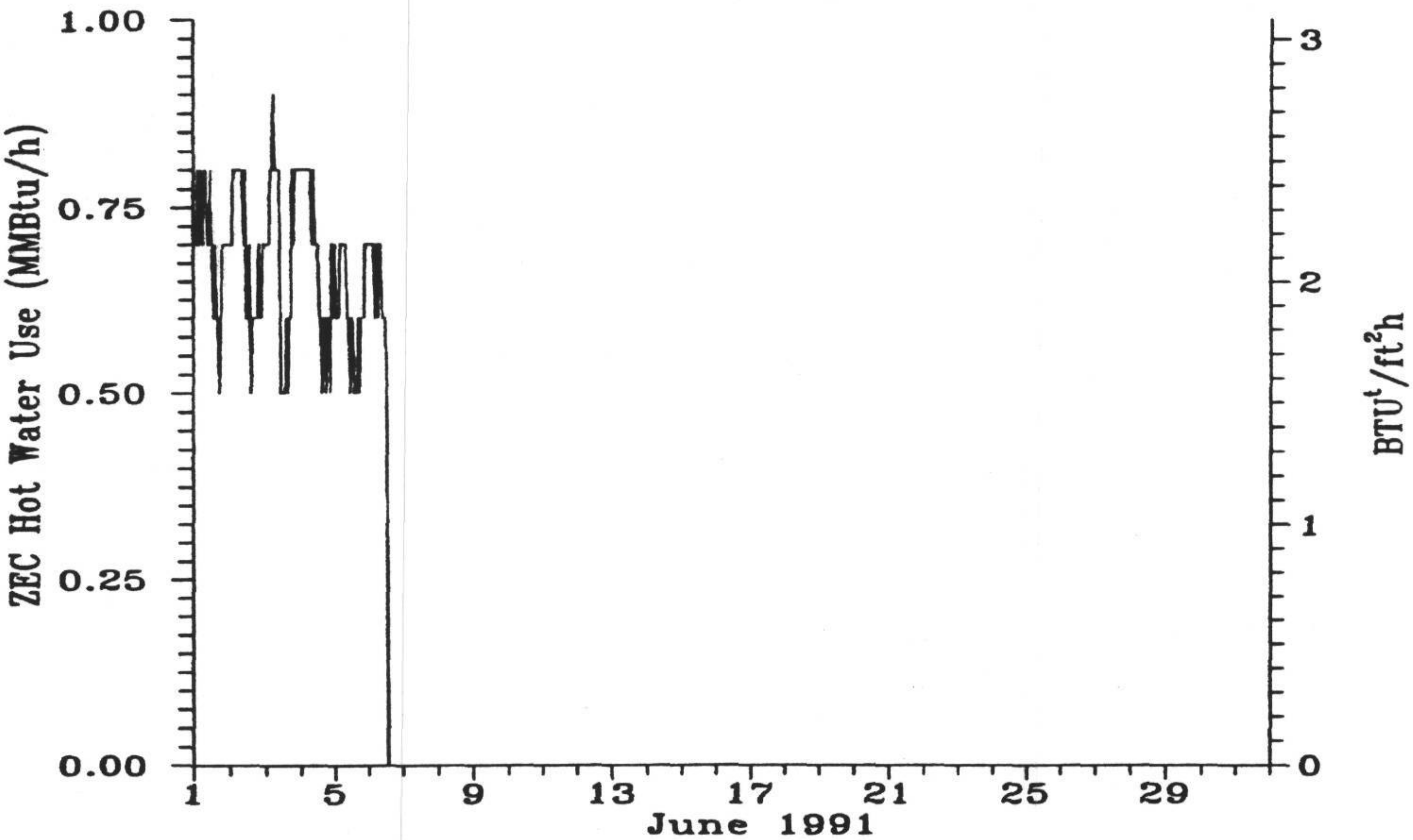
★ **There appears to be a change in system operation near the middle of the month.**

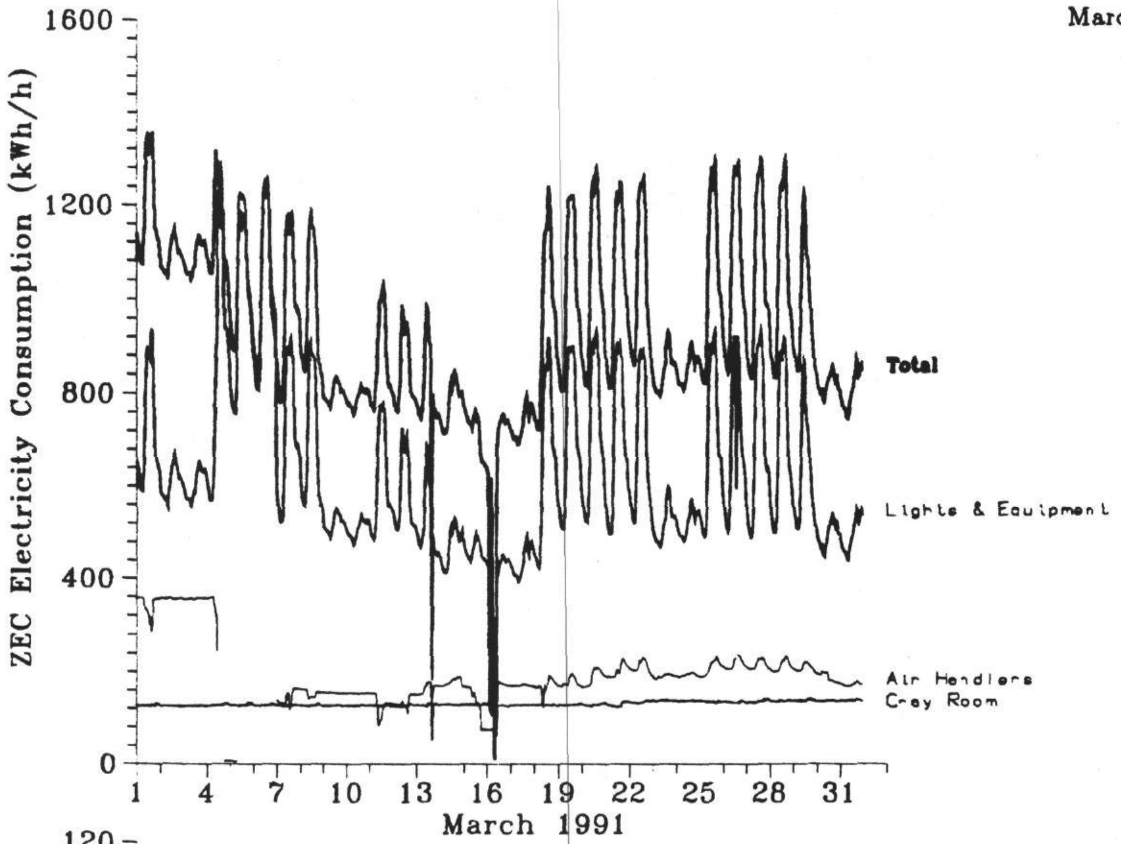


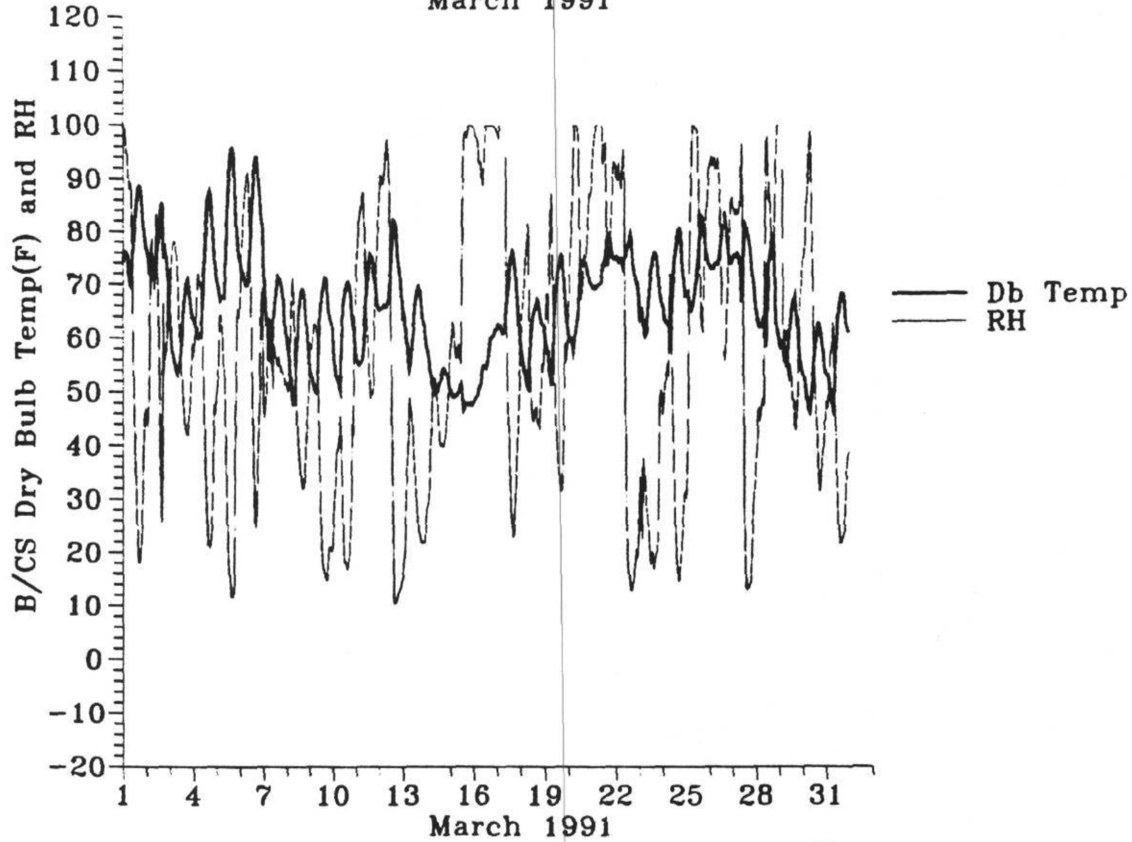


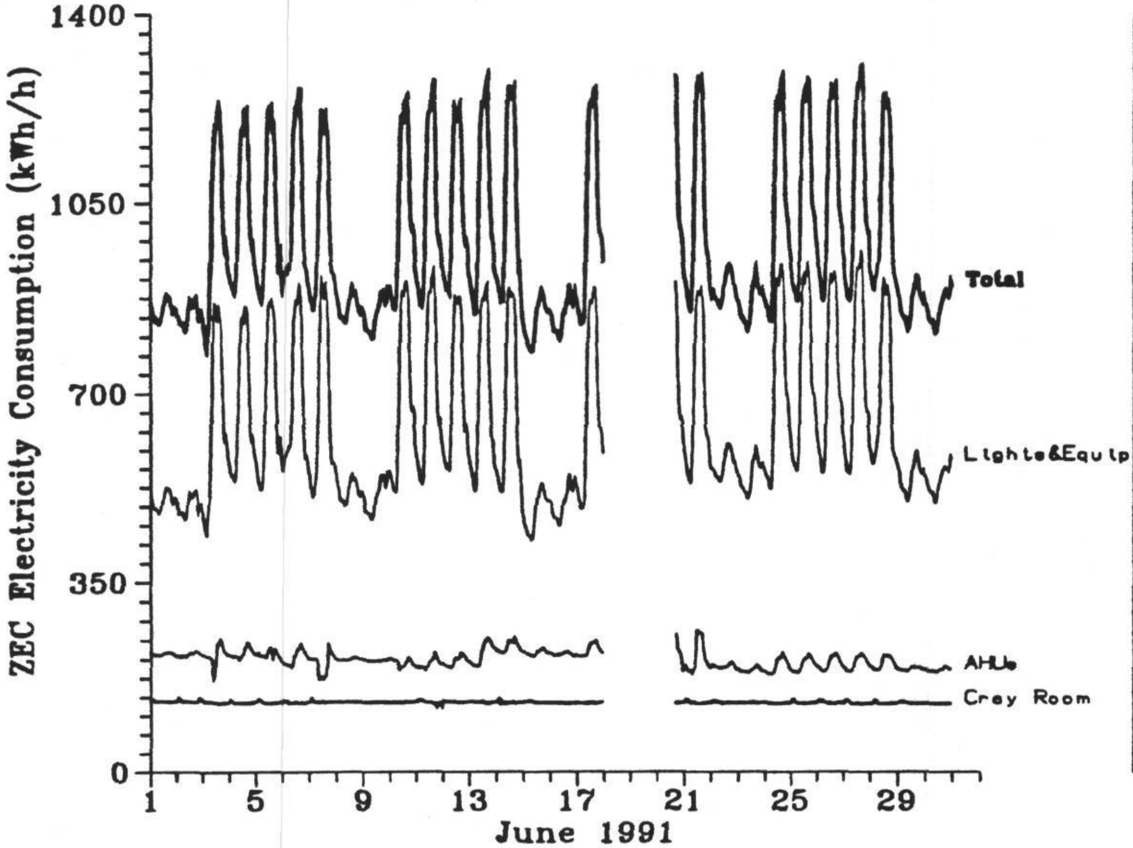
Data points for the current month are shown as letters.
Monday through Sunday are represented as M,T,W,H,F,S,U.

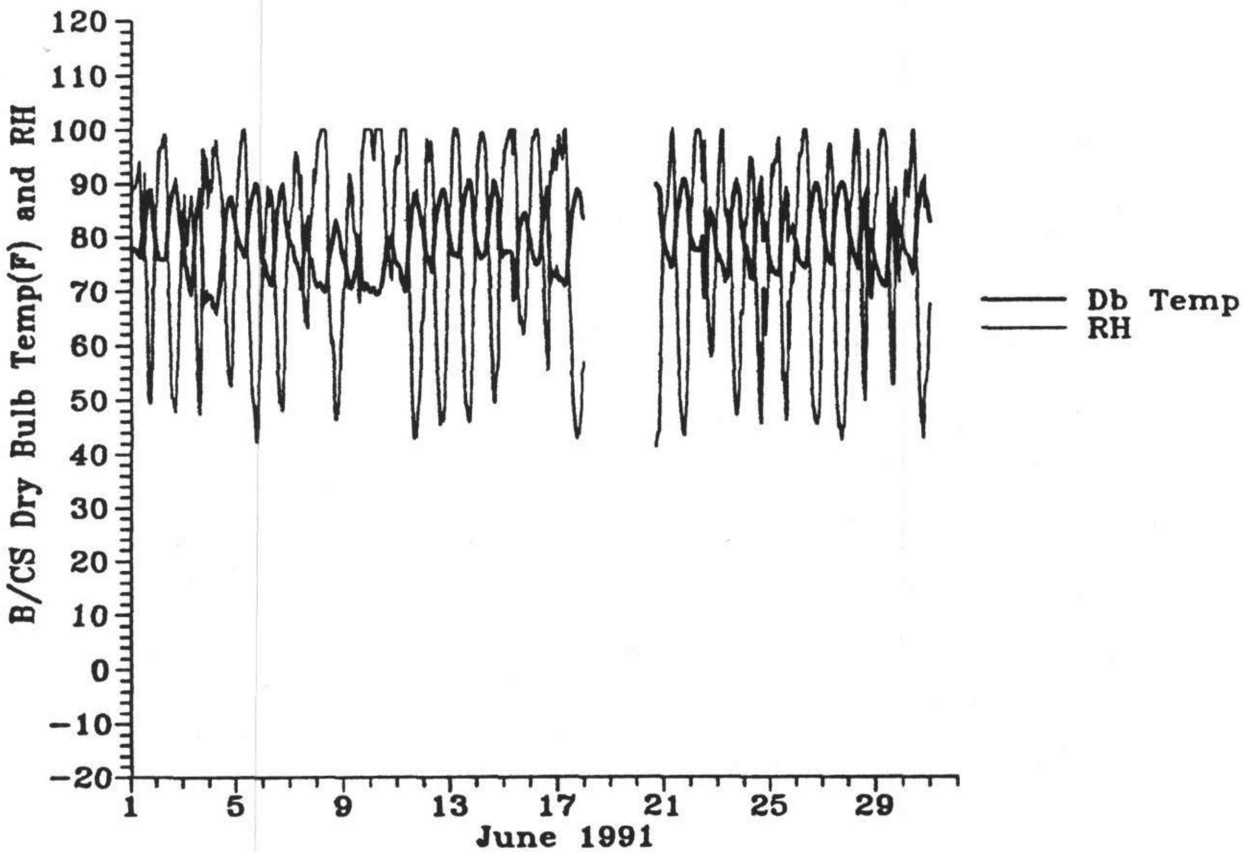

8.00
6.00
4.00
2.00
0.00
ZEC Chilled Water Use (MMBtu/h)
20
15
10
5
0
BTU^t/ft^2h
1
5
9
13
17
21
25
29
June 1991


1.00
0.75
0.50
0.25
0.00
ZEC Hot Water Use (MMBtu/h)
3
2
1
0
BTU^t/ft^2h
1
5
9
13
17
21
25
29
June 1991


1600
1200
800
400
0
ZEC Electricity Consumption (kWh/h)
Total
Lights & Equipment
Air Handlers
Crey Room
1
4
7
10
13
16
19
22
25
28
31
March 1991

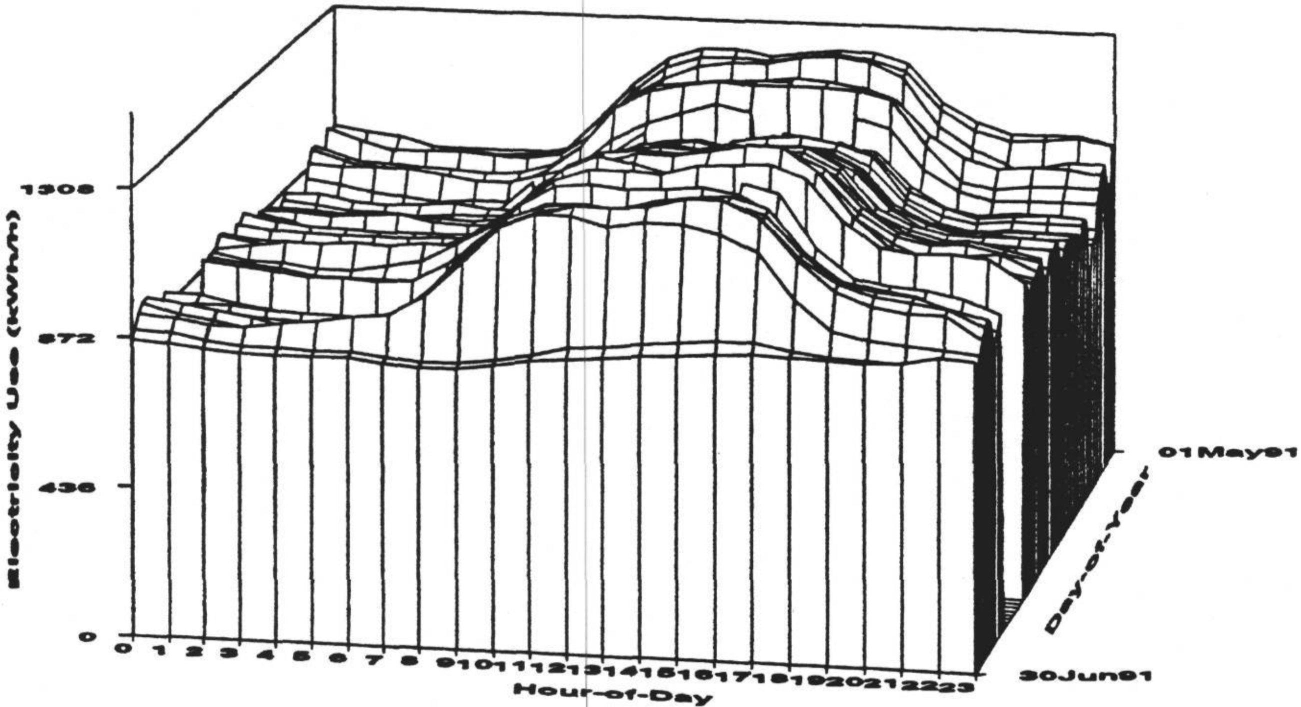

120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
B/CS Dry Bulb Temp(F) and RH
Db Temp
RH
1
4
7
10
13
16
19
22
25
28
31
March 1991



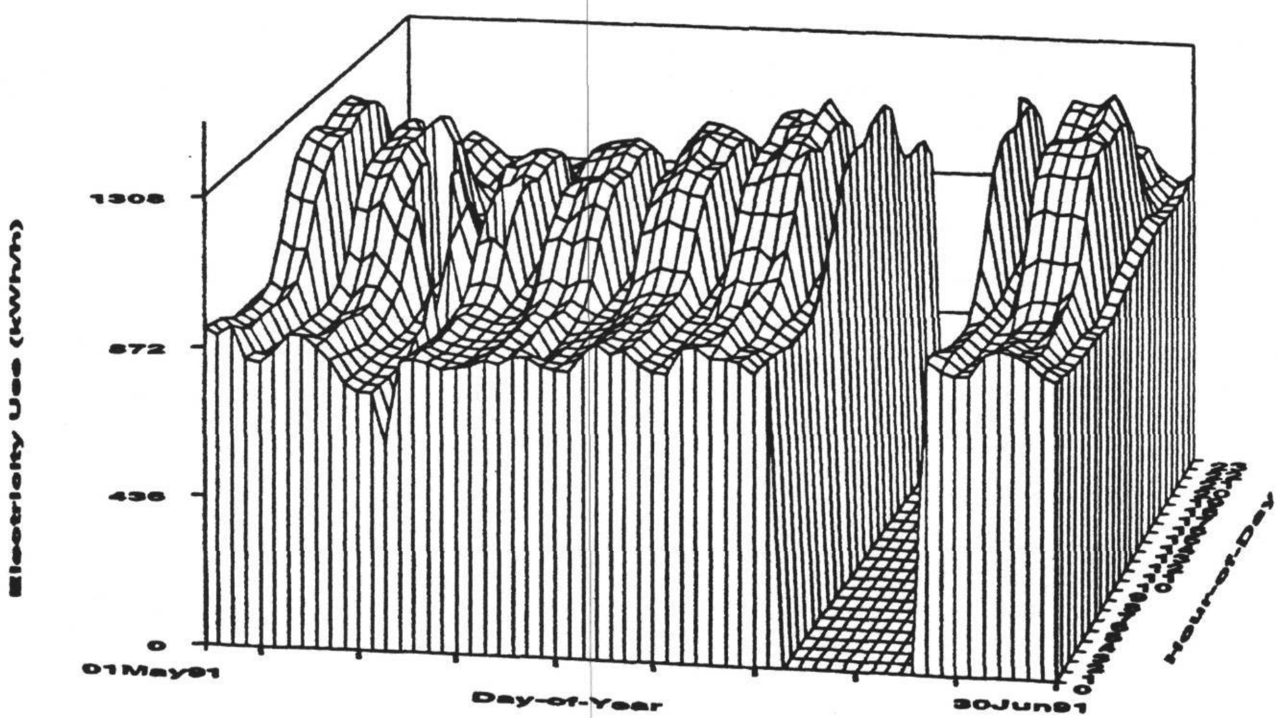


Zachry Engineering Center - Texas A&M University - June 1991

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: 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

Proposed Retrofits:

- use of parabolic light fixtures
- control modifications to the dual duct system
- variable volume dual duct system

Other Information:

- EMCS system to control HVAC is installed

Date of Retrofits:

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

CONCLUSIONS

1. Inspection Plots used for data quality control and diagnosis of operating changes and problems.

2. Data Exploration Software used to examine system performance and analyze consumption data.

3. Monthly Energy Consumption Reports provide hard copy tabular and graphical feedback on monthly, daily and hourly performance of building systems.

All three forms have been found useful by:

- **Building operators**
- **Building administrators**
- **Facility engineers**
- **Design engineers**
- **Monitoring and analysis engineers**
- **Project managers**

THE TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

CONTACTING & DESCRIBING SITES

A PRESENTATION

BY

AAMER ATHAR

MUSTAFA ABBAS

NAVEEN BALAKRISHNAN

ENERGY SYSTEMS LAB
TEXAS A&M UNIVERSITY

AGENCY CONTACT & SITE DESCRIPTION GROUP

OBJECTIVES:

AGENCY CONTACT

Provides 2-Way Communication Channel for:

- **Follow-up on Monthly Reports**
- **O&M Identification & Verification**
- **Determining Status of Retrofits**
- **Setting up Meetings & Scheduling Visits**
- **Verification of Monitored Data**

SITE INFORMATION

- **Collected in the form of *Site Description Note Books***

RESPONSIBILITIES:

- **Prepare Site Description Note Books**

- Identify O&M Opportunities

- Generate Comments for Monthly Energy Consumption Reports (MECRs)

- Follow-Up on MECRs. Gather Answers to all the Comments

- Update Information on Status of Retrofits

- Special Data Problems

- Develop Building Indices (W/sq.ft, Btu/hr.sq.ft, etc...)

- Develop Database for Recommended ECRMs

SITE DESCRIPTION NOTE-BOOKS:

1) Photographs of the Site

2) Site Summary Form

3) Site Description Form

4) Data Channel List

5) Monitoring Diagram

6) ECRM List from Pre-MAP

7) O&M Opportunities

8) Estimated Savings from the Audit Report

9) Modelling Characteristics

10) Monthly Energy Consumption Reports (MECRs)

11) Comments & Answers

12) Weekly Inspection Plots

13) Appendix

RESPONSIBILITIES:

- Prepare Site Description Note Books

- **Identify O&M Opportunities**

- Generate Comments for Monthly Energy Consumption Reports (MECRs)

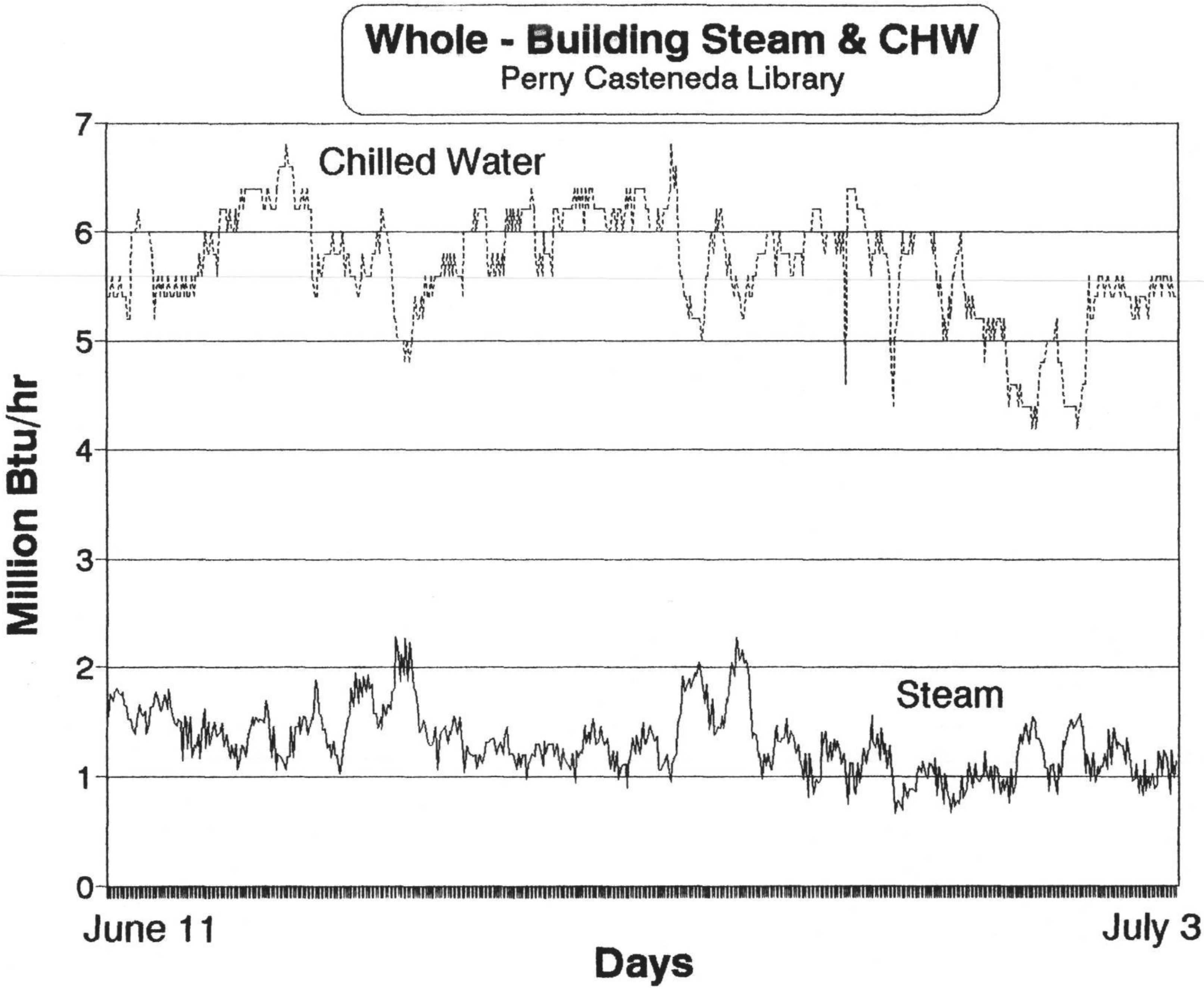
- Follow-Up on MECRs. Gather Answers to all the Comments

- Update Information on Status of Retrofits

- Special Data Problems

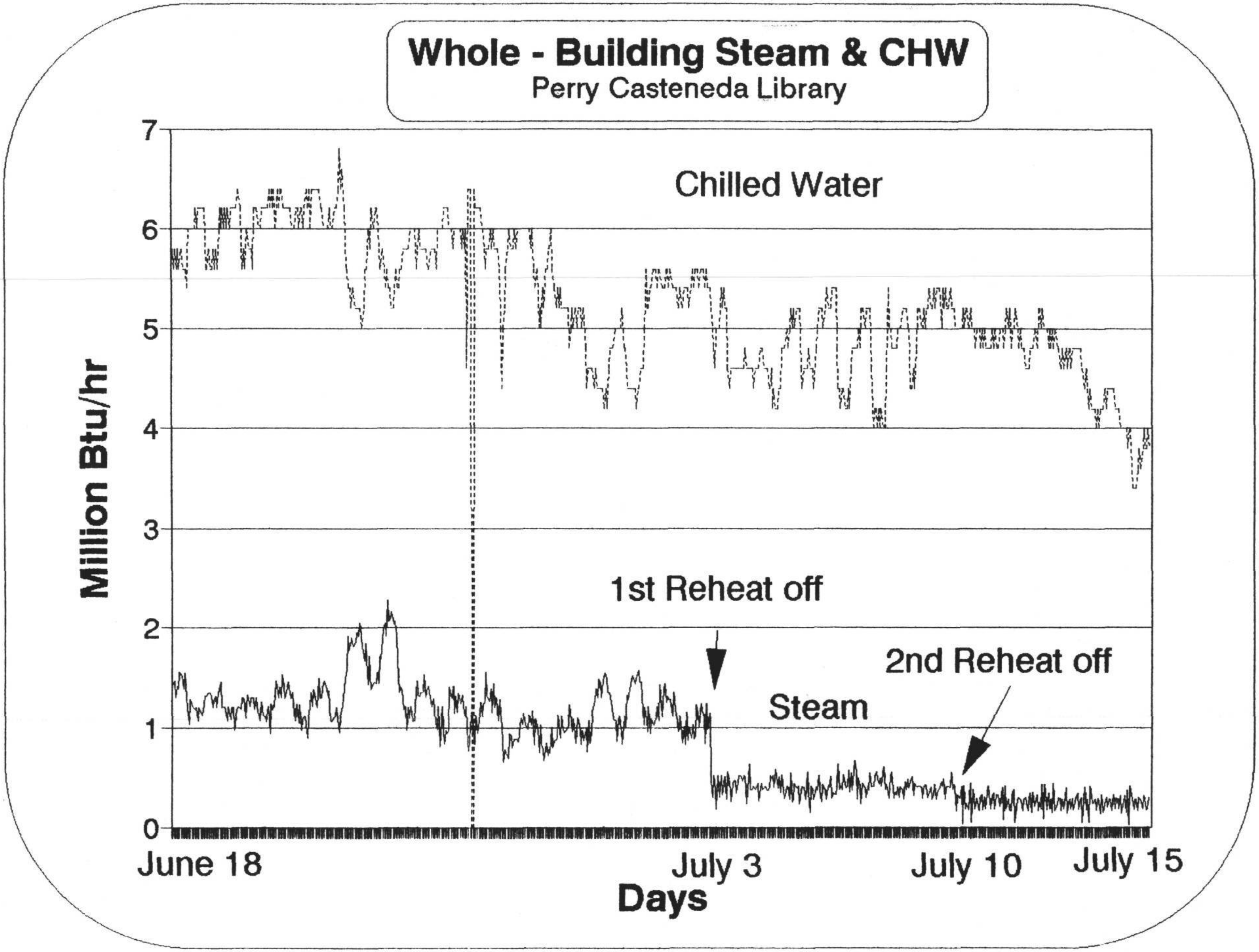
- Develop Building Indices (W/sq.ft, Btu/hr.sq.ft, etc...)

- Develop Database for Recommended ECRMs


Whole - Building Steam & CHW
Perry Casteneda Library
Chilled Water
Steam
Million Btu/hr
7
6
5
4
3
2
1
0
June 11
July 3
Days

CLOSURE OF REHEAT VALVES AT PCL:

- **Questions were Raised about High Steam Consumption at PCL (May 1991)**
- **1st Site Visit to Verify Our Instrumentation (June 1991)**
- **Discussion of Problem with Facility Engineer & Building Operator (June 1991)**
- **Building Operator & Facility Engineer Suggested Closure of Reheat Valves (June 1991)**
- **Distribution of More Detailed Data to Facility Engineer (June 1991)**
- **Analysis of Monitored Data**
- **Partial Closure of Valves to Reheat Coils (July 3, 1991)**
- **2nd Site Visit Accompanied by Dr. Steve Jaeger & Design Engineer (July 5, 1991)**
- **Total Reheat Shut-Off (July 10, 1991)**

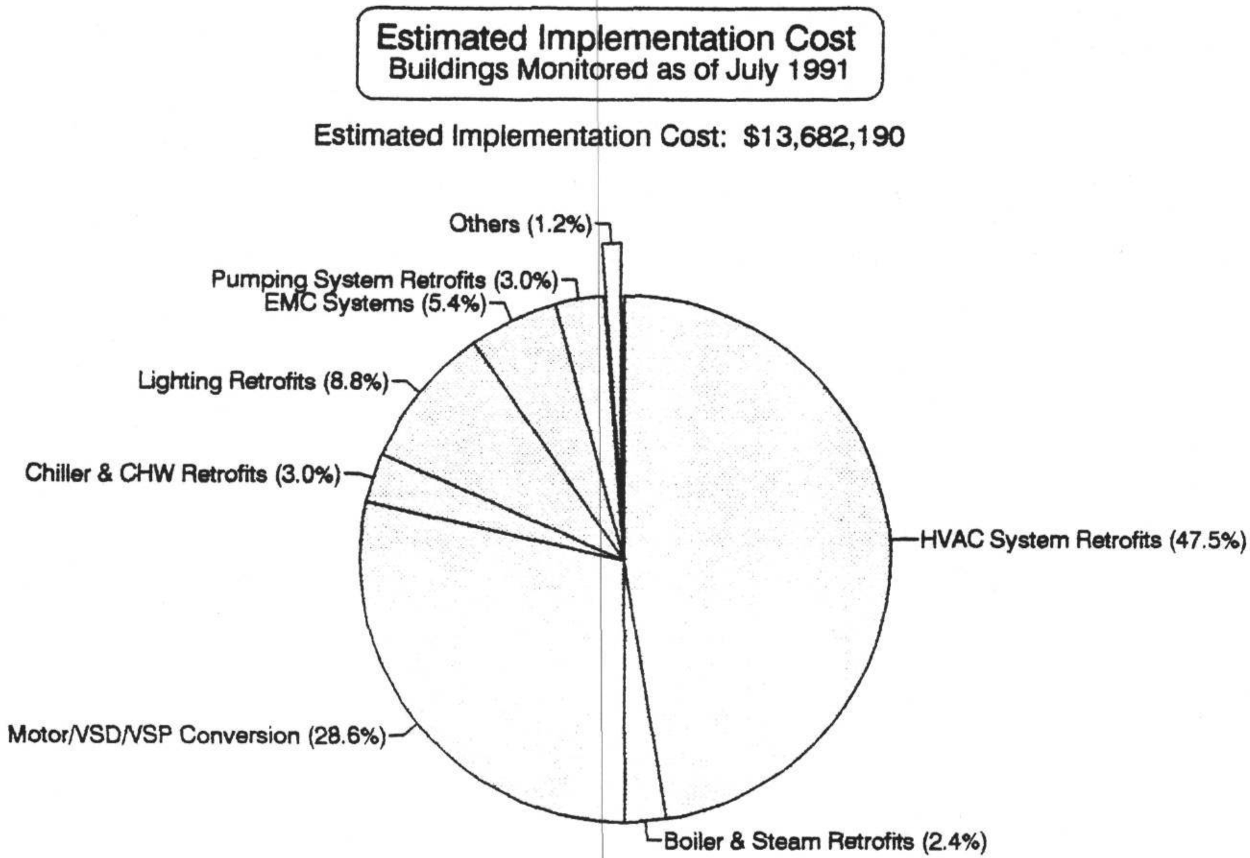

Whole - Building Steam & CHW
Perry Casteneda Library
Chilled Water
1st Reheat off
2nd Reheat off
Steam
Million Btu/hr
7
6
5
4
3
2
1
0
June 18
July 3
July 10
July 15
Days

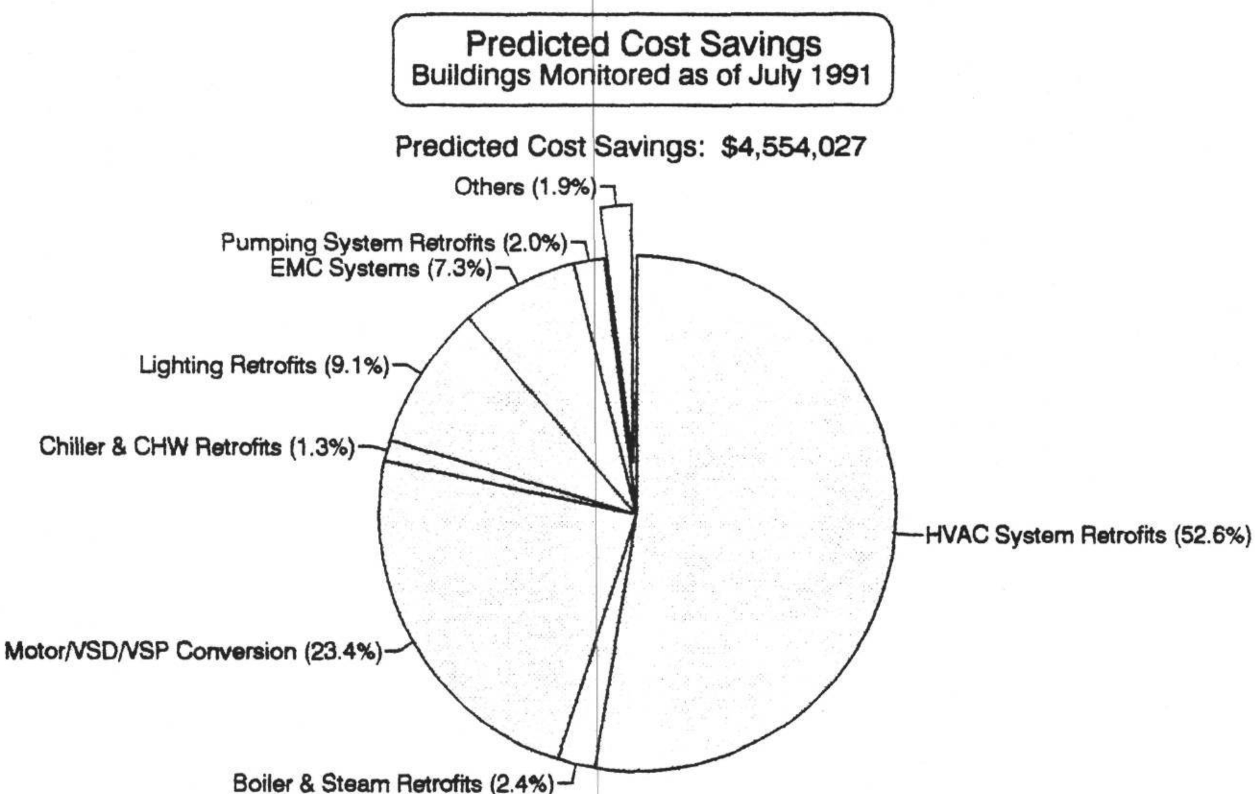
SAVINGS DUE TO REHEAT SHUT-OFF:

Date: **(Reheat Shut-off)**		**July 3, 1991**
Steam Savings	≈	**1 Million Btu/hr**
Chilled Water Savings	≈	**1 Million Btu/hr**
Cost Savings:	≈	**\$ 10.00/hr** **(\$7,000/month)**

RESPONSIBILITIES:

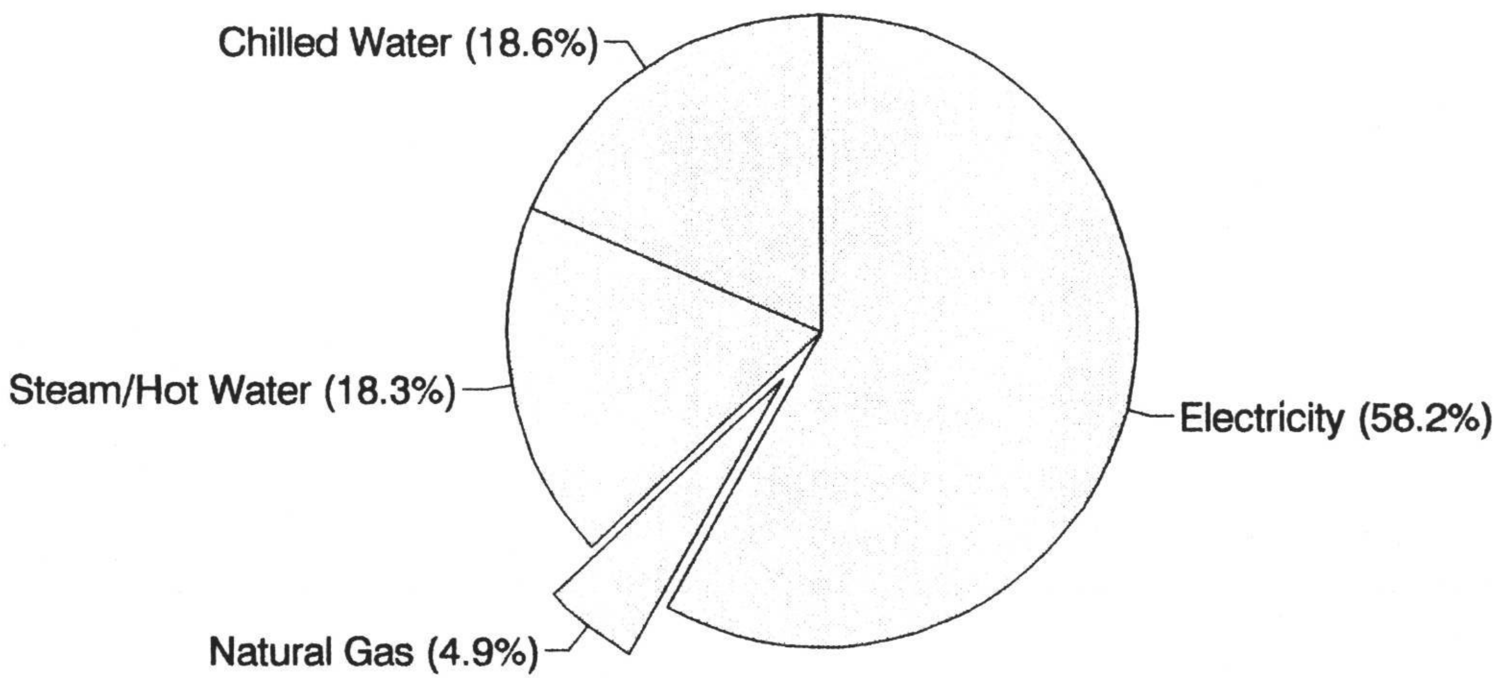
- Prepare Site Description Note Books
- Identify O&M Opportunities
- **Generate Comments for Monthly Energy Consumption Reports**
- **Follow-Up on MECRs. Gather Answers to all the Comments**
- **Update Information on Status of Retrofits**
- **Special Data Problems**
- **Develop Building Indices (W/sq.ft, Btu/hr.sq.ft, etc...)**
- **Develop Database for ECRMs**


Estimated Implementation Cost
Buildings Monitored as of July 1991
Estimated Implementation Cost: $13,682,190
Others (1.2%)
Pumping System Retrofits (3.0%)
EMC Systems (5.4%)
Lighting Retrofits (8.8%)
Chiller & CHW Retrofits (3.0%)
HVAC System Retrofits (47.5%)
Motor/VSD/VSP Conversion (28.6%)
Boiler & Steam Retrofits (2.4%)


Predicted Cost Savings
Buildings Monitored as of July 1991
Predicted Cost Savings: $4,554,027
Others (1.9%)
Pumping System Retrofits (2.0%)
EMC Systems (7.3%)
Lighting Retrofits (9.1%)
Chiller & CHW Retrofits (1.3%)
HVAC System Retrofits (52.6%)
Motor/VSD/VSP Conversion (23.4%)
Boiler & Steam Retrofits (2.4%)

PREDICTED ENERGY SAVINGS
Buildings Monitored as of July 1991

Source Energy Savings: 1,316,814 MMBtu/yr



Btu savings calculated on the basis of source Btus (i.e. 11,600 Btu/kWh, 1,030,000 Btu/MCF, & 12,000 Btu/ton-hr

ACCOMPLISHMENTS:

- **13 Site Description Note Books Completed**

- **9 Interviews (4 Facility Administrators and 5 Building Operators)**

- **O&M Identification & Follow-Up**

  1) **Hot Water Pump Shut Down at Zachry Engineering Center**

  2) **Closure of Reheat Valves at PCL (U.T. Austin)**

- **Building Indices Prepared**

- **Regular Follow-Up/Status Update**

Measured Retrofit Savings For Eight Texas LoanSTAR Buildings

-

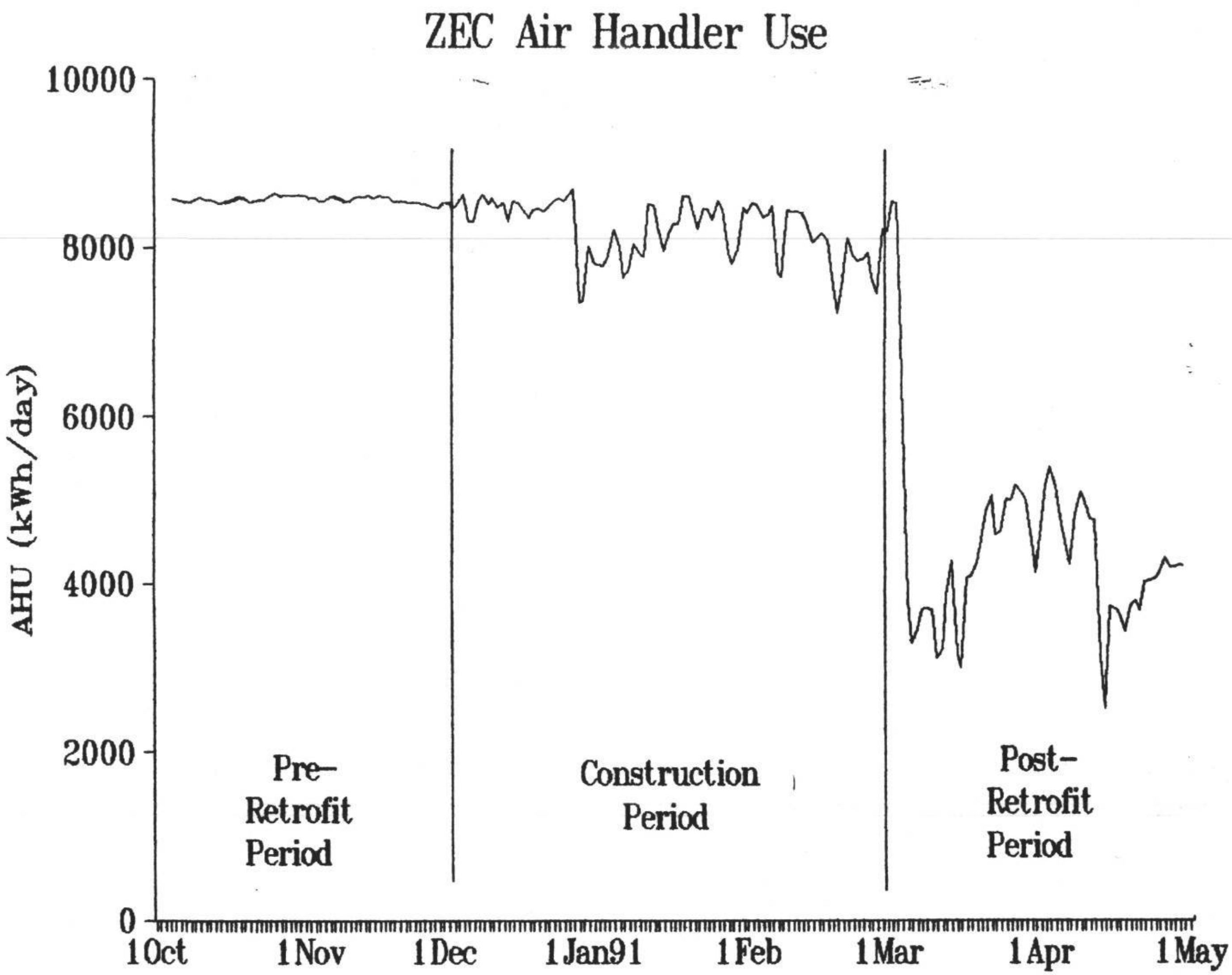
Preliminary Methodology and Results

-

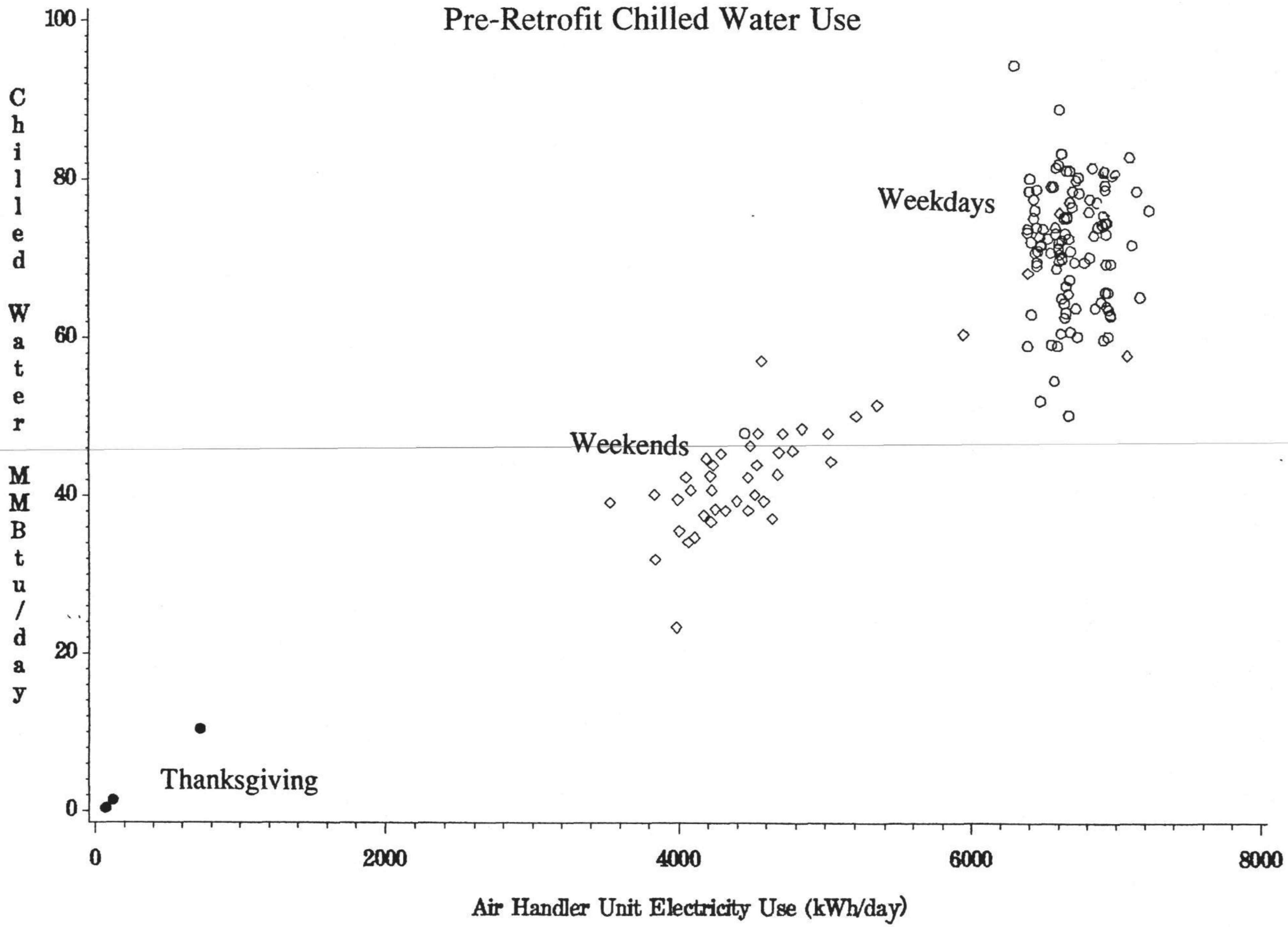
Kelly Kissock

-

August 19, 1991

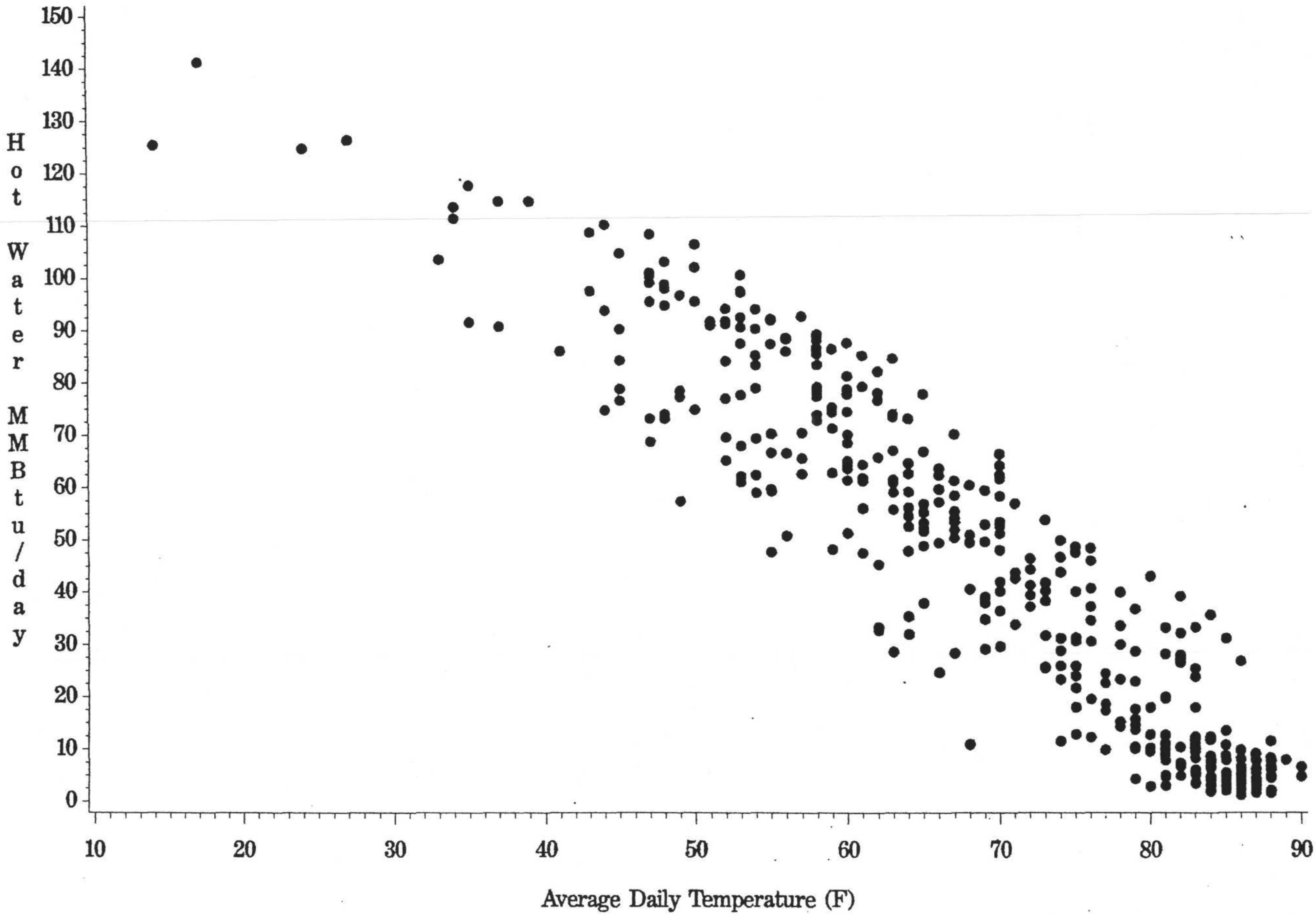

ZEC Air Handler Use
10000
8000
6000
4000
2000
0
AHU (kWh/day)
Pre-
Retrofit
Period
Construction
Period
Post-
Retrofit
Period
1 Oct
1 Nov
1 Dec
1 Jan91
1 Feb
1 Mar
1 Apr
1 May

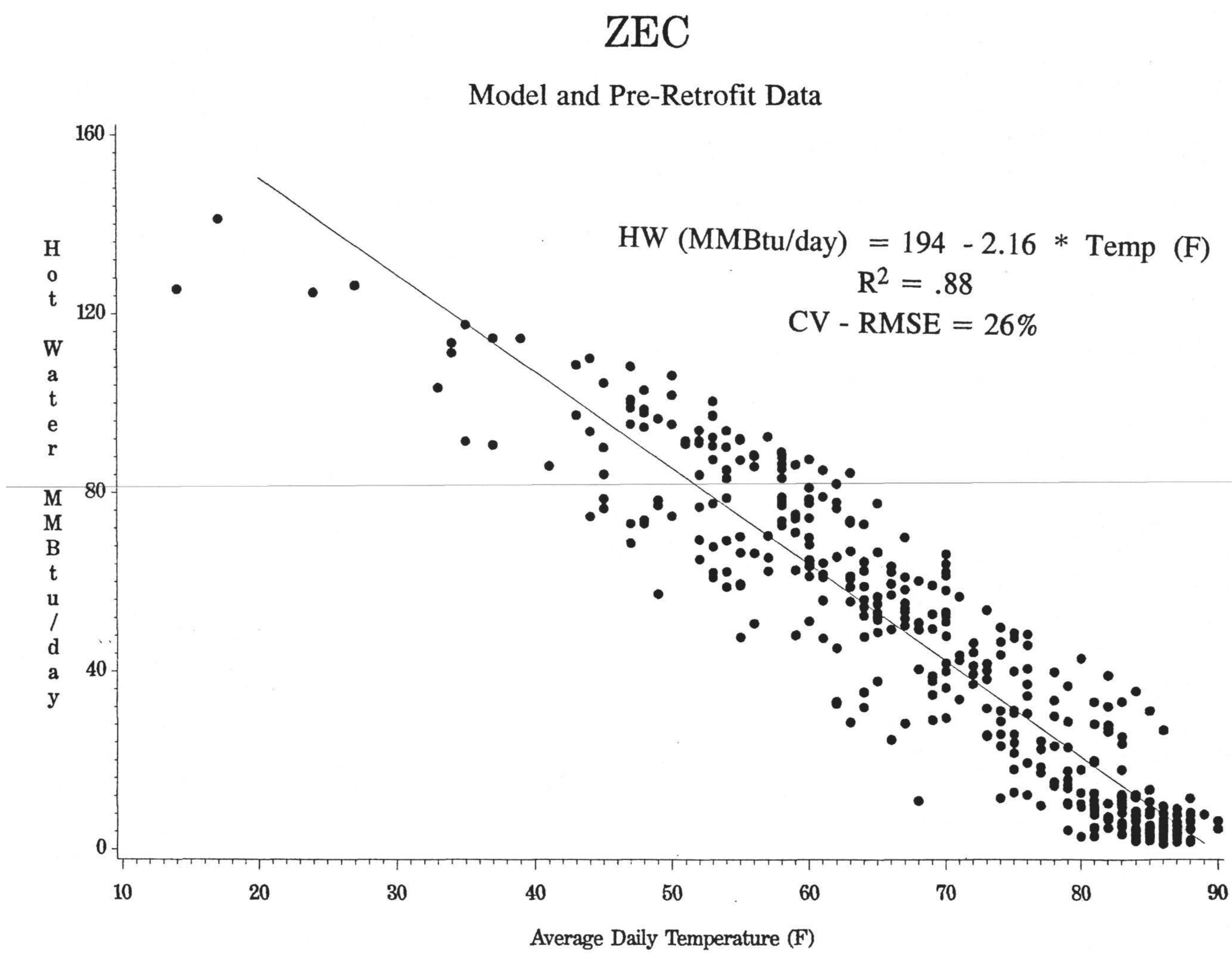
Education Building



ZEC

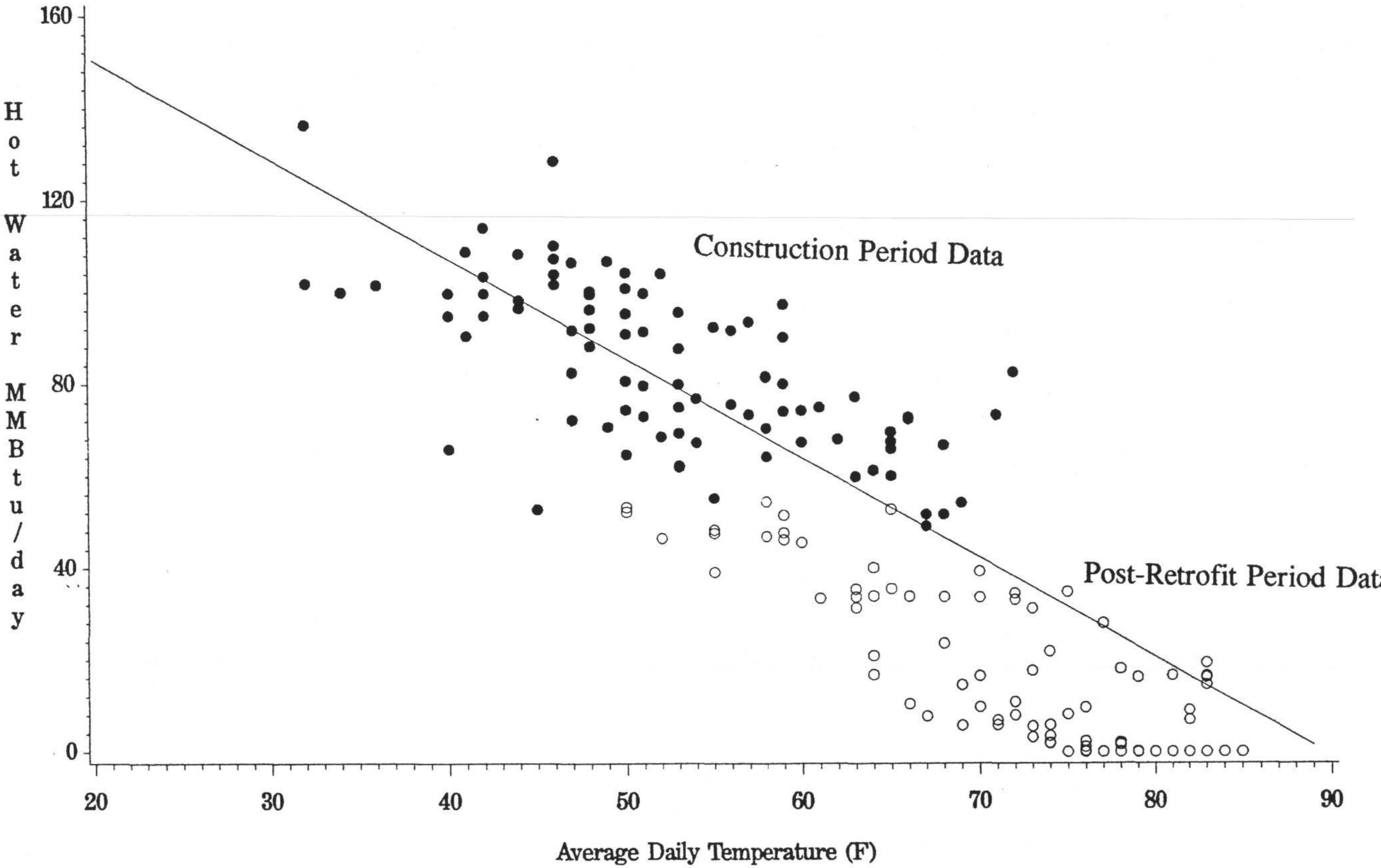
Pre-Retrofit Hot Water Use




ZEC
Model and Pre-Retrofit Data
HW (MMBtu/day) = 194 - 2.16 * Temp (F)
R^2 = .88
CV - RMSE = 26%
Hot Water MMBtu/day
160
120
80
40
0
10
20
30
40
50
60
70
80
90
Average Daily Temperature (F)

ZEC

Model and Post-Retrofit Data



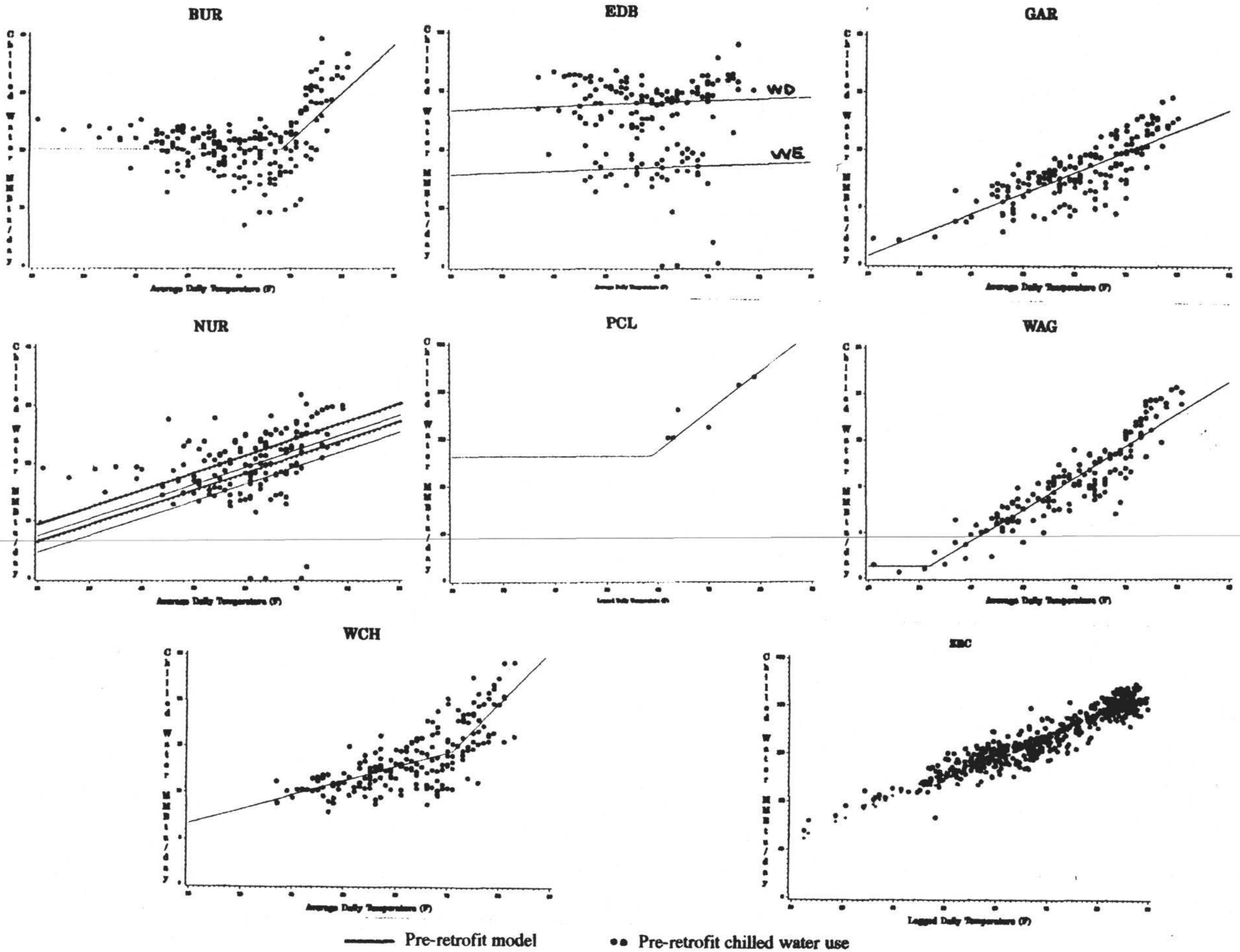
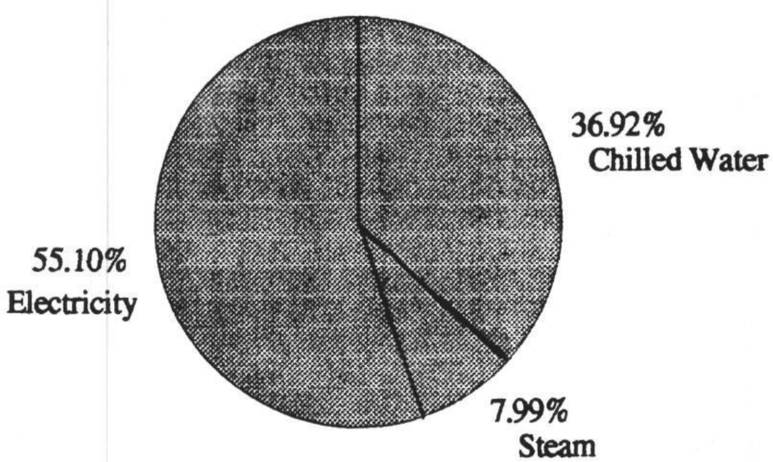
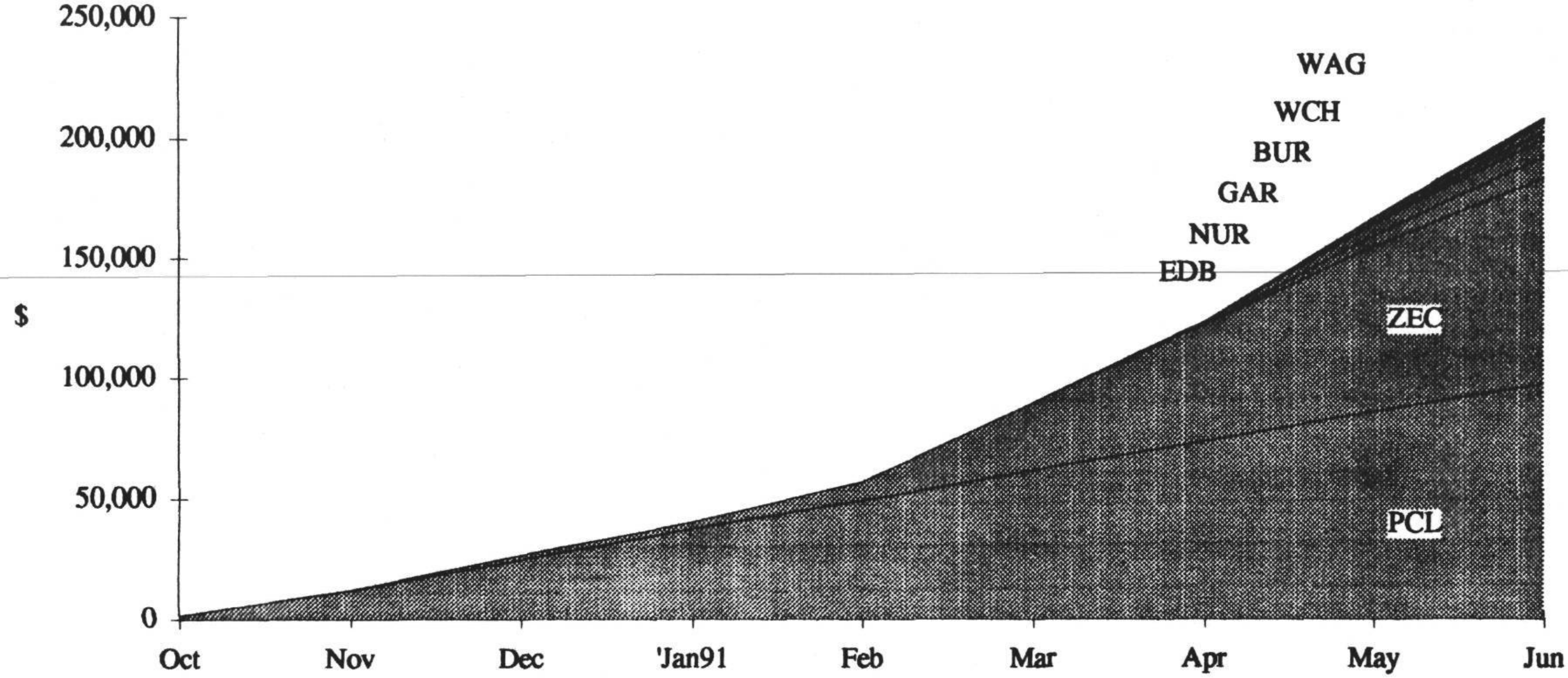


Figure 2.1 Pre-retrofit chilled water use and models for eight LoanSTAR buildings.

Energy Savings By Energy Type For Eight LoanSTAR Buildings



Cumulative Savings For Eight LoanSTAR Buildings



UNCERTAINTY IN SAVINGS ANALYSIS

Task 5: Analysis and Planning

T. Agami Reddy
Kelly Kissock

Energy Systems Laboratory
Dept. of Mechanical Engineering
Texas A&M University
August 19, 1991

Total Savings Calculations

Total Savings

$$= \sum_{j=1}^{m} \hat{E}_{pre,j} - \sum_{j=1}^{m} E_{meas,j}$$

where

$m =$ **number of post-retrofit days**

$E =$ **daily energy consumption**

- **chilled water**
- **hot water**
- **electricity**

$\hat{E}_{pre} =$ **model determined daily energy use**

$E_{meas} =$ **measured post-retrofit daily energy use.**

Source of Uncertainty (Errors)

- **Measurement Errors** E_{pre}, E_{meas}, T

  — **Approximate effect of small errors can be studied by differentiation in which the behavior of the errors is indicated by the behavior of the differentials. Thus**

$$d(x + y) = dx + dy.$$

- **Prediction Errors**

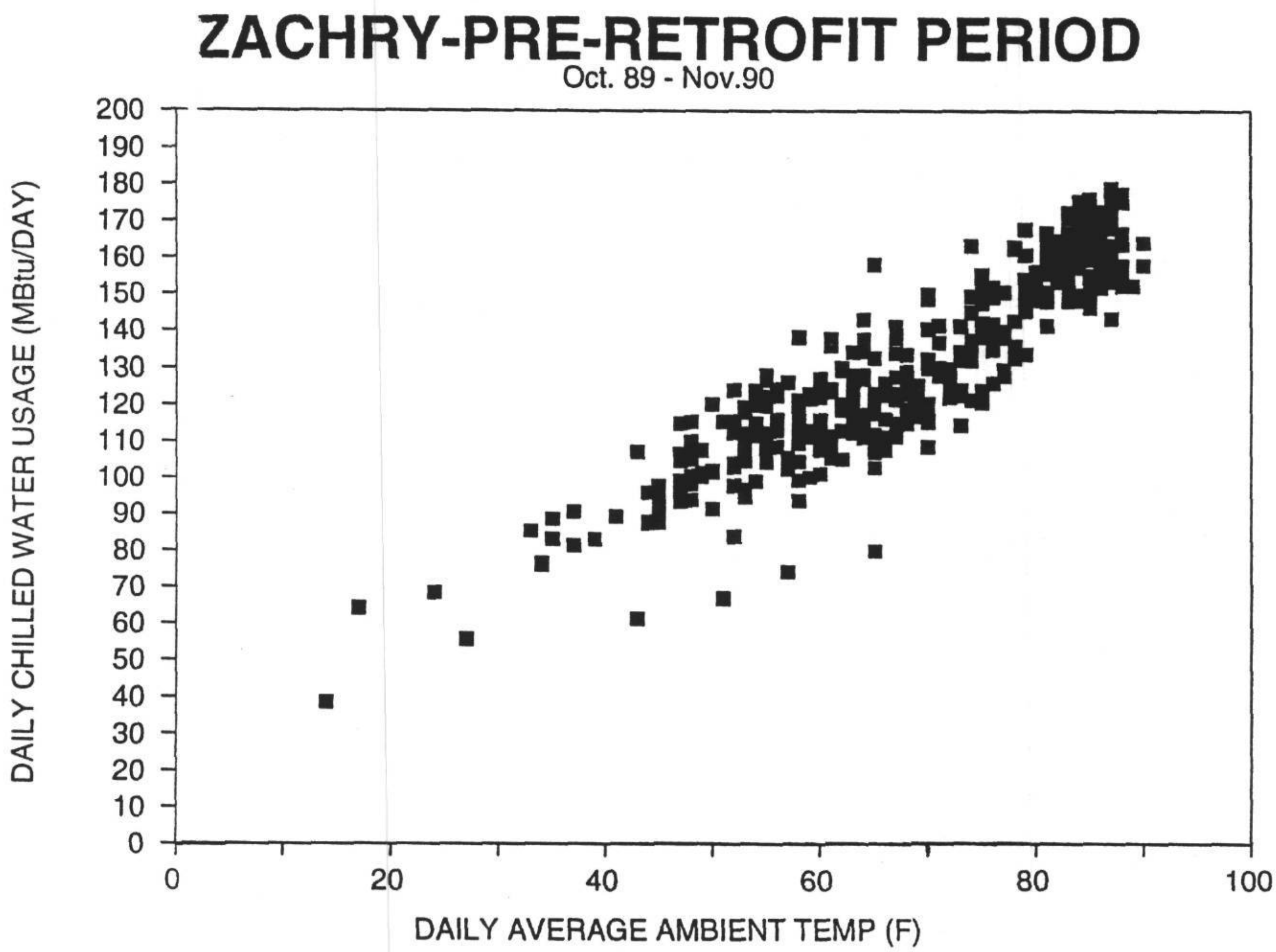
  — **Use of a model to predict** $\hat{E}_{pre,j}$

Prediction Errors

Uncertainty in the sum of $\hat{E}_{pre,j}$ values

= Uncertainties due to the following:

- **Finite number of pre-retrofit days (n)**
- **Finite number of post-retrofit days (m)**
- **Auto-correlated measured E_{pre} values**
- **Away from mid-range of T_{pre} values**



Prediction Uncertainty on the Sum of $\hat{E}_{pre}$ values

$$= t(m-2, 1-\frac{\alpha}{2}) \times RMSE \times m \times \left[\frac{1}{n} + \frac{1}{m} + \frac{2(n-2)}{n^2}p + \frac{\sum_{j=1}^{m}(T_{post,j} - \overline{T}_{pre})^2}{m \times SS_T}\right]^{\frac{1}{2}}$$

where

$t(m-2, 1-\frac{\alpha}{2}) = 100(1-\frac{\alpha}{2})$ **percentage point of a t-distribution with (m-2) degrees of freedom [For $m = 60, t = 2.0$ at 95%C.L.]**

$RSME =$ **Root Mean Square Error**

$$= [\frac{1}{n-2}\sum_{i=1}^{n}(E_{pre,i} - \hat{E}_{pre,i})^2]^{\frac{1}{2}}$$

$p =$ **auto-correlation coefficient of $E_{pre,i}$ values**

$SS_T =$ **sum of squares** $= \sum_{i=1}^{n}(T_{pre,i} - \overline{T}_{pre})^2$

$\overline{T}_{pre} =$ **mean ambient temperature during the pre-retrofit period.**

For Zachry Data:

- No. of pre-retrofit days n = 399
- No. of post-retrofit days m = 107
- Autocorrelation coefficient p = 0.91
- Mean Temperature $\overline{T}_{pre}$ = 68.9 F
- RMSE (chilled water) = 10.5 MMBtu/day
- RMSE (hot water) = 11.7 MMBtu/day

- Prediction uncertainty on total pre-retrofit energy USE = t × RMSE × m × 0.132

— chilled water: 2% at 95% C.L

— hot water: 8% at 95% C.L.

[Note: On a monthly basis, uncertainty = t × RMSE × m × 0.204]

- Prediction uncertainty on total energy savings

— Chilled water: 3% at 95% C.L.

— Hot water: 16% at 95% C.L

NORMALIZED ANNUAL CONSUMPTION (NAC)
FOR LINEAR AND CHANGE-POINT ENERGY MODELS

DEFINITION: The NAC index for an energy model is the expected energy consumption in a year with average conditions.

BACKGROUND: The PRISM method calculates NAC with rigorous error analysis for a three parameter change-point model.

Linear and four parameter change-point energy models appear appropriate for the majority of LoanSTAR buildings.

GOALS:

- Develop NAC with rigorous error analysis for the linear and four parameter change-point energy models.
- Compute NAC using several models on the same buildings and assess the performance of each model.
- Study the importance of goodness-of-fit toward producing an accurate NAC estimate for daily data.

NAC for the two-parameter linear model:

$$\mathbf{E = a + b*T}$$

For an average year of temperature data $\{ T_j \}$,

$$NAC = \sum \hat{E}_j = \sum (a + b*T_j) = 365 + b * \sum T_j$$

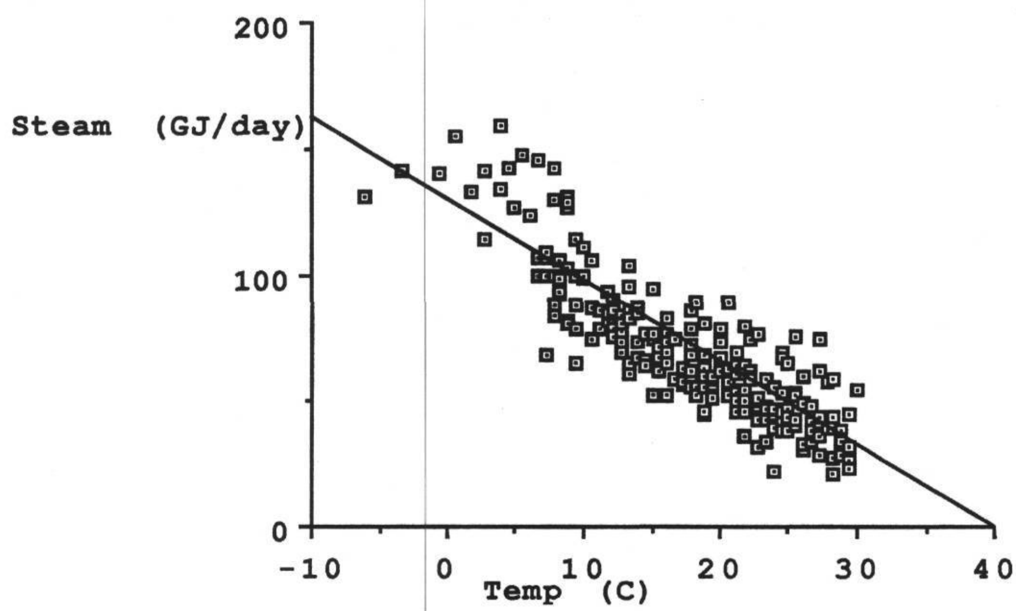
so

$$\mathbf{NAC = 365(a + b*T_{LAV})}$$

where $\mathbf{T}_{LAV}$ is the (long-term) average temperature for the region.

Using the properties of variance and covariance,

$$s.e.(NAC) = 365 * \sqrt{[var(a) + 2*T_{LAV}*cov(a,b) + T_{LAV}^2 * var(b)]}$$



Linear Heating Model Results:

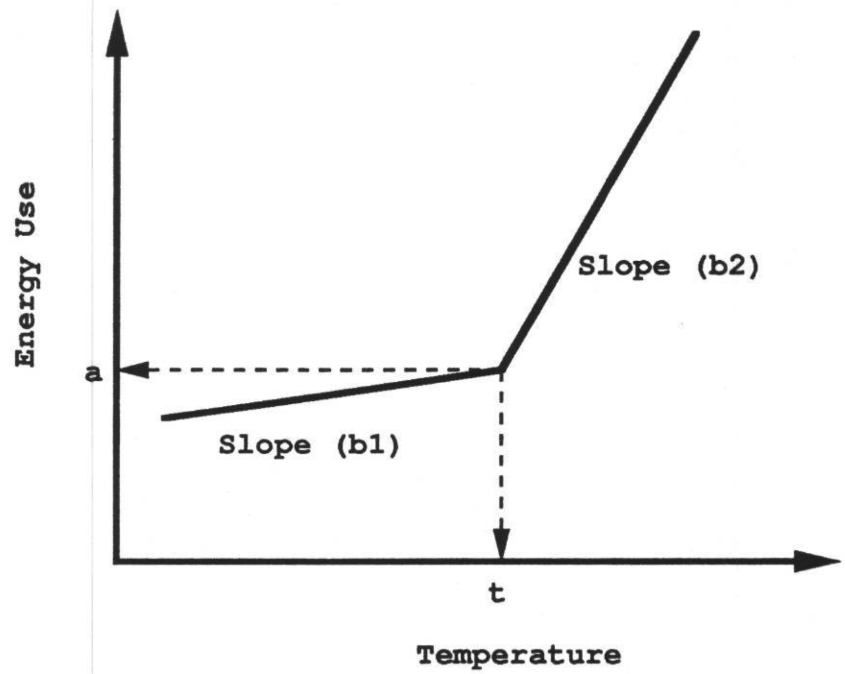
H = 129.3 - 3.4T (GJ/day) NAC = 21939

(GJ)

Parameter	Standard error	c.v. [parameter]
a	2.4	1.85%
b	0.12	3.62%
NAC	356	1.62%

Four Parameter Change-Point Model:

$$E = a + b_2 * (T - \tau)^+ - b_1 * (\tau - T)^+$$



$$\mathbf{NAC = 365*a + b_2 * DD_+(\tau) - b_1 * DD_-(\tau)}$$

where $DD_-(\tau)$ is the average number of degree-days below the reference temperature t in the average year, and $DD_+(\tau)$ is the average number above τ.

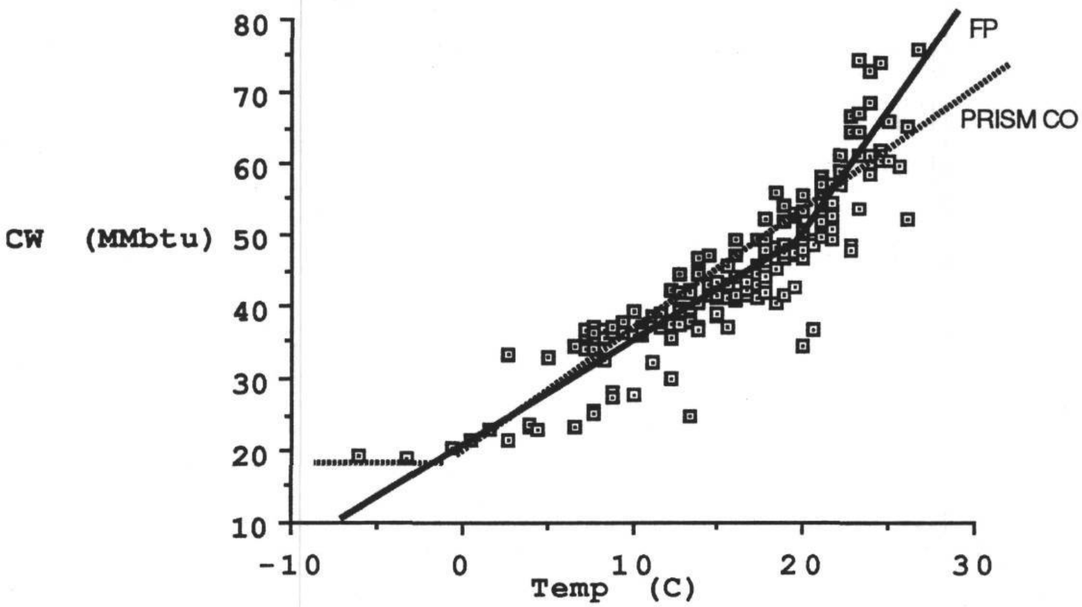
A likelihood-based standard error and confidence intervals for NAC are calculated for this model.

Monte Carlo results for the reliability of NAC error diagnostics.

	Theoretical	**confidence**	**level**
sample size	**68%**	**95%**	**99%**
365	68	95	99.5
120	68	94.5	99
12	66	94	98

The table entries denote the percentage of the estimated confidence intervals containing true value of NAC.

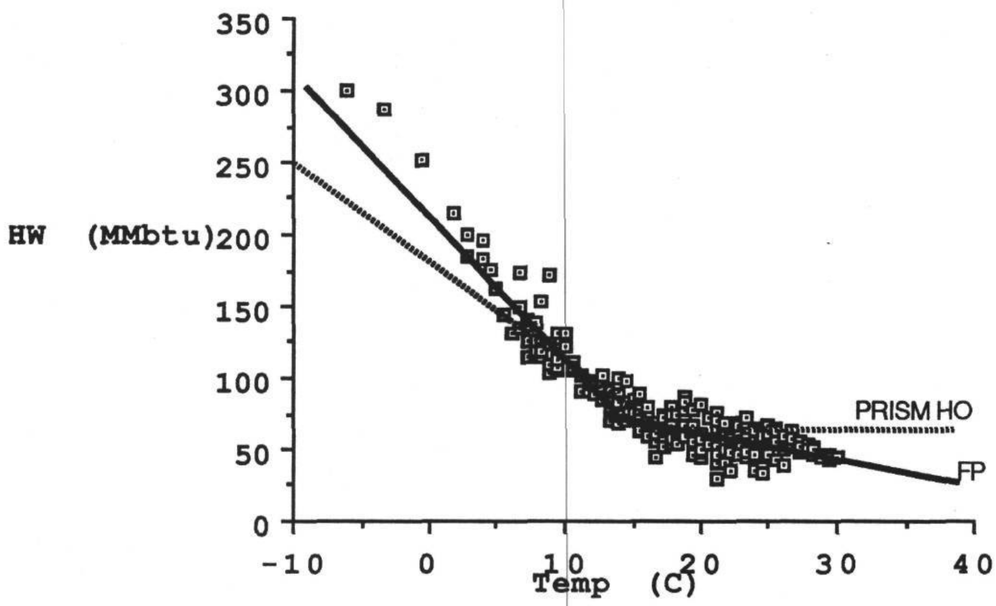
Conclusion: The error diagnostics of NAC are very accurate for data sets with "nice" (i.i.d.) errors.



Pre-retrofit Winship Data with four parameter (FP) and PRISM CO models. About half the days in normal year fall above 21 C.

	Linear	PRISM CO	FP
R-Square	0.80	0.57	0.85
NAC	19133	18690	20639
se(NAC)	174	261	344
CV(NAC)	0.9%	1.4%	1.7%

The PRISM CO NAC estimate is 9.2% less than the FP NAC estimate.



Welch Data with FP and PRISM HO models.

	Linear	PRISM HO	FP
R-Square	0.73	0.62	0.92
NAC	24565	27733	26402
se(NAC)	511	590	305
CV(NAC)	2.1%	2.1%	1.2%

The PRISM HO NAC estimate is 5% more than the FP model's NAC estimate.

Texas LoanSTAR Monitoring and Analysis Program

DOE-2 Calibration Procedures

Progress Report

Jeff S. Haberl
Doug Bronson
Sharon Hinchey
Dennis O'Neal
David Claridge

August 1991

Why Calibrate a DOE-2 Simulation?

-> Energy Audit Firms occasionally use DOE-2 or ASEAM to calculate energy savings of retrofits.

-> New buildings are often simulated with DOE-2 or ASEAM.

-> A calibrated DOE-2 run might be used to calculate energy savings and/or for commissioning.

Pros and Cons of Calibrated Models:

Pros:

-> DOE-2, BLAST, ASEAM, are well known to engineering community.

-> Calibrated models could offer very accurate savings calculations.

-> Calibrated models could be used to synthesize missing data, perform what-ifs, etc.

Cons:

-> Too many "knobs". Which "knob" to turn?

-> Simulation programs are tree killers. How does one "view" the goodness of fit?

-> TMY, TRY, WYEC weather tapes not representative of "real" weather data. What is the impact of using real weather?

Progress with Calibrated Models:

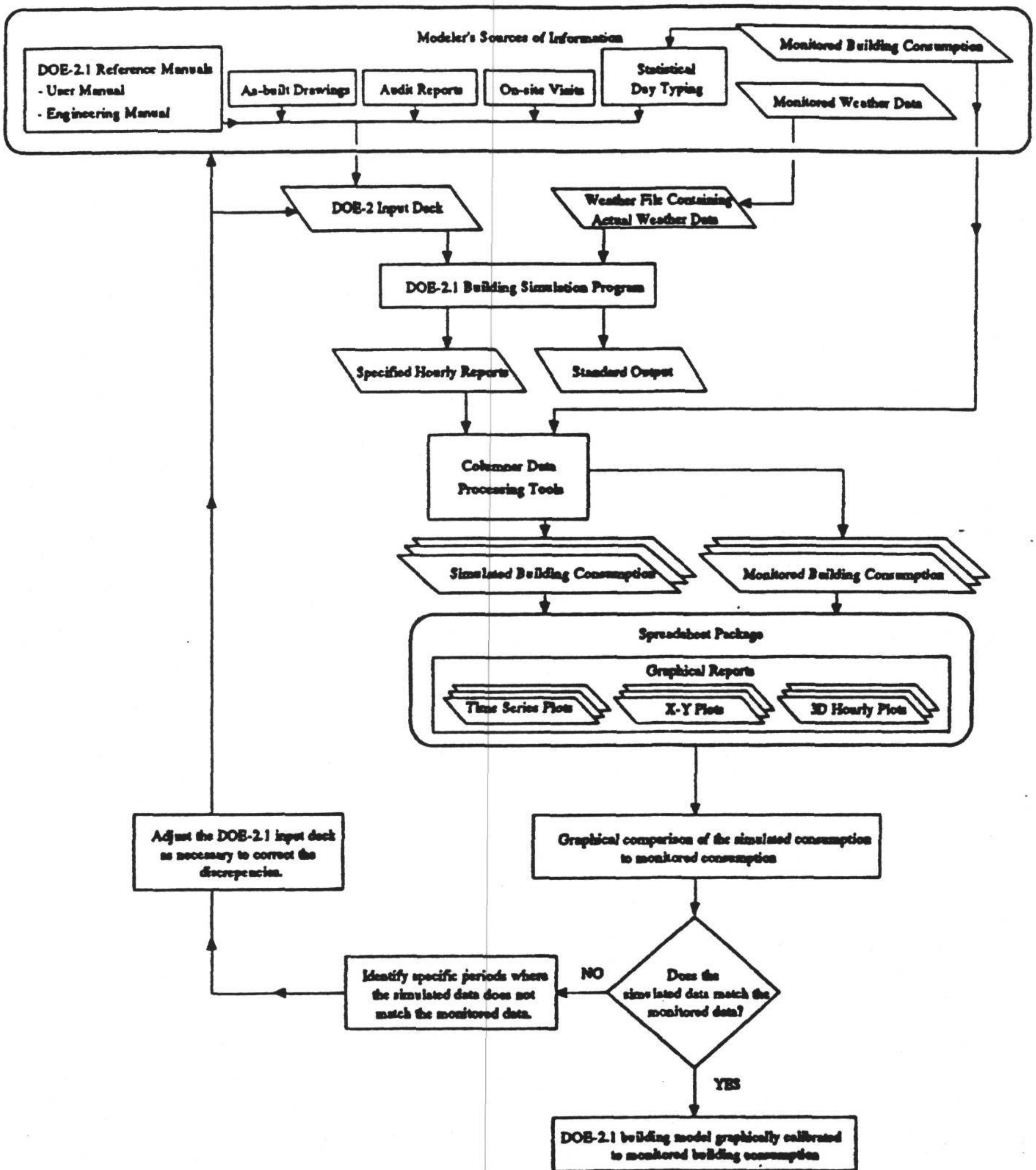
-> Development of calibration toolkits:

Non-weather dependent calibration toolkit

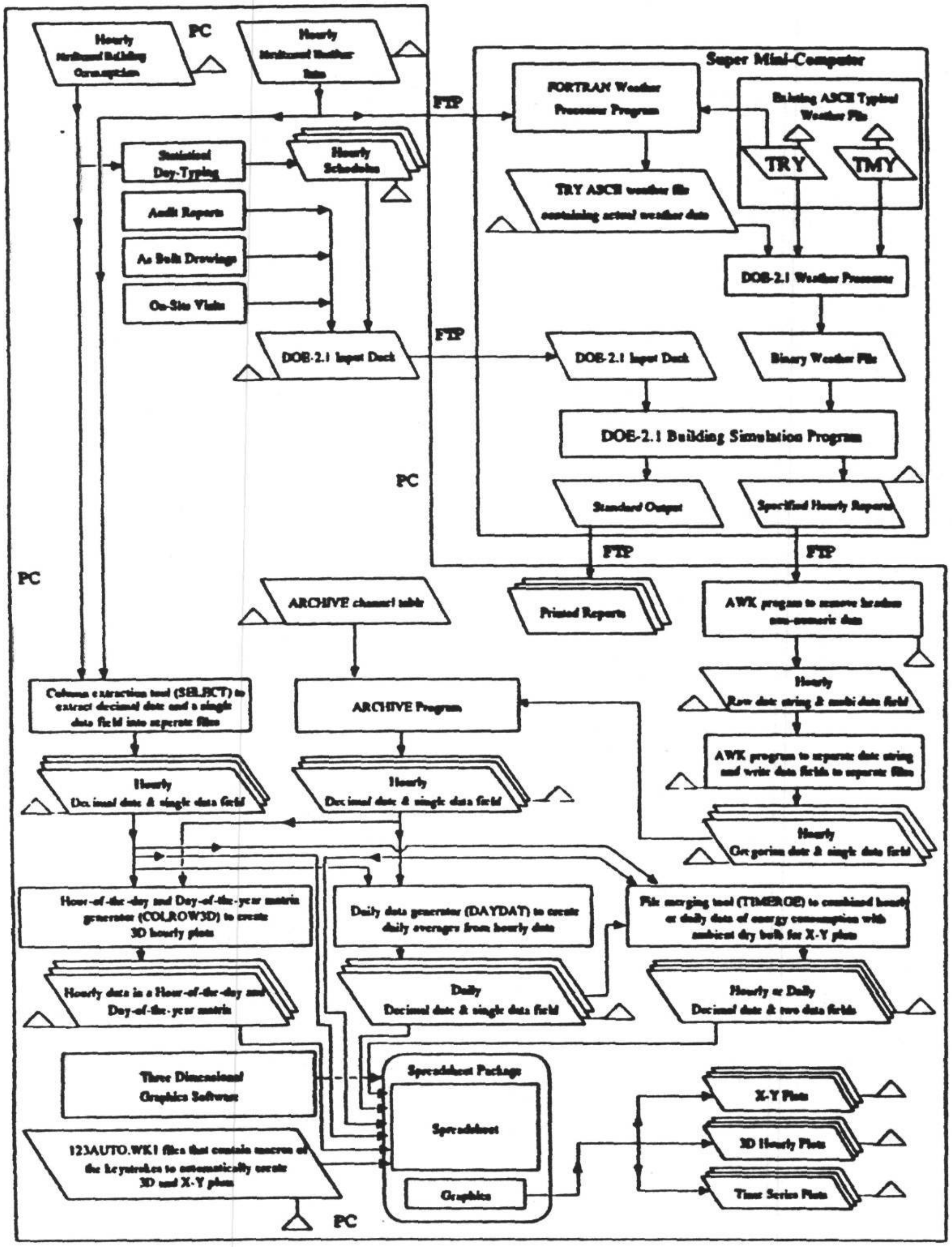
Weather effect (Tdb, RH) visualization toolkit

-> Development of calibrated simplified models (SK):

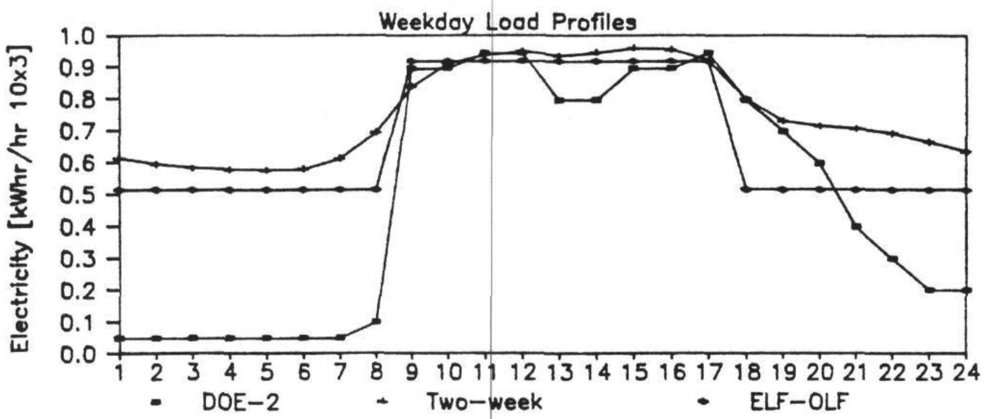
Non-weather dependent toolkit:
(General Flow Chart)

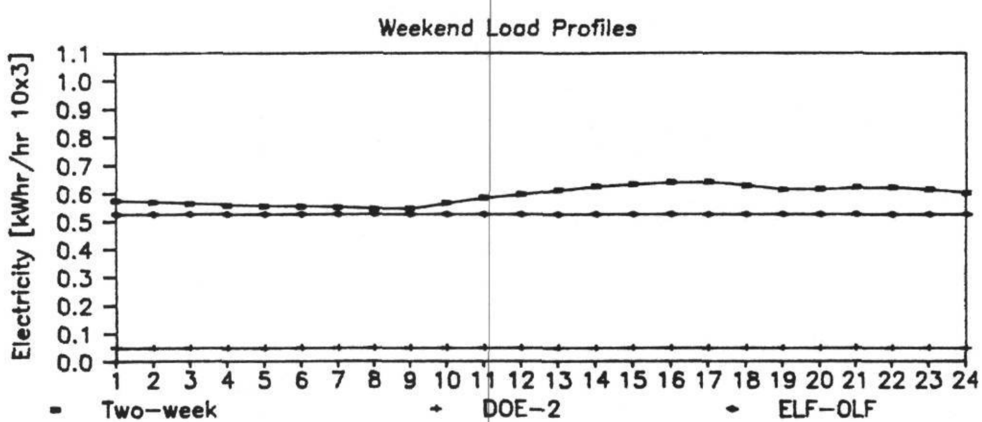


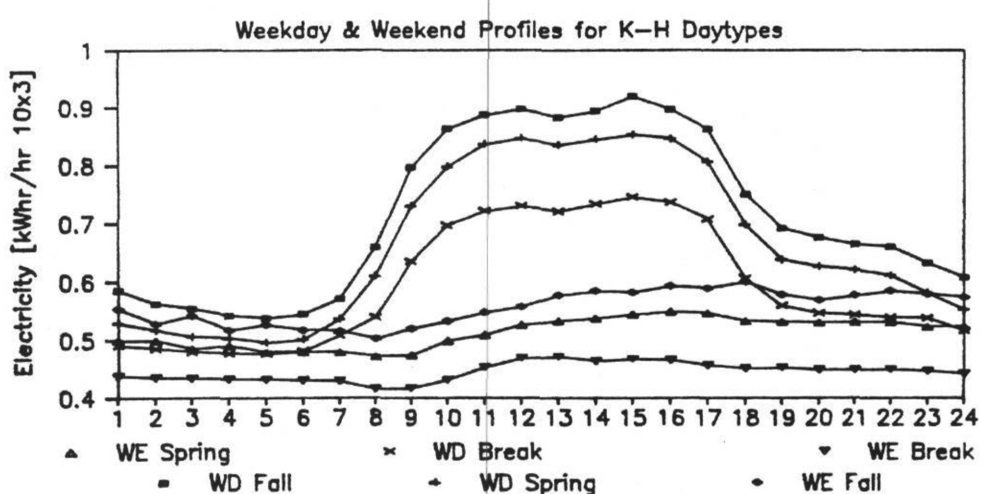
Non-weather dependent toolkit: (Software Routines)



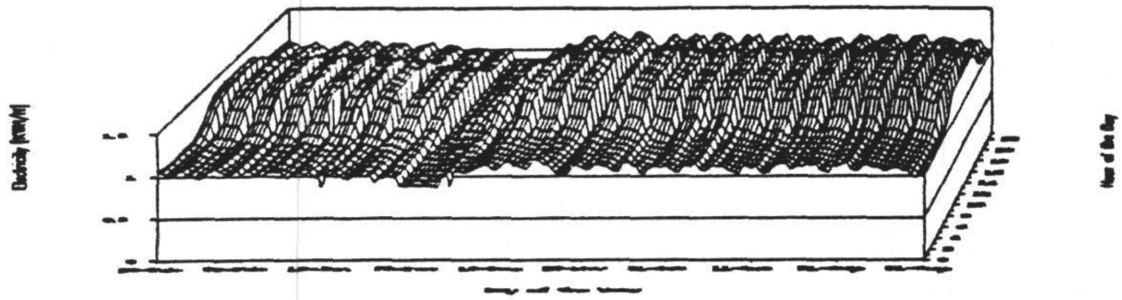
Non-weather dependent toolkit: (Example: Daytype Profiles)

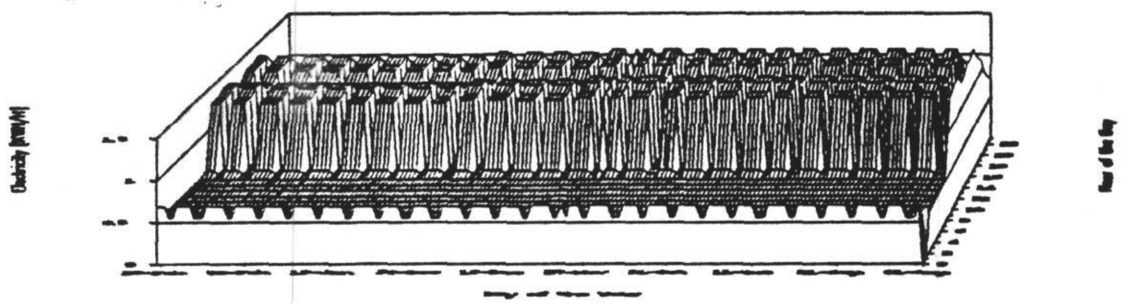


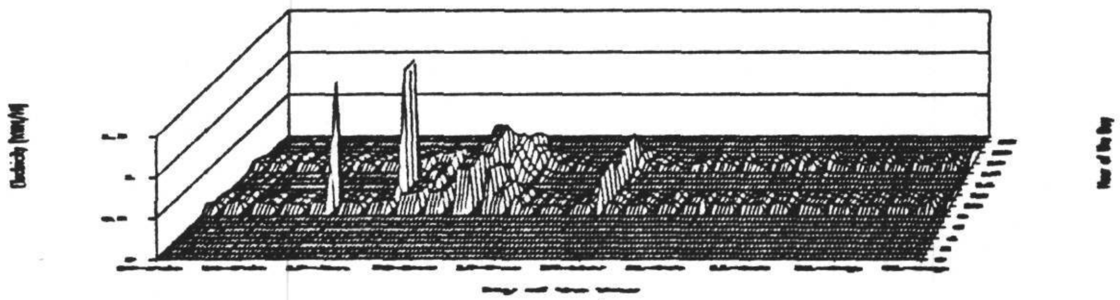


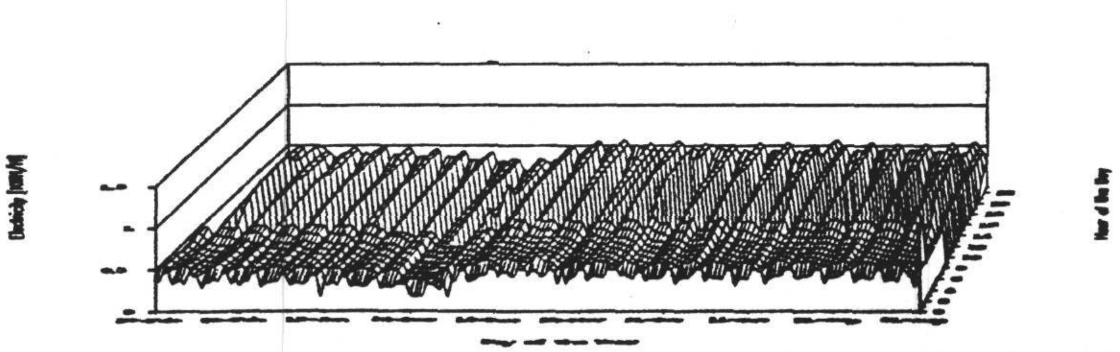


Non-weather dependent toolkit:
(Example: 3-D DOE-2 Daytypes)

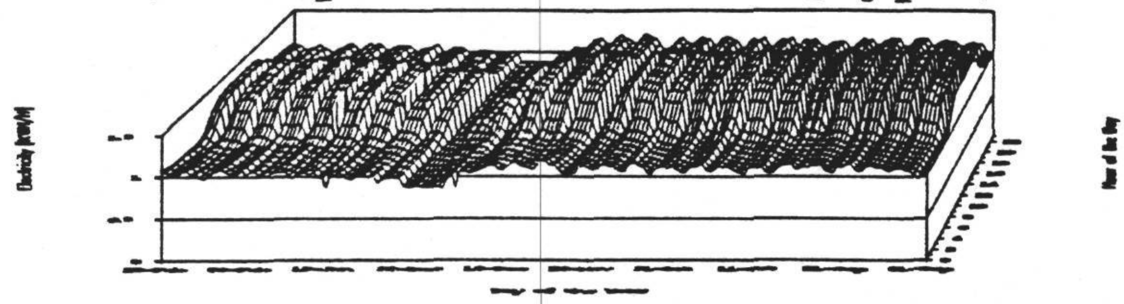


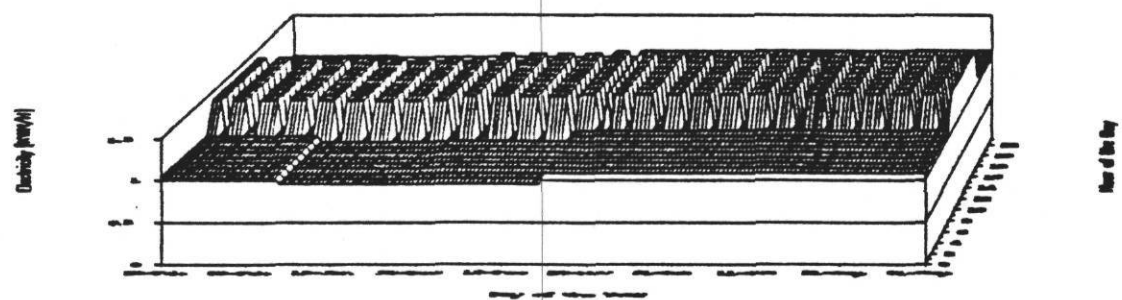


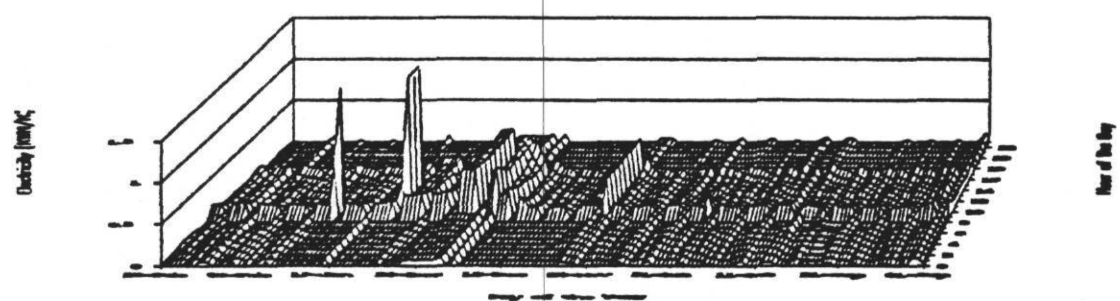


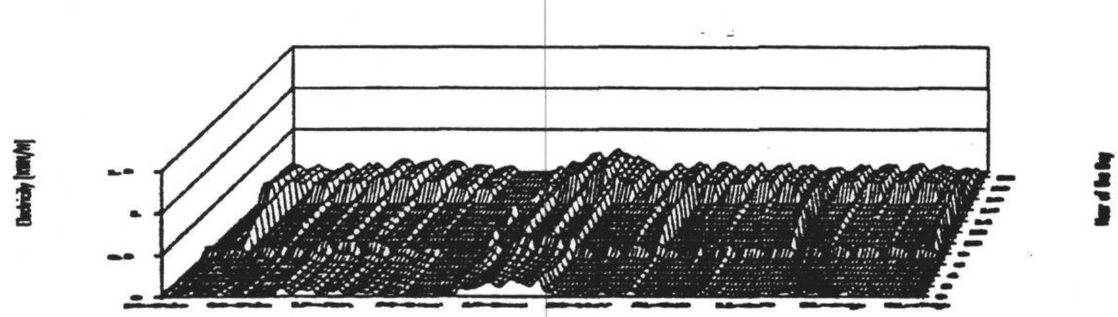


Non-weather dependent toolkit: (Example: ELF/OLF Daytypes)

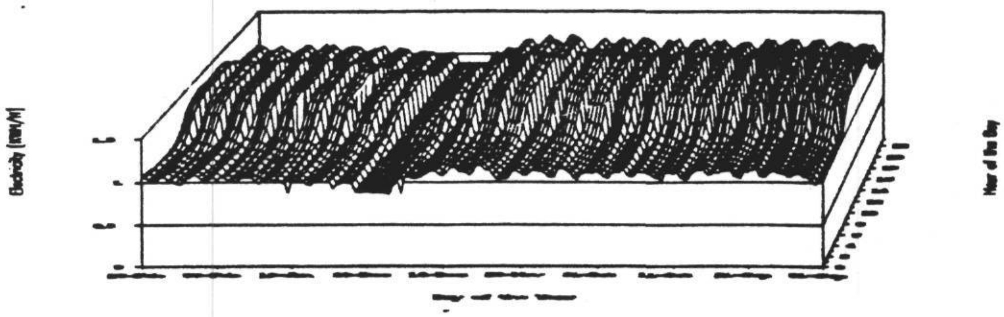


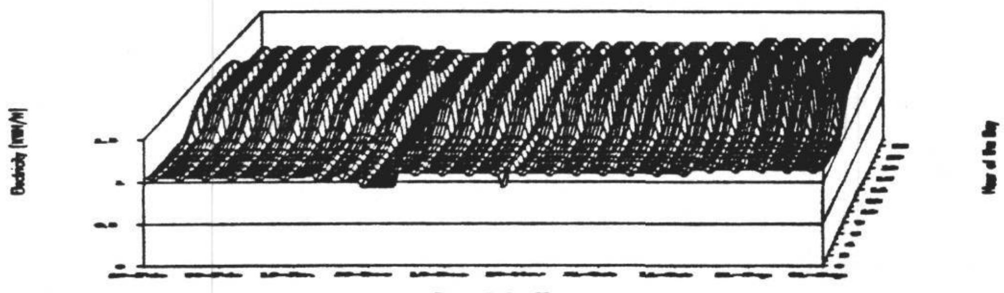


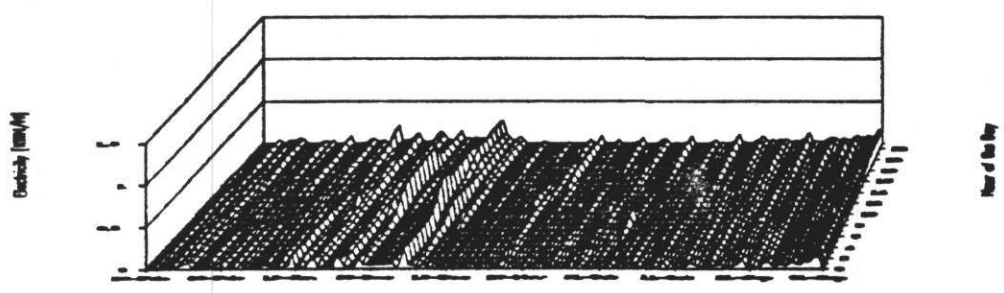


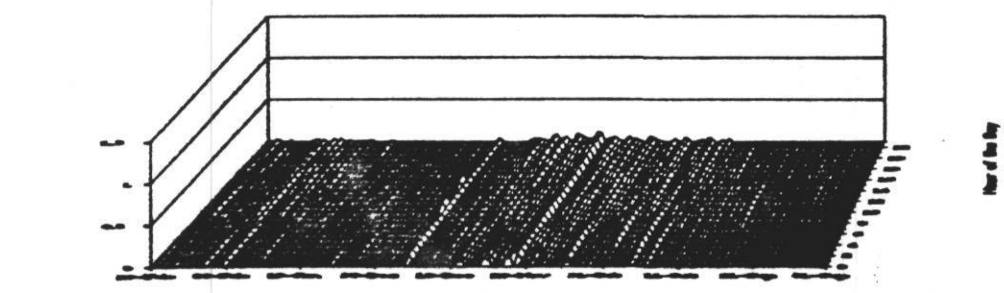


Non-weather dependent toolkit:
(Example: 3-D K-H Daytypes)





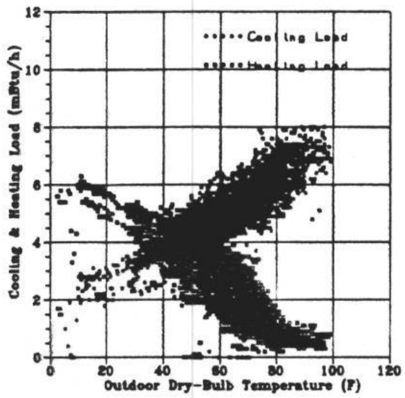


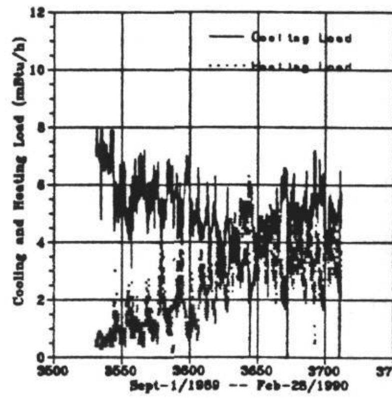


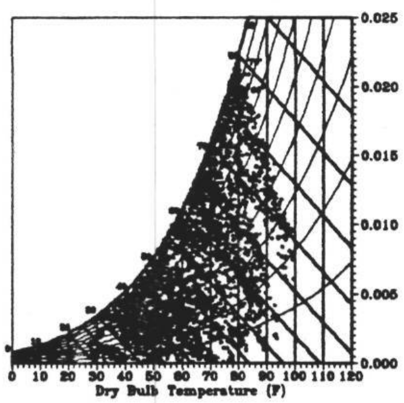
Non-weather dependent toolkit: (Summary Chart)

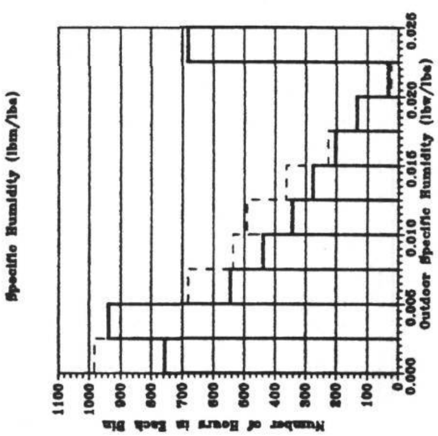
	Sep.1989	Oct.1989	Nov.1989	Dec.1989	Jan.1990	Feb.1990	Total
All units are in MWh							
Monitored	847.6	879.5	848.4	796.5	792.1	749.8	4,914.0
DOE-2	611.9	636.5	612.6	614.0	624.6	555.7	3655.3
(% diff.)	-27.8%	-27.6%	-27.8%	-22.5%	-21.2%	-25.9%	-25.6%
ELF/OLF	847.0	878.8	848.0	795.9	791.7	749.1	4,910.7
(% diff.)	-0.1%	-0.1%	-0.03%	-0.1%	-0.05%	-0.1%	-0.1%
Auditor's	795.7	823.8	792.3	801.0	789.5	744.4	4,746.6
(% diff.)	-6.1%	-6.3%	-6.6%	0.6%	-0.3%	-0.7%	-3.4%
Full Data	874.0	876.4	832.0	815.4	823.4	725.0	4,946.3
(% diff.)	3.1%	-0.4%	-1.9%	2.4%	4.0%	-3.3%	0.7%

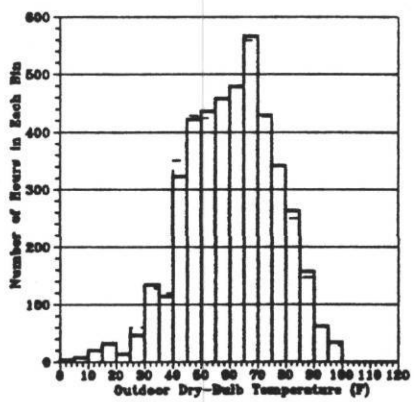
Weather Impact Visualization Toolkit: (Measured data)

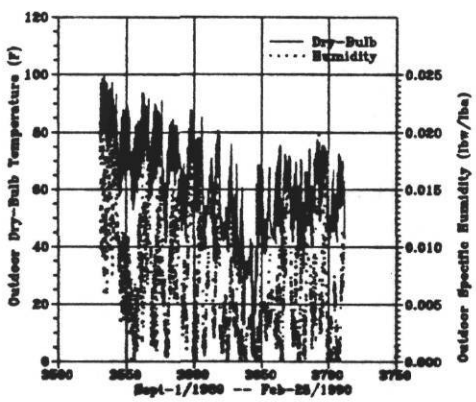




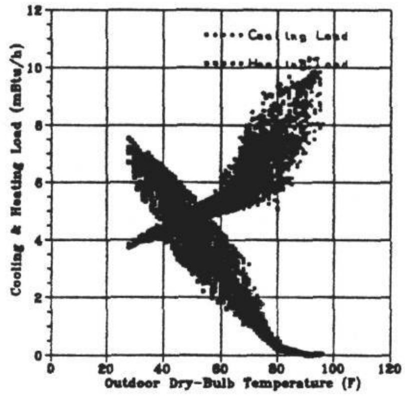


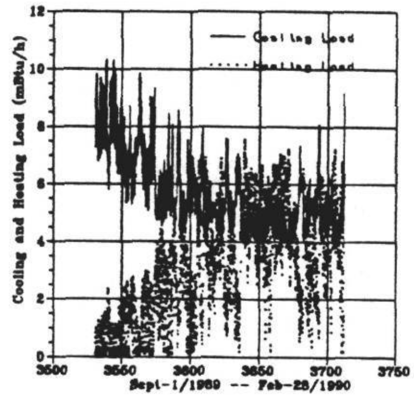


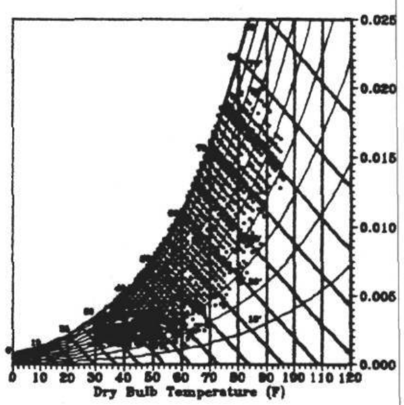


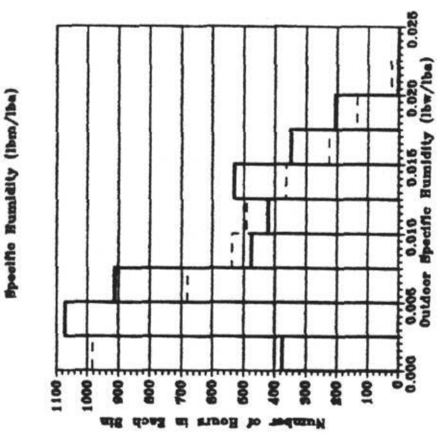


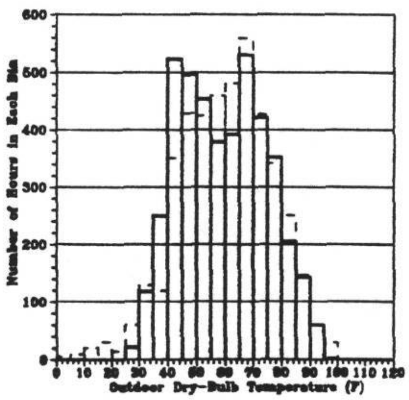
Weather Impact Visualization Toolkit: (DOE-2 TMY Simulated)

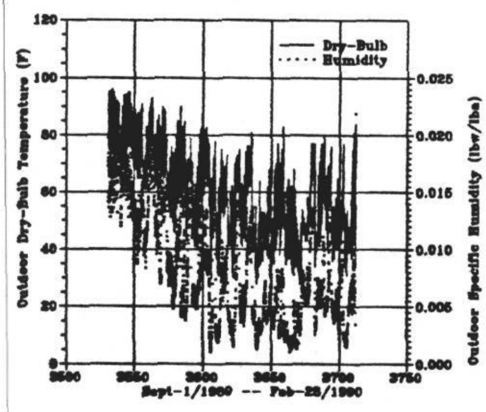




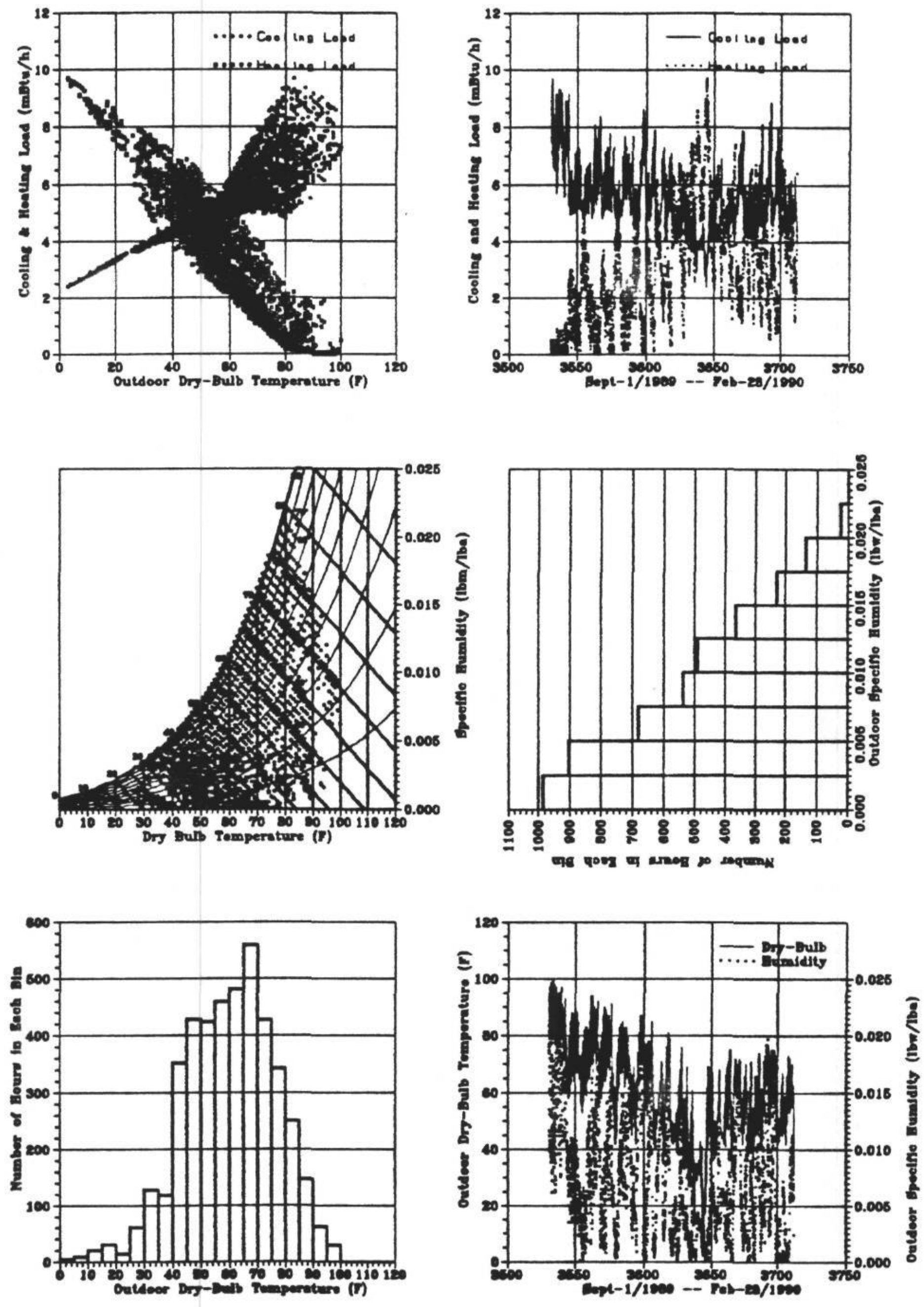




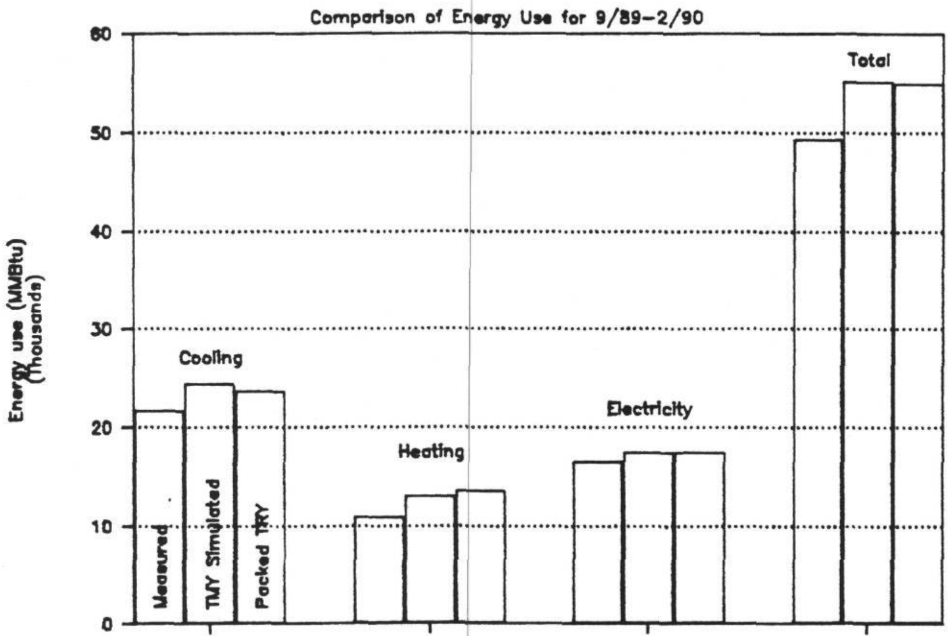


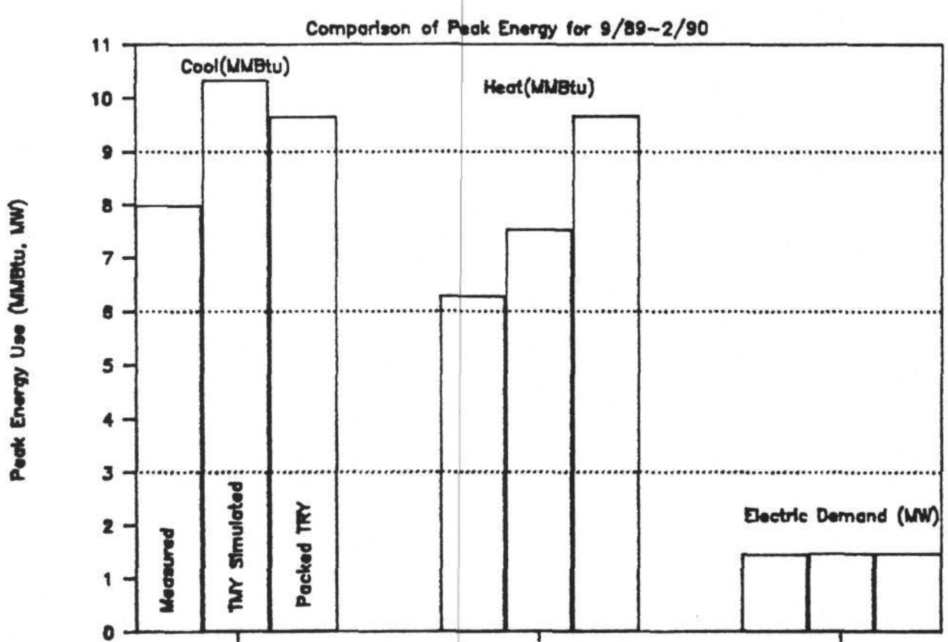


Weather Impact Visualization Toolkit: (DOE-2 Packed TRY)



Weather Impact Visualization Toolkit: (Summary Chart)





Calibrated DOE-2 Simulations:

Summary:

-> Specific Toolkits developed & tested.

Non-weather dependent

Weather effect visualization

-> Future Work.

Weather dependent toolkit.

Presentation
of
Use of Simplified Systems Model to Measure Retrofit Energy Savings

to
Monitoring and Analysis Review Commitee

Srinivas Katipamula
David E. Claridge

Energy Systems Laboratory
Dept. of Mechanical Engineering
Texas A&M University
August 19, 1991

OUTLINE OF THE PRESENTATION

- INTRODUCTION
- OBJECTIVES OF THIS STUDY
- VAV MODEL DEVELOPMENT
- DESCRIPTION OF MONITORED BUILDING AND SYSTEMS
- CALIBRATION OF VAV MODEL
- DDCV SYSTEM SIMULATION
- COMPARISON OF ENERGY SAVINGS
- QUESTIONS !

INTRODUCTION

- Typically energy savings are estimated
  - — Engineering judgement
  - — Utility bill comparison
  - — Uncalibrated hourly simulation
  - — Regression models with monitored data

- Several buildings with DDCV systems are being retrofitted with energy efficient VAV systems as part of the LoanSTAR program

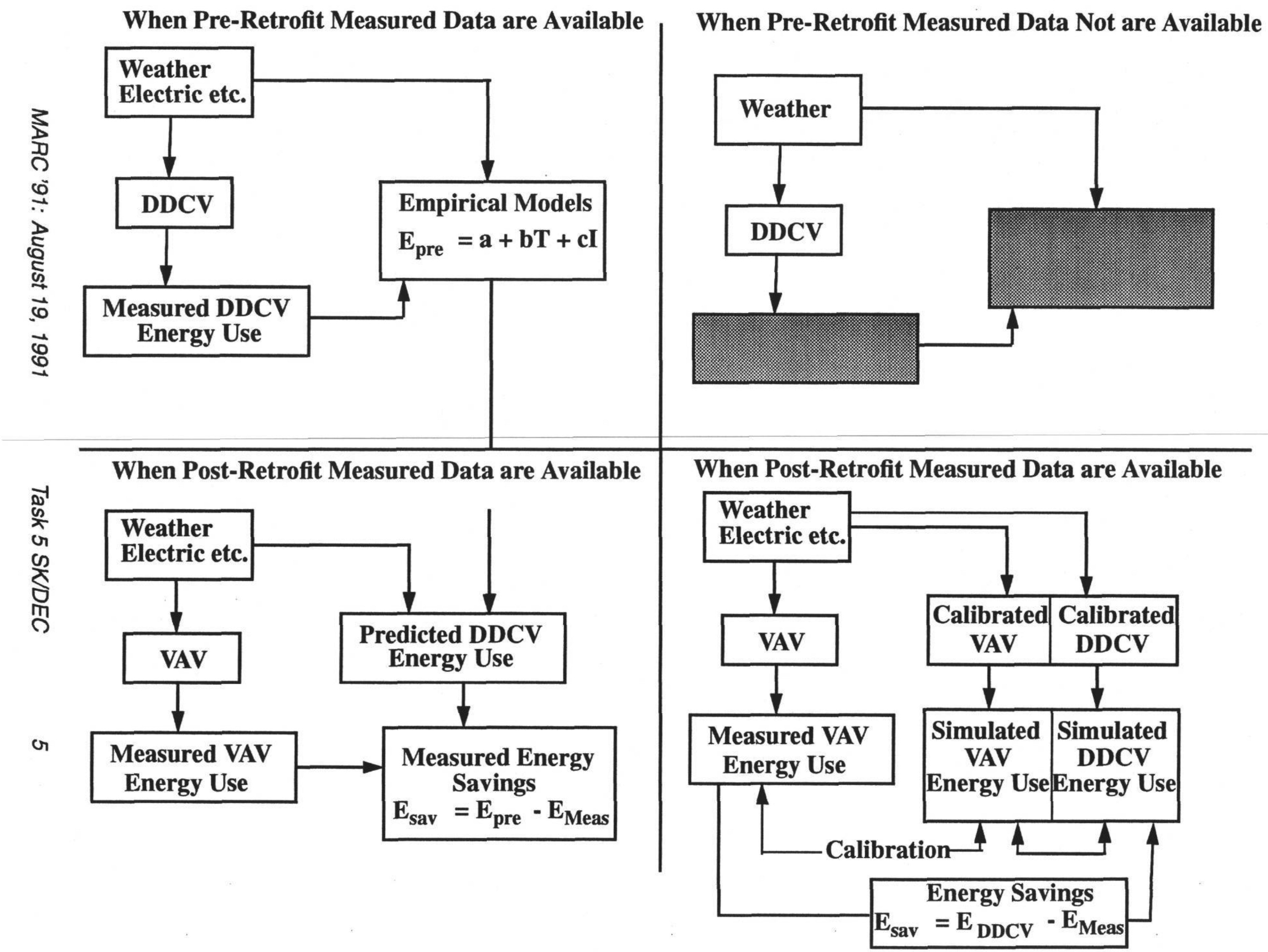
- Some buildings in the LoanSTAR program do not have pre-retrofit data

OBJECTIVE

- Develop calibrated simplified systems models to determine energy savings from HVAC retrofits

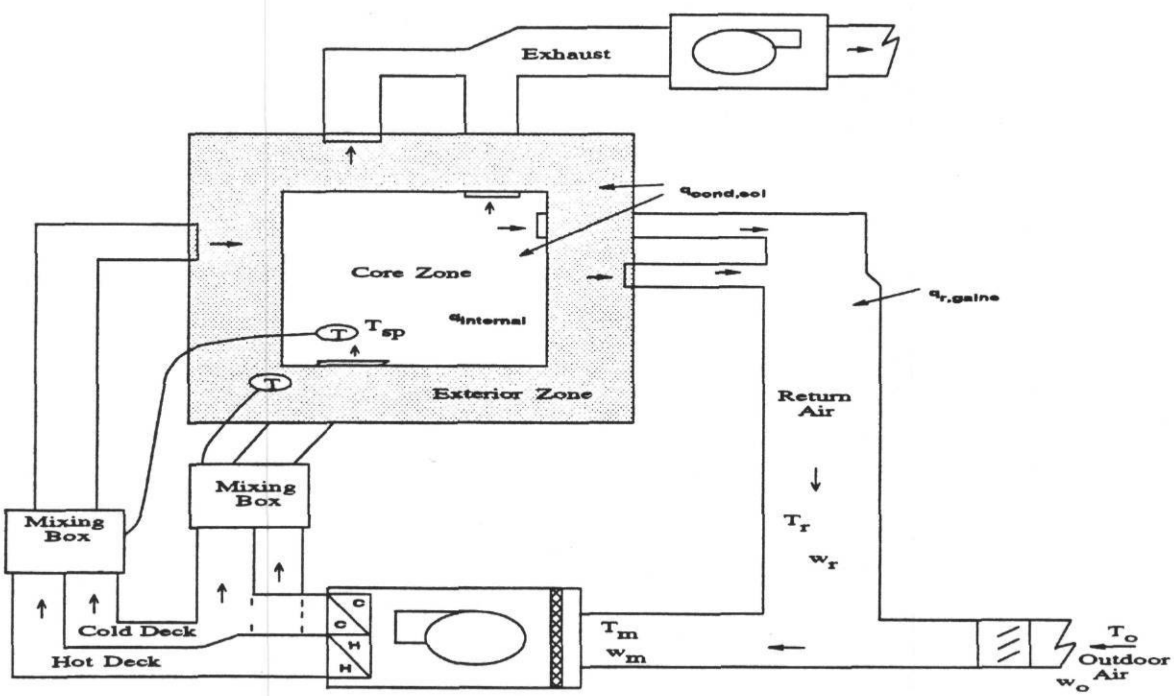
How Did We Achieve It ?

- Adapt VAV and DDCV models based on TC4.7 SEAP methodology
- Calibrate VAV model with post-retrofit data
- Use calibrated loads from VAV model with a DDCV model and measured energy use to determine savings


When Pre-Retrofit Measured Data are Available
Weather Electric etc.
DDCV
Empirical Models
$E_{pre} = a + bT + cI$
Measured DDCV Energy Use
When Pre-Retrofit Measured Data Not are Available
Weather
DDCV
When Post-Retrofit Measured Data are Available
Weather Electric etc.
VAV
Predicted DDCV Energy Use
Measured VAV Energy Use
Measured Energy Savings
$E_{sav} = E_{pre} - E_{Meas}$
When Post-Retrofit Measured Data are Available
Weather Electric etc.
VAV
Calibrated VAV
Calibrated DDCV
Measured VAV Energy Use
Simulated VAV Energy Use
Simulated DDCV Energy Use
Calibration
Energy Savings
$E_{sav} = E_{DDCV} - E_{Meas}$

VAV MODEL

- EC is divided into two zones
- Isolated core zone
- Envelope loads linear with temperature
- Internal loads for both zones are estimated based on hour of day and day of week
- O/A reset on hot deck and fixed temperature on cold deck (55 F)
- Measured outdoor dry-bulb temperature, and relative humidity and decimal date used in model



Schematic of Zones and the Dual-Duct System

DESCRIPTION OF MONITORED BUILDING

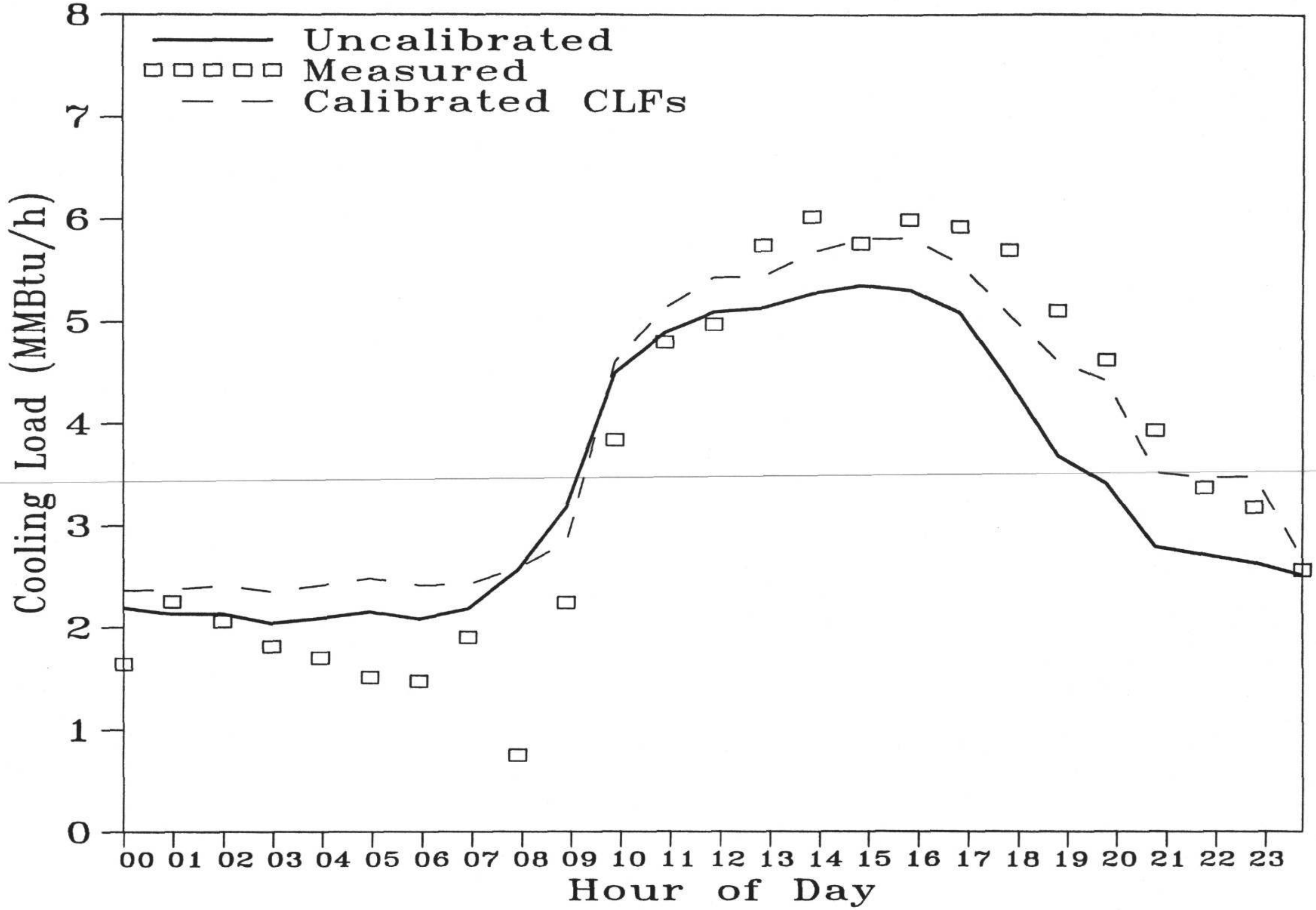
- Engineering Center (EC) is 324,000 sf gross
- EC is heavy 6-inch concrete floors and insulated concrete walls
- Office, class rooms, laboratories, and computer rooms
- Open 24 hours per day, 365 days per year
- Consumptions shows marked WD/WE differences
- EC has 12 identical dual-duct systems

VAV MODEL CALIBRATION

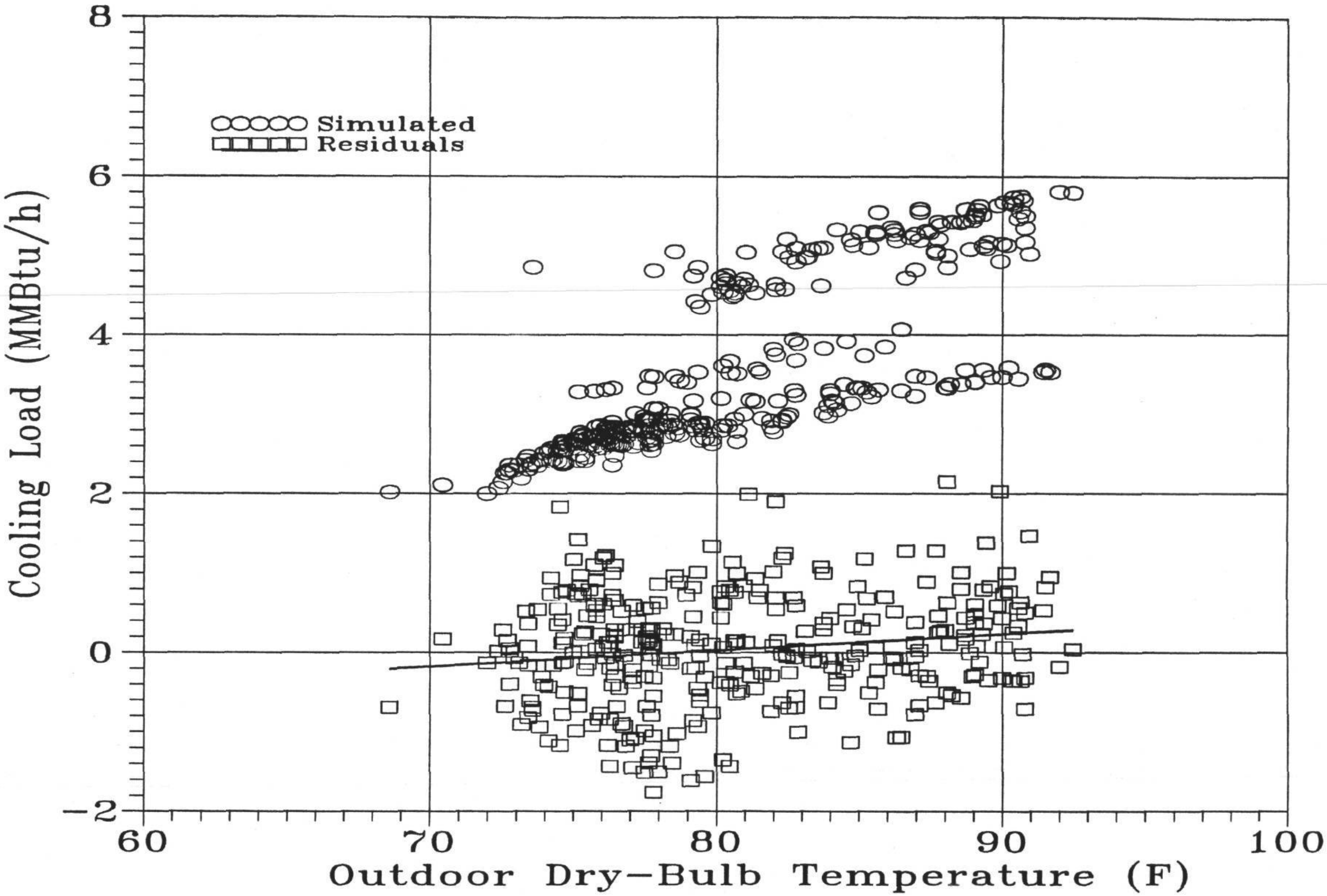
- Variables used in calibration
  - CLFs
  - Zone temperature
  - Outdoor air intake
  - Measured hot and cold deck temperatures

- Matched typical hourly simulated profile with measured hourly profile by changing CLFs

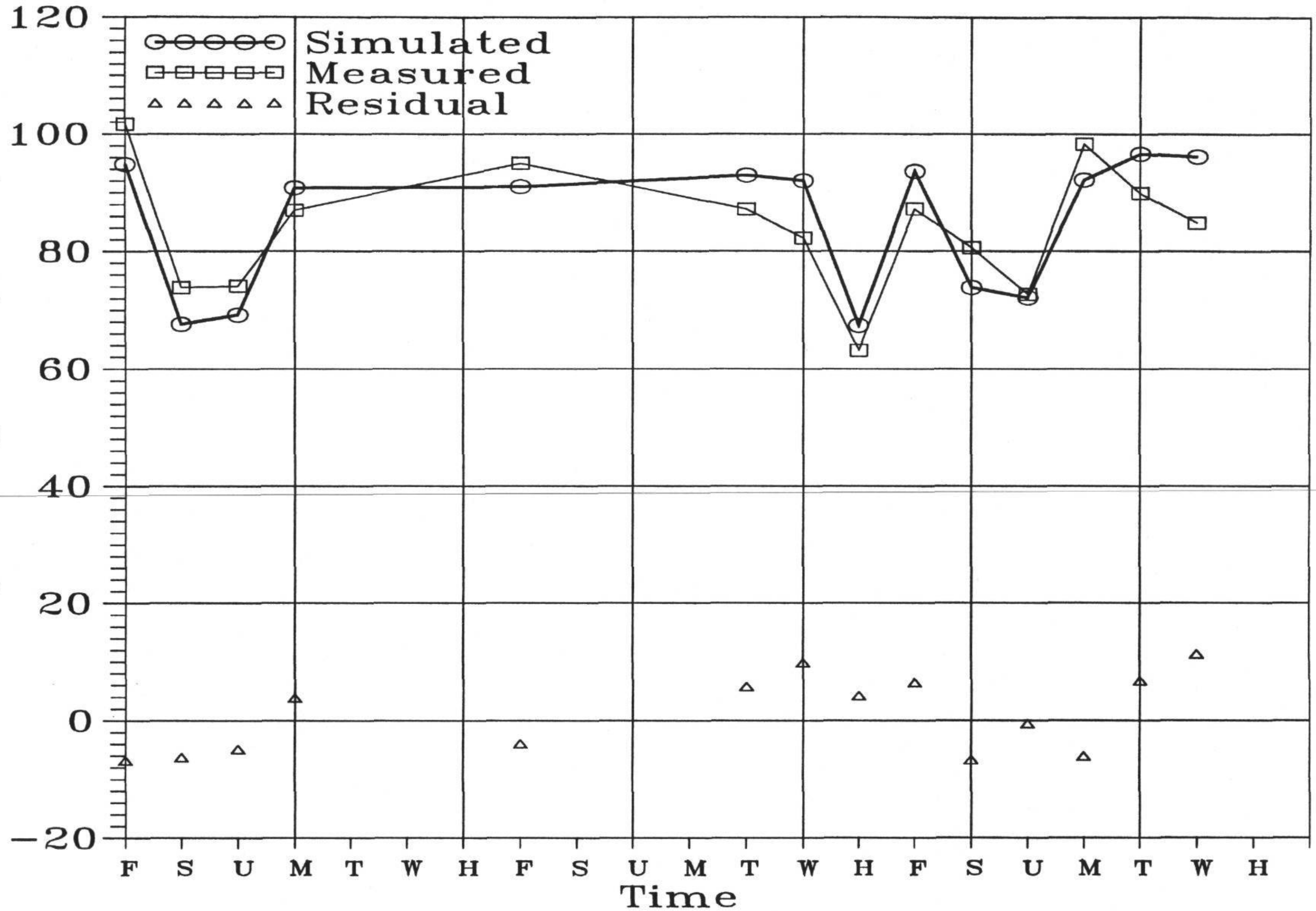
- Minimized RMSE by changing zone temperature and outdoor air intake



Comparison of Simulated, and Measured Cooling Load and Residuals for a Typical 24 Hour Period(July 2, 1991)



Simulated Cooling Load and Residuals vs Outdoor Dry-Bulb Temperature (June 21 - July 11, 1991)



Comparison of Simulated Daily and Measured Daily Cooling Load and Residuals Without Air-Handler Shut Down Days (June 21 - July 11, 1991)

COMPARISON OF ENERGY SAVING FOR THREE WEEK PERIOD

- **Savings from calibrated model**
  - * $CW_{DDCV,sim}$ - $CW_{VAV,sim}$ = 598 MMBtu
  - * $HW_{DDCV,sim}$ - $HW_{VAV,sim}$ = 56 MMBtu

- **Measured savings**
  - * $CW_{DDCV,reg}$ - $CW_{VAV,mes}$ = 905 MMBtu
  - * $HW_{DDCV,reg}$ - $HW_{VAV,mes}$ = 270 MMBtu

- **Savings discrepancy due to pre-retrofit control problem**

⇓

Methodology is promising for use with buildings lacking pre-retrofit data

TASK 5 SUMMARY

Presentation to MARC Meeting

by

David E. Claridge

August 19, 1991

ANALYSIS AND REPORTING ACCOMPLISHMENTS

Results

- Reports
- Agency Contact/O&Ms
- Measured Savings

Analysis Improvement/Development

- Uncertainty in Savings
- Normalized Annual Consumption Measures
- DOE-2 Calibration
- Calibrated Simplified Systems Models

Future Directions

- Reports
- Agency Contact/O&Ms
- Measured Savings
- Data Base
- Analysis Development

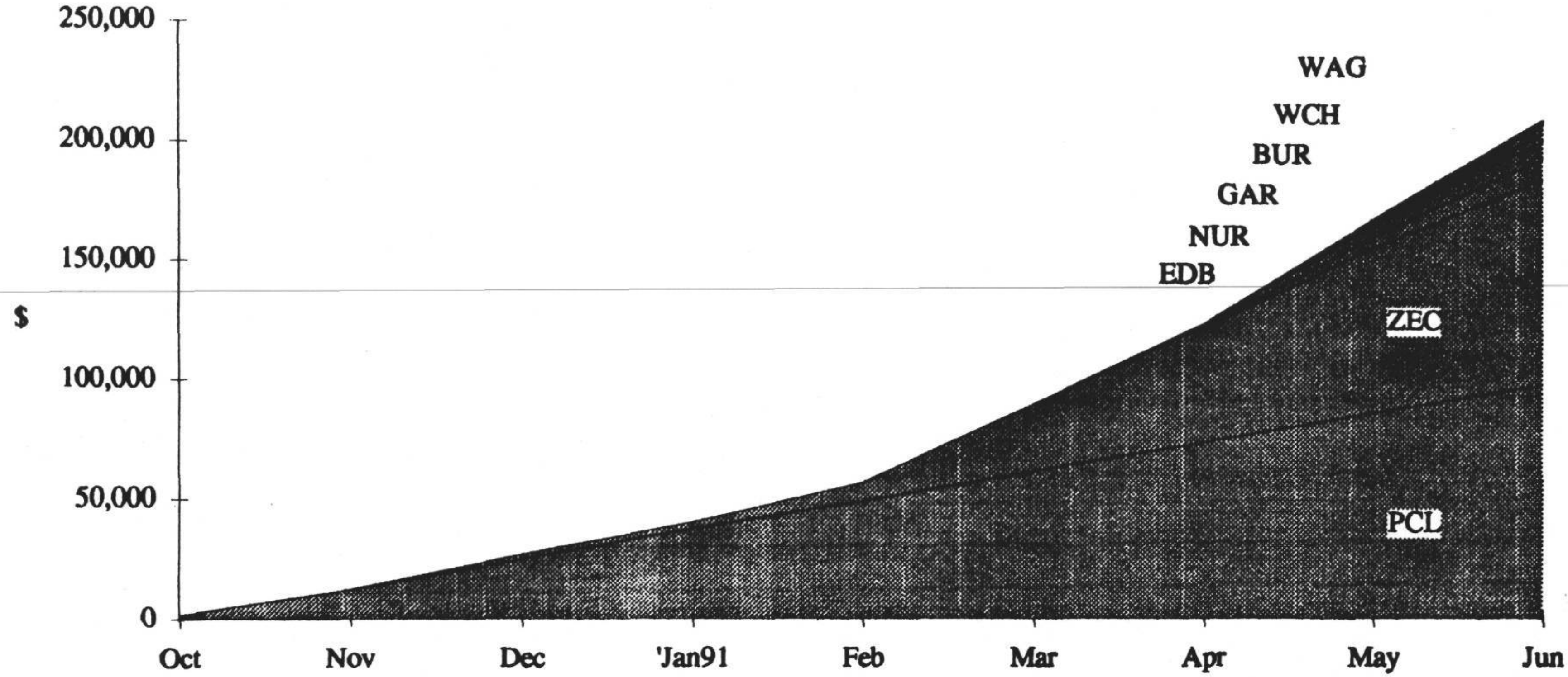
REPORTING

- Monthly Energy Consumption Reports to 29 Sites at 7 Locations
- Voyager Software at 5 Locations
- Inspection Plots Distributed on a Request Basis

AGENCY CONTACT SUMMARY

- **O&Ms Identified Jointly with Facilities Personnel & Implemented**
    - **Closure of Reheat Valves at PCL (U.T. Austin)**
    - **Hot Water Pump Shut Down at Zachry Engineering Center**
    - **Annual Savings Approach $100,000**
- **13 Site Description Note Books Completed**
- **9 Interviews/27 Buildings**
- **Building Indices Prepared**
- **Follow-Up Implemented**

Cumulative Savings For Eight LoanSTAR Buildings



ANALYSIS IMPROVEMENT/DEVELOPMENT

Uncertainty in Savings

- **Zachry Uncertainty Determined**
- **General Approach Being Defined**

Normalized Annual Consumption Measures

- **NAC Developed for Linear, Multivariate and 4-Parameter Models**
- **Error Diagnostics Developed for Linear, Multivariate and 4-Parameter NACs**
- **Normalized Systematic Residuals Index Defined**

DOE-2 Calibration

- **Procedure Developed for Calibration to Non-Weather Dependent Loads**
- **Procedure Developed for Using Measured Weather Data in Simulations**

Calibrated Simplified Systems Models

- **Procedure Developed and Applied to Zachry Data**

FUTURE DIRECTIONS

Reporting

- Improve Inspection Plots and Add Sites
- Send Voyager Files
- Improve Monthly Energy Reports and Add Sites

Future Directions - Agency Contacts/O&Ms

- Add engineer
- Review all site data for O&Ms
- Provide Timely Feedback/Follow-up
- Develop Efficient Methodology/Procedures

Future Directions - Measured Savings

- Complete Savings Measurement for Current Buildings
- Determine Savings for Additional Buildings
- Update Utility Cost Basis
- Energy End-Use Data Base
- Individual-Measure Savings Data Base

Future Directions - Analysis Development

Uncertainty Analysis

- Amount of Post-Retrofit Data
- Amount of Pre-Retrofit Data
- Range of Predictors in Pre-Retrofit and Post-Retrofit Data

Model Error Diagnostics

Model Development

- PCA
- Hourly Methods
- Improved Predictors

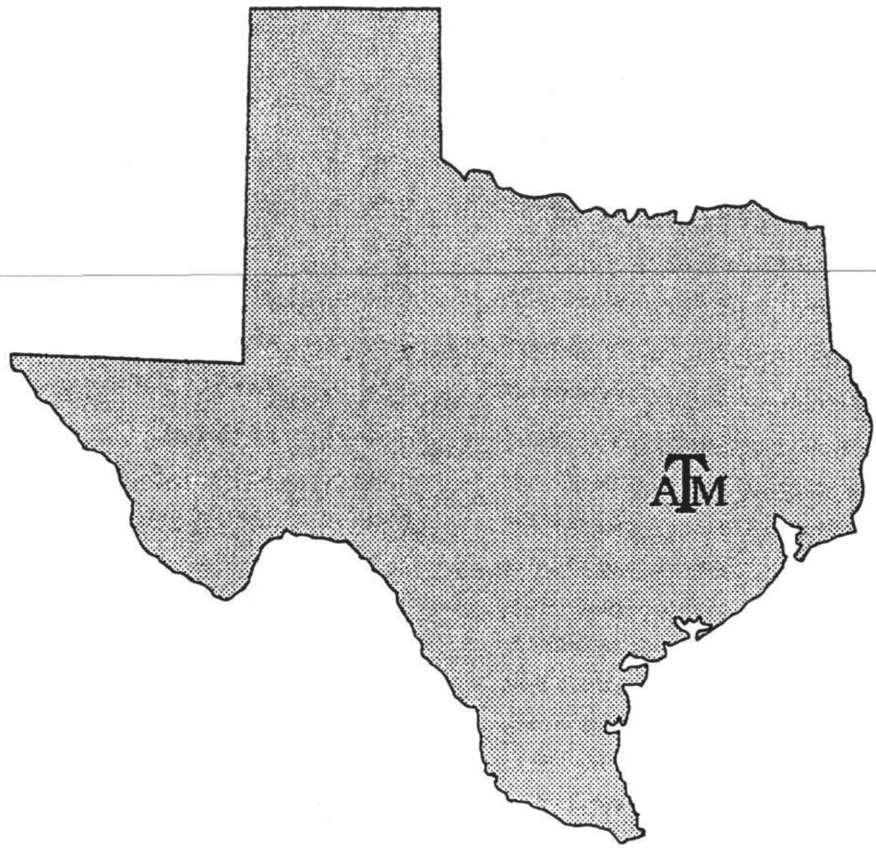
DOE-2 Calibration

Calibrated Systems Models

- Test and Refine Methodology

Diagnostic Capabilities

LoanSTAR Project



Computer Systems
And
Support

Staff

Dean Willis
Emily Lybarger
John Lybarger

Systems Support Functions

- Selection, Acquisition, and Maintenance of Computing Facilities.
- Security of Systems and Data, including:
  - Physical Security (Locks)
  - Logical Security (Passwords)
  - Archival Security (Backups)
- Consulting for Feasibility, Planning, and Development Issues.

Review from Last Meeting

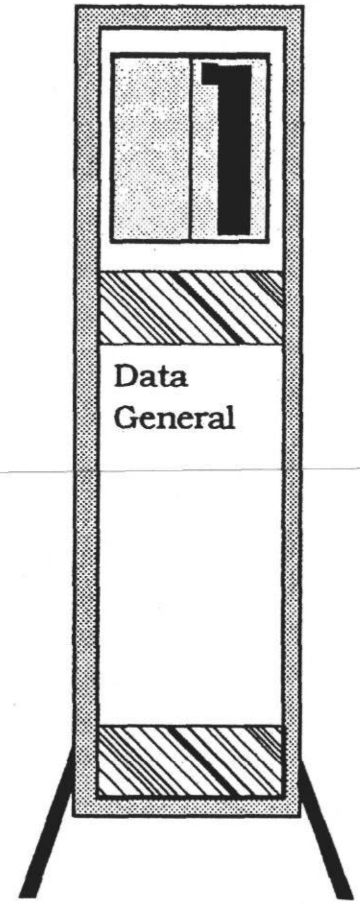
LoanSTAR Computing Resources

UNIX Systems:	AV-4000 Server 2 Diskless Workstations 2 X-Window Terminals 1.5 Gigabytes Disk Storage Streaming Cartridge Tape
PC-DOS Systems:	22 Project Computers 13 In-Kind TAMU Computers
Output Devices:	5 TAMU In-Kind Laser Printers 7 Asst. Project Printers 10 Asst. TAMU In-Kind Printers Multi-Pen Plotter

LoanSTAR Computing Resources

UNIX Systems:	AV-4000 Server, 32 Mb R.A.M., 32 Ordered
	2 Diskless AV-300 Monochrome Stations, 24Mb RAM
	1.5 Gb Disk, 1 Gb Ordered
	1 AV-310C Color Station, 24 Mb RAM, 334 Mb Disk (Ordered)
	2 Monochrome X Terminals
	1 Color X Terminal (Ordered)
	1 PC UNIX System (Ordered)
PC-DOS Systems:	25 Project Computers
	16 In-Kind TAMU Computers
Output:	5 TAMU In-Kind Laser Printers
	3 Project Laser Printers
	1 Project Color Printer
	1 Project Color Plotter
	6 Other Project Printers
	10 TAMU In-Kind Printers
Input:	Logitech Hand Scanner
	AT&T 200 DPI Scanner
	Epson 300 DPI Color Scanner

UNIX Server



Data General AV-4000

Dual Motorola 88000 RISC CPU

16 Mhz Clock Speed

32 MB RAM (Upgrade on Order)

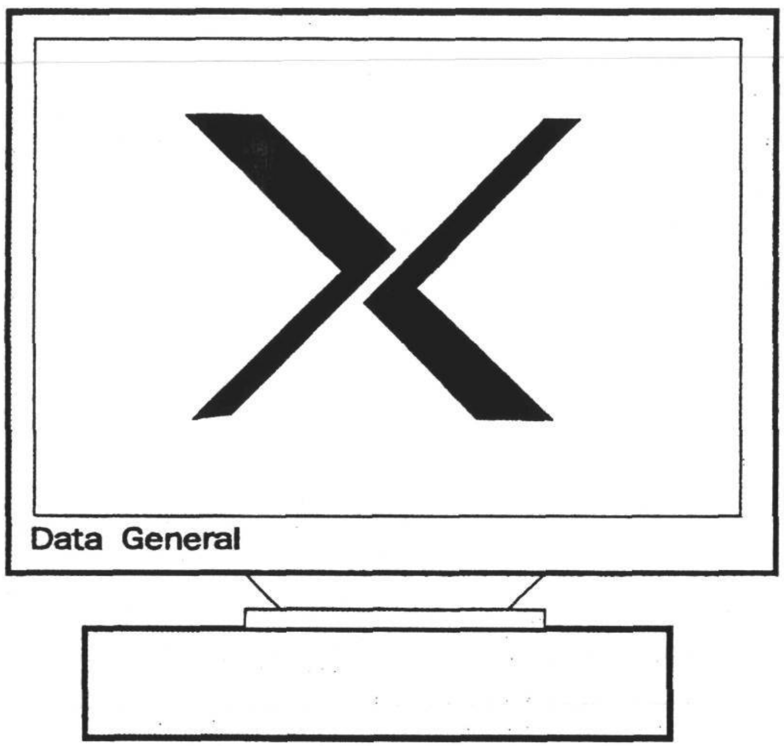
1.5 Gb Disk (Upgrade on Order)

32 MIPS Performance

Symmetric Multiprocessing

DG/UX UNIX Operating System

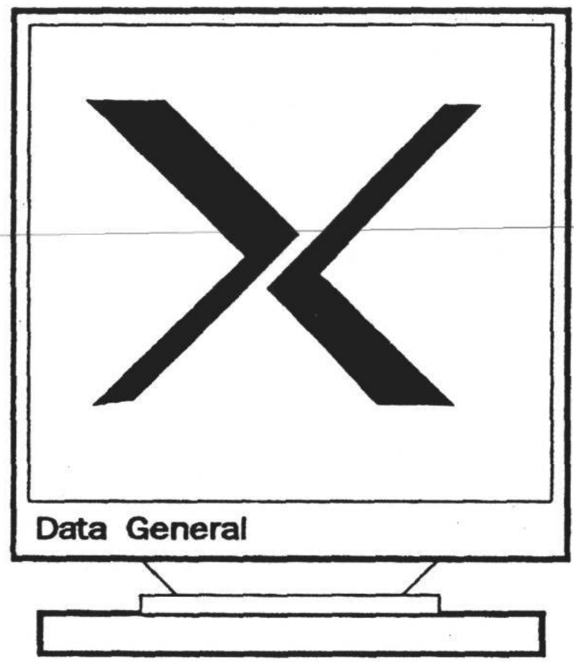
UNIX Workstations



Data General AV-300

- Motorola 88100 RISC CPU
- 16Mhz Clock Speed
- 24Mb RAM
- 0 to 334Mb Disk
- 16 MIPS Performance
- 1280 by 1024 Graphics
- DG/UX UNIX Operating System
- MIT X Window System v11
- OSF/Motif User Interface

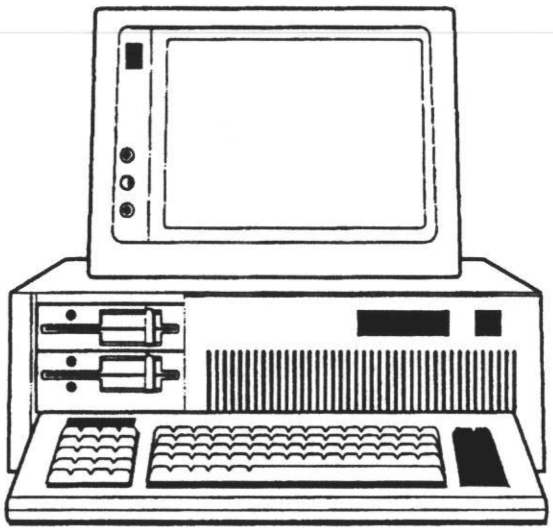
X Terminals



Data General AV-30x

- Run Jobs On Server
- Remove User I/O from Server
- 1024 by 1024 Graphics
- Connect to Variety of Hosts
- Require Minimal Support
- MIT X Window System v11
- OSF/Motif User Interface
- $1,800 to $2,500

Personal Computers



Intel 8088, 286, 386SX, 386, 486 CPUs

4.77 to 33 MHz Clock Speeds

640kb to 8Mb RAM

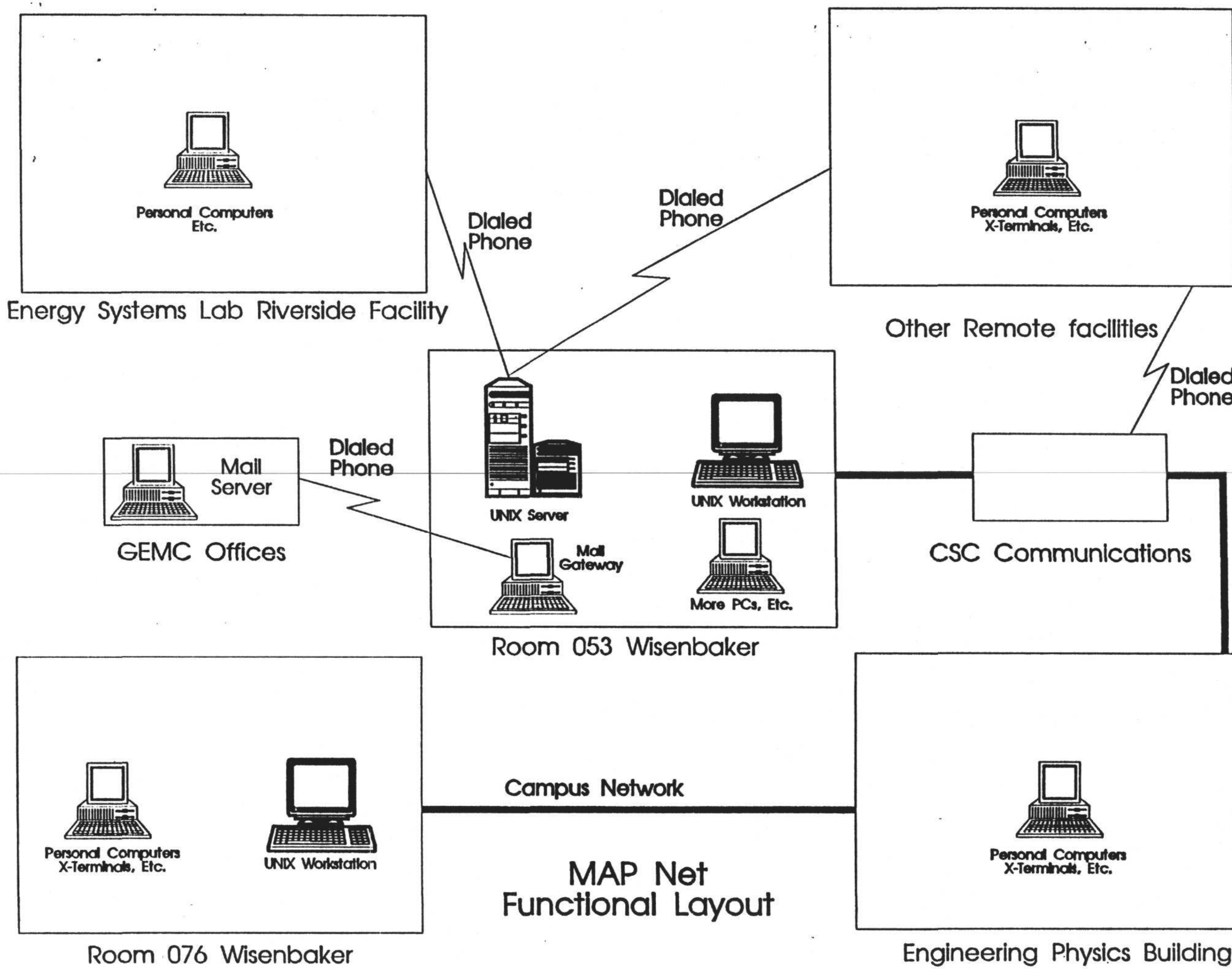
20 to 200 Mb Disk

640 x 200 x 2 to 1024 x 768 x 256 Graphics

MS-DOS 4.01 and 5.0

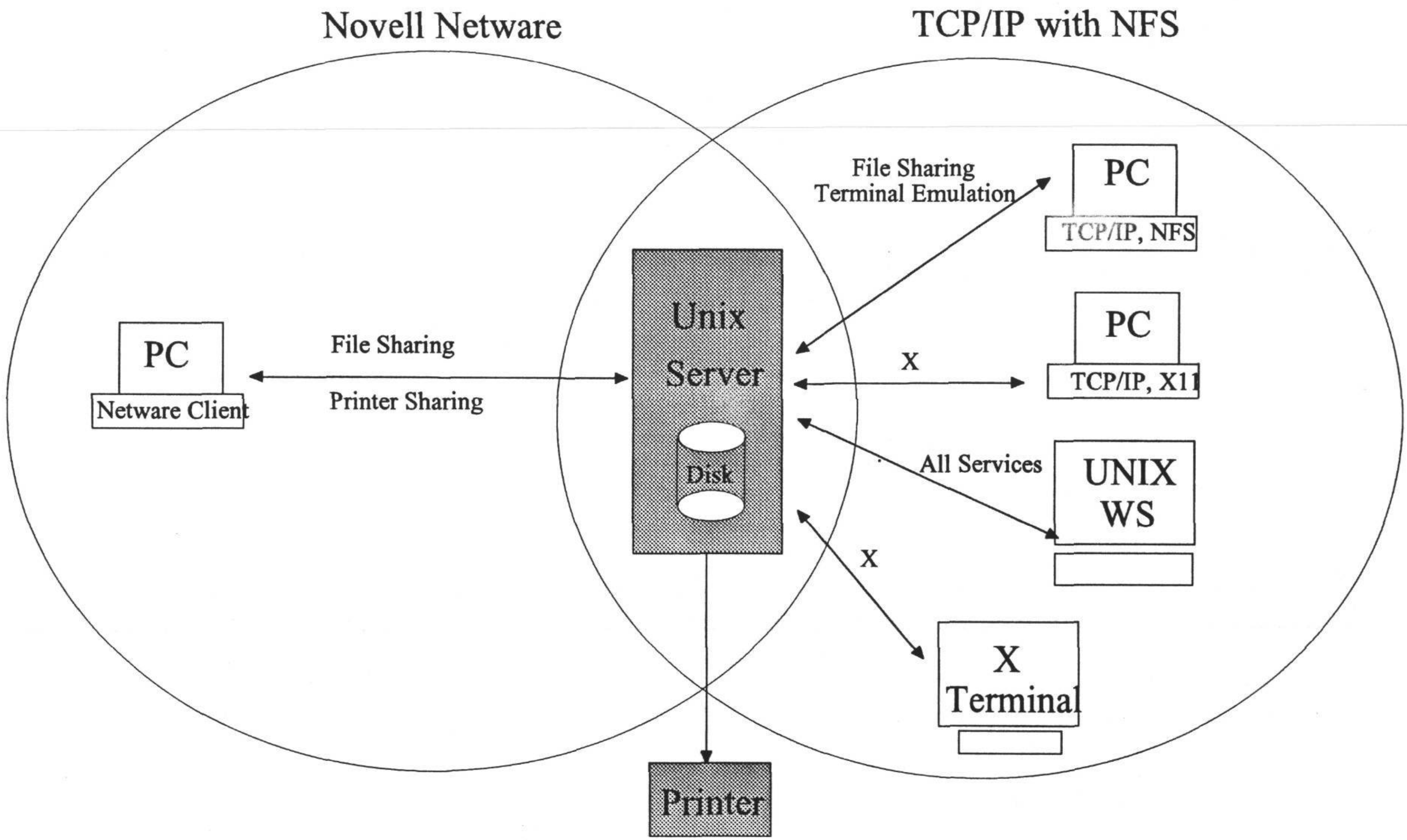
Windows 3.0a

$1,500 to $4,000 each



MAP Net
Functional Layout

Logical Network Structure



Commercial Software Systems

User Interface:	Microsoft Windows on PC OSF/Motif on UNIX
Word Processing:	Windows Word on PC Framemaker and TeX on UNIX
Analysis:	Microsoft Excel on PC Quatro Pro on PC Lotus 1-2-3 on PC Voyager on PC SC Spreadsheet on UNIX SAS on PC and UNIX
Graphics:	Grapher/Surfer on PCs Corel Draw on PCs Intek 3D on PC XGraph on UNIX
Database:	Reflex and Paradox on PC Informix SE on UNIX (Ordered)

Future Plans

- High-Capacity Backup -- 4mm or 8mm
- Read/Write Optical Disk Drives
- Wingz Graphical Spreadsheet on UNIX
- More Extensive use of NetWare for PCs

Texas LoanSTAR
Monitoring and Analysis Program

Technical Support
Data Acquisition and Storage

Submitted by:

Robert E. López
Vandana Jagannathan
Jinrong Wang

Energy Systems Laboratory
Mechanical Engineering
Texas A&M University
College Station, Texas

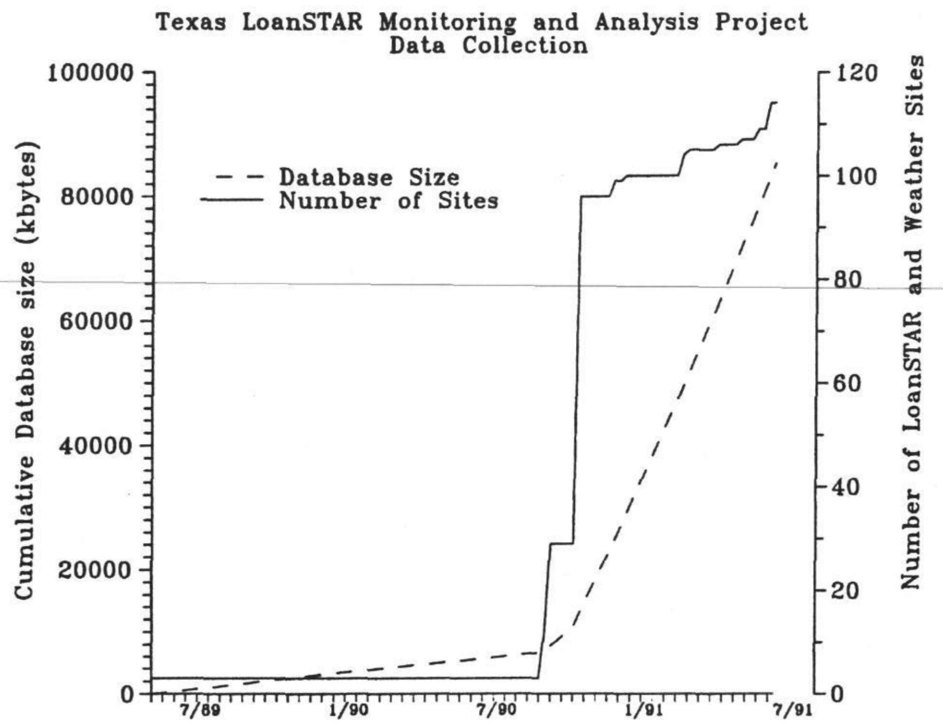
August 1991

Texas LoanSTAR Project
Data Acquisition and Storage

Primary Responsibilities:

- Data Collection/Polling LoanSTAR sites
- Processing and Archiving of Data
- Data Quality Control
- Report Generation
- Data Release

Data Collection Overview



Weekly Collection:

LoanSTAR sites	
January 1991	28
August 1991	47
LoanSTAR channels	
January 1991	532
August 1991	717
Kilobytes collected each week	
January 1991	844
August 1991	1,209

National Weather Service data
1,217 kilobytes each week

Total weekly collection: ***2,426*** *kbytes*

Texas LoanSTAR Project
Data Acquisition and Storage

Time Requirements:

Weekly

- Data Collection/Polling 47 LoanSTAR sites
  ***6** hours per week*

- Processing and Archiving of Data
  ***8** hours per week*

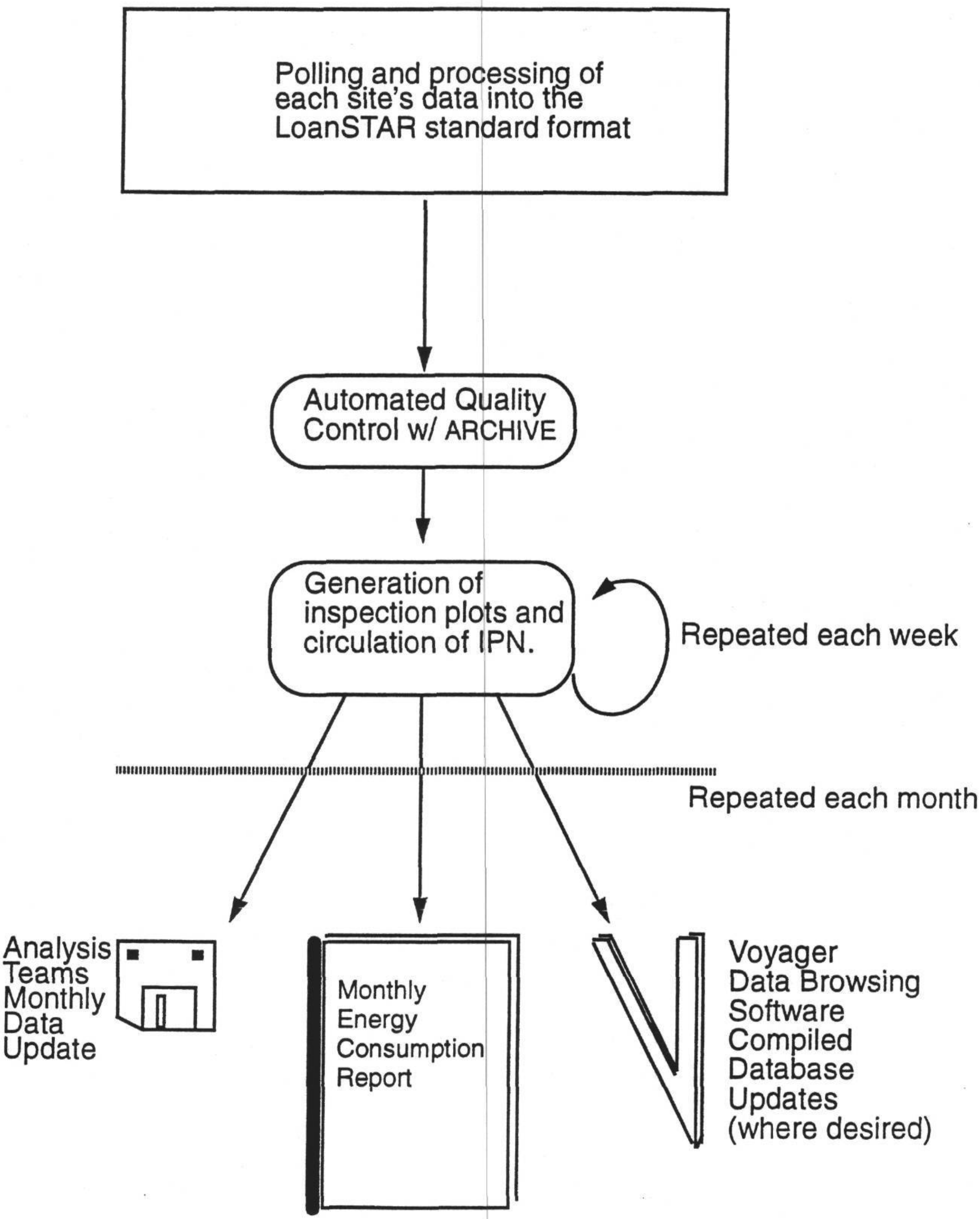
- Data Quality Control
  ***15** hours per week*

Monthly

- Report Generation
  ***120 - 160** hours per month*

- Data Release
  ***10 - 20** hours per month*

LoanSTAR Data Management

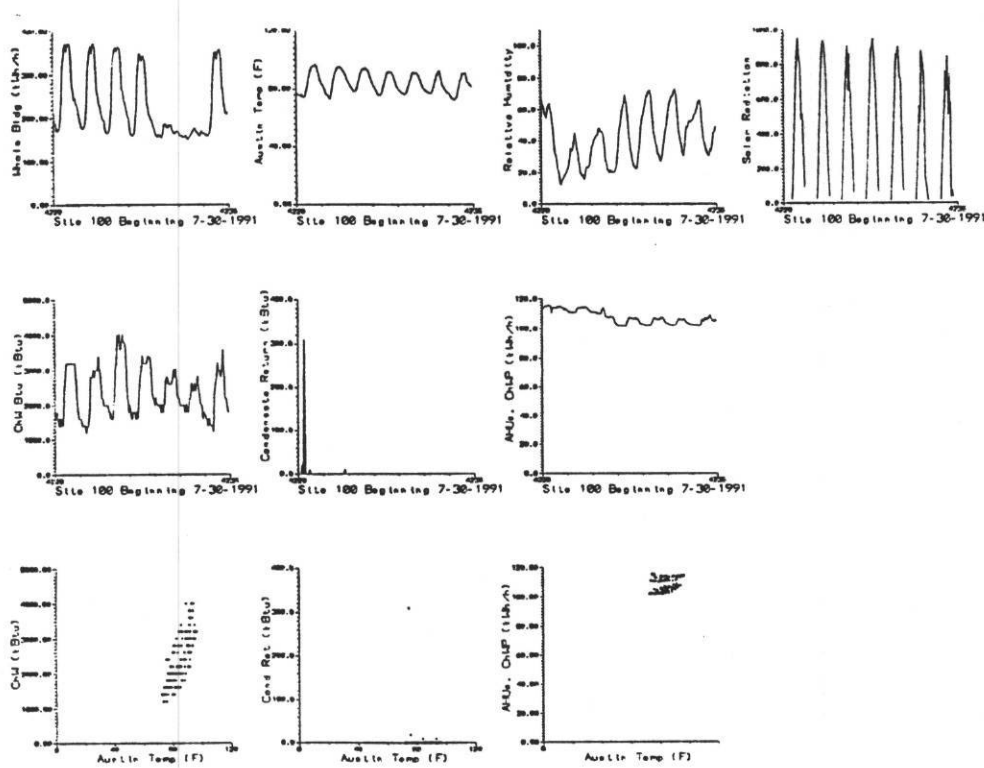


Weekly Quality Control
Inspection Plot Notebook

- Weekly time series plot of every channel at every LoanSTAR site.

- Derived summary page for each site.
  - + Time series of whole building electricity consumption.
  - + Time series of submetered electricity consumption.
  - + Time series of chilled water usage and hot water usage.
  - + Scatterplots of thermal energy consumption vs. O/A temp.
  - + Time series of local weather (dry bulb, RH, solar).

- New plots placed in a notebook (by site) and circulated between the Principal Investigators and staff. The plots are reviewed and any problems identified.



Monthly Report Generation
Monthly Energy Consumption Report

Every accepted LoanSTAR site receives a 6 page report each month.

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 Contact

Mohsen Farzad or Aamer Athar
053 WERC
Texas A&M University
College Station, TX 77842-3123
(409)-845-9213

Summary of Energy Consumption

	Measured Use	% hours reported	Unit Cost	Estimated Cost
Electricity	661201 kWh	97.8	-	-
Peak 60 Minute Demand	1223 kW	97.8	-	-
Chilled Water	1953.0 MMBtu	97.8	-	-
Hot Water	135.5 MMBtu	41.7	-	-

Peak 60 minute demand was recorded at 1500 Friday 5/3/91.
There were 744 hours in this month.

Measured Monthly Savings

Actual	Predicted
$25,500	$-

Comments

★ Hot water data is missing for 5/11–5/28 and chilled water data appears abnormal for 5/10–5/23 apparently due to construction activity.

★ Measured "savings" are partly attributable to the construction activity.

Monthly Report Generation
Monthly Energy Consumption Report

Production of this report requires ***120** man-hours* to complete the first draft. Currently, this consists of two people working full time for a week and a half.

This time includes:

- Concatenation of the weekly files into one summary dataset for the month.

- Creation of daily total files from the monthly data.

- Production of the graphs which appear on pages 2-4 occurs on a PC. Production of the graphs on page 5 is accomplished by SAS on the UNIX file server.

- Postscript output from the PC is transferred over the campus network to the UNIX file server.

- Creation of reports by knitting together the Postscript output into a TEX framework.

The first draft is circulated to the Principal Investigators and staff of Tasks 4 - 5. Comments for page 1 are discussed and any presentation or data problems are identified.

A second draft with an initial set of comments on page 1 is circulated.

The final draft is mailed to participating agencies.

The whole process generally takes two weeks.

Texas LoanSTAR Project
Data Acquisition and Storage

Future Directions:

- Maintenance of data within an Integrated Relational Database Management System.

- Automation of the polling and processing phases using routines developed by the programming staff.

- Maintenance of ARCHIVE's .LOG files with an automated organizer and reporting tool.

- Extension of automated quality control to use dynamic ranges rather than static upper and lower bounds.

- Continued development of the Inspection Plot Notebook based on comments by the Principal Investigators and staff.

- Continued development of the Monthly Energy Consumption Report based on comments by staff and the participating agencies.

Texas LoanSTAR Monitoring and Analysis Program

Technical Support Software Development / Testbench

Submitted by :

Robert Sparks
Raghuveer Belur*
Souvik Bhattacharyya
Sugato Chakrabarty
Murthy Rayaprolu
Sriram Vadlamani
Jinrong Wang
Kristel Weber

*Funded by DOE-EMCS project

Energy Systems Laboratory
Mechanical Engineering
Texas A&M University
College Station, Texas

August 1991

Responsibilities

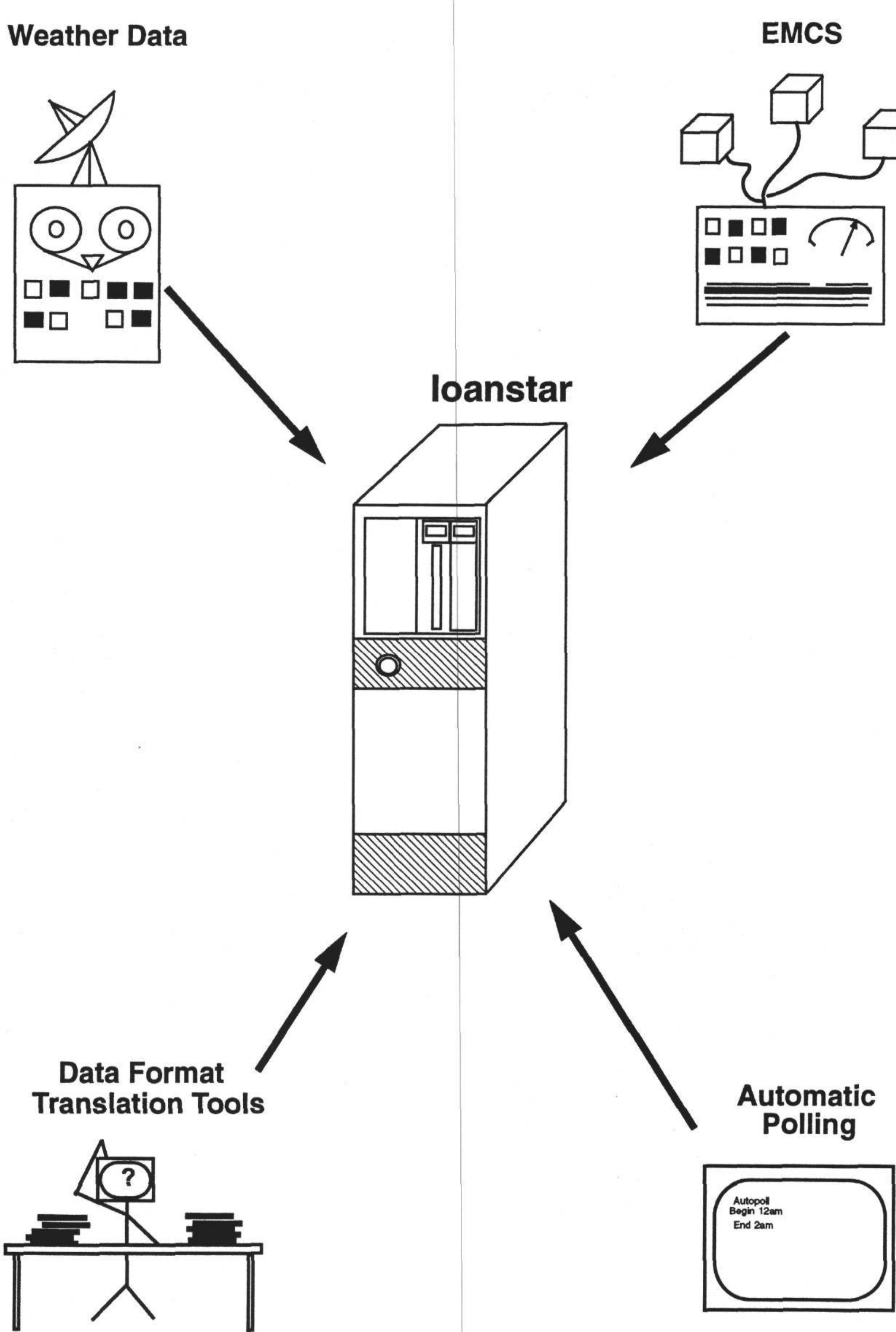
Programming

- Software Design, Development and Maintenance
- Source Code Control
- Software Distribution

Testbench

- Evaluating the usability of each vendor's product
- Translating each vendor's communication format to LoanSTAR's standard format
- Rigorous testing of the accuracy of each logger

Programming
Data Acquisition Tools



Available for Distribution

KWC
ColRow3D
ActPre3D
3DMac
Air
023to124
124to023

Available for Distribution in 1991

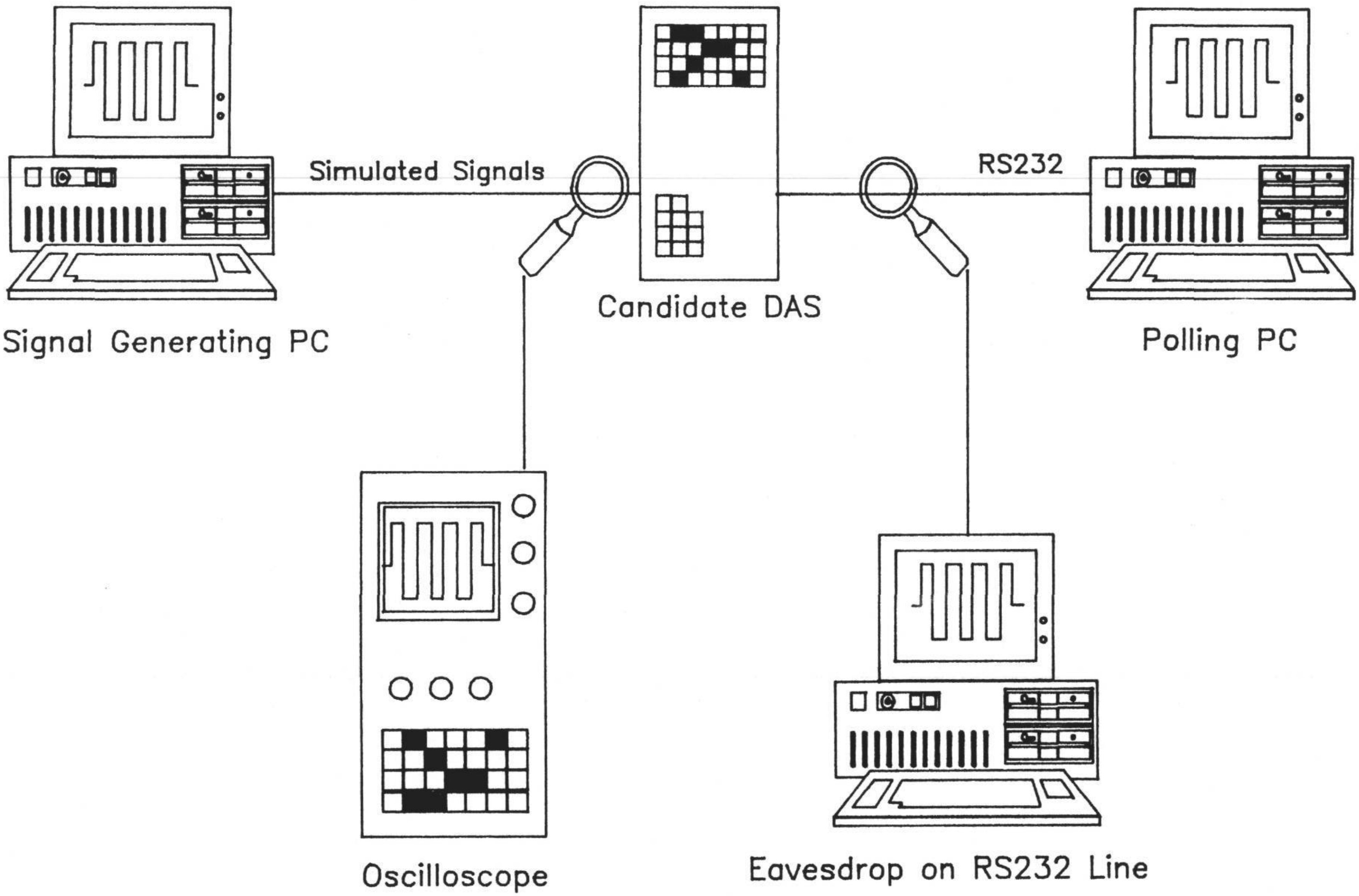
PredVal
CR - FourP
DateTool
Archive/A&M

Programming
Monthly Energy Consumption Report

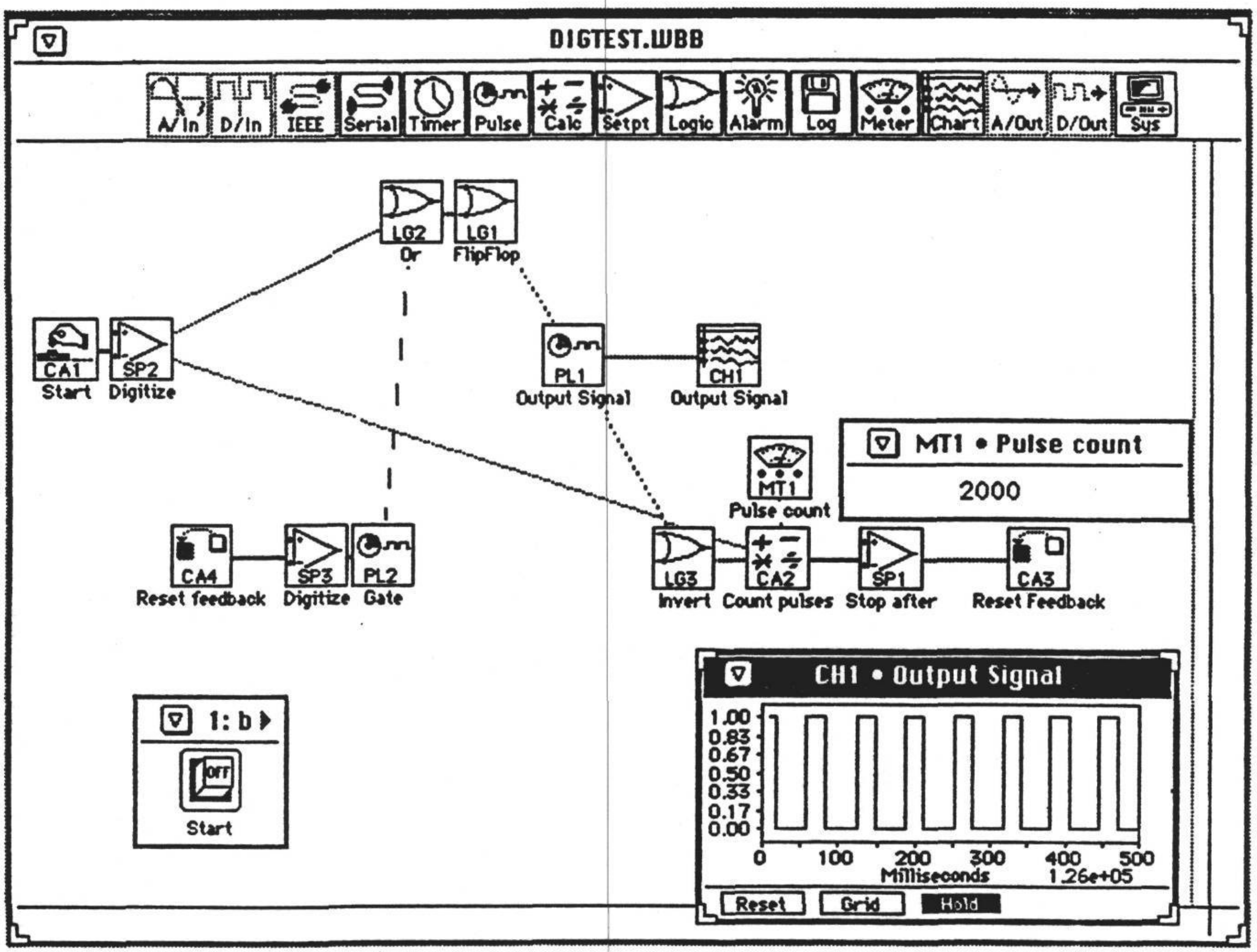
Programs have been written to automatically

- Fill in missing records
- Convert multichannel hourly data to daily data
- Merge weather data files with building data files
- Customize Grapher files for each site
- Choose good axis values
- Convert from Gregorian to Decimal Dates
- Create custom SAS programs for each site
- Modify PostScript output from SAS
- Compile all graphs into a single document under the control of TeX

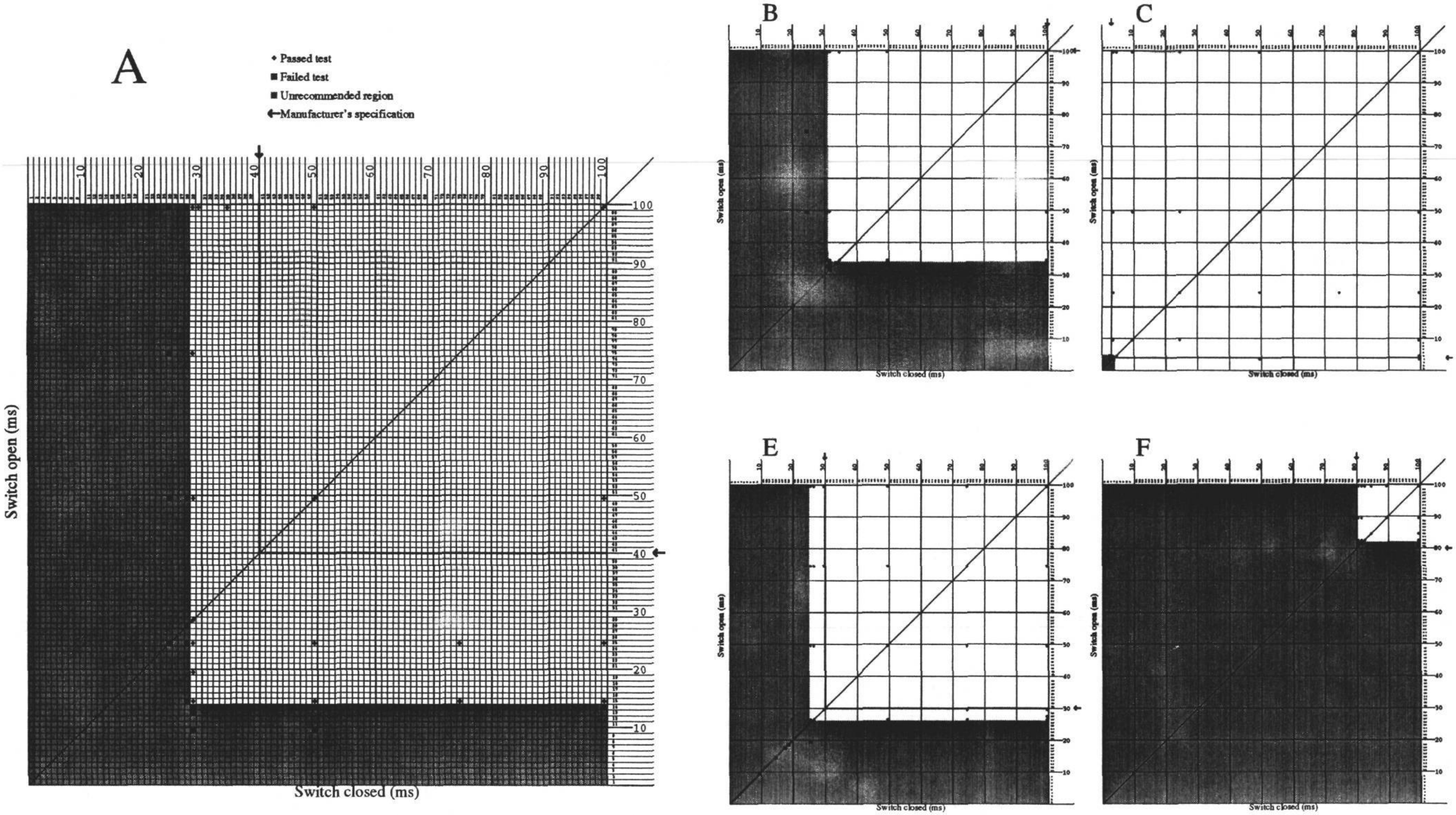
Testbench Setup



Digital Test Setup



Digital Test Results



Typical Logger Characteristics and Testbench Measurements

Manufacturer	A	B	C	D	E	F	G	H	I
Maximum Pulse Channels	16	8	4	4	4	4	8	4	14
Maximum Analog Channels	15	none	16	4	none	none	32	none	14
Analog Type[1]	V,R,C	none	V	V	none	none	V,R,C	none	V
Maximum Memory	32K	128K	40K	256K	48K	64K	512K	64K	512K
Communications Protocol[2]	P	P	D	P	P	P	D	P	D

[1] V = voltage, R = resistance, C = current

[2] P = Proprietary, D = public Domain

Manufacturer	Min[3] On Time	Min[3] Off Time	Max Square Frequency	Triggering Event	Pullup	Trigger Current
A	30/40	15/40	16.7Hz	closure	4.5V 3mA	2.3mA
B	32/100	35/100	14.3Hz	transition	13.9V 7.3mA	-
C[4]	-/3	-/4	125Hz	opening	1.8V 47uA	20.5uA
E	26/30	27/30	18.5Hz	transition	10.4V 3.8mA	.5mA,3mA[5]
F	81/80	83/80	6Hz	opening	20.7V 11.8mA	1.58mA
H	27/30	27/30	18.5Hz	closure	17.5V 23.75mA	8.5mA

[3] Observed/Manufacturer's published specifications

[4] Logger performs correctly to the limit of our abilities to test it

[5] Input exhibits hysterisis

Future Directions

Programming

Conversion to Relational Database
PollC180
SCCM
Generic Missing
Generic Interval Conversion
Pattern Recognition for Data Quality Control

Testbench

Complete Analog Tests
Finalize Reports

Texas LoanSTAR Monitoring and Analysis Program

Task 4 Communications Testbench, & Technical Support

Summary - Progress Report

Jeff S. Haberl PI
Robert Sparks
Rob Lopez
Dean Willis
Kristel Weber
Souvik Bhattacharyya
Sugato Chakrabarty
Murthy Rayaprolu
Sriram Vadlamani
Jinrong Wang
John & Emily Hogg

August 1991

TASK 4 - RESPONSIBILITIES

-> Ensure that the LoanSTAR MAP Net can communicate with the instrumentation installed in each building.

-> Develop procedures for verifying the accuracy of the data acquisition systems to be used in the program.

-> Develop public domain software for communicating with selected data acquisition systems.

-> Develop procedures to test the accuracy of the data being collected by the data acquisition systems.

-> Develop and implement a data base structure for efficiently analyzing LoanSTAR data.

-> Archive and distribute LoanSTAR data, data products, and data processing procedures.

Data Gathering Progress
(since July 1990)

July 1990

3 sites

1 weather station

January 1991

28 agencies

75 weather stations

August 1991

47 sites

50+ weather stations

Communications Testbench Progress

-> **Digital Tests Nearing Completion for:**
Automated Measurements (Datrex)
Campbell Scientific
GfE Energy Management
Gulton Industries (Rustrak)
Lambert Engineering
Landis & Gyr
Process Systems
Slumberger Industries
Synergistics Control Systems

-> **Analog testbench Established and Underway.**

-> **DRUMS - PollC180 Prototype working**

-> **Final Reports to be Completed in Fall 1991.**

-> **Communications Testbench to Sunset in Fall 1991.**

Technical Support Progress

January 1991

1 Unix Server
4 Unix
1.5 GBytes
22 LoanSTAR PCs
13 In-kind PCs

August 1991

1 Unix Server
4 Unix (1 ordered)
1.5 GBytes (1 ordered)
25 LoanSTAR PCs
16 In-kind PCs

LoanSTAR Data Gathering from Energy Management & Control Systems (Cofunded by USDOE) (Joint effort with LBL)

Basic Motivation:

Why install dedicated data loggers if EMCSs can be used to gather data?

Pros:

-> Use of an existing EMCSs might save monitoring money.

-> EMCSs as Energy Retrofits might save monitoring money.

Cons:

-> EMCSs are often proprietary.

-> EMCS data might not be in the right format.

-> LoanSTAR personnel had no experience w/ EMCSs.

LoanSTAR Progress with EMCS Effort: (Joint Effort w/ LBL)

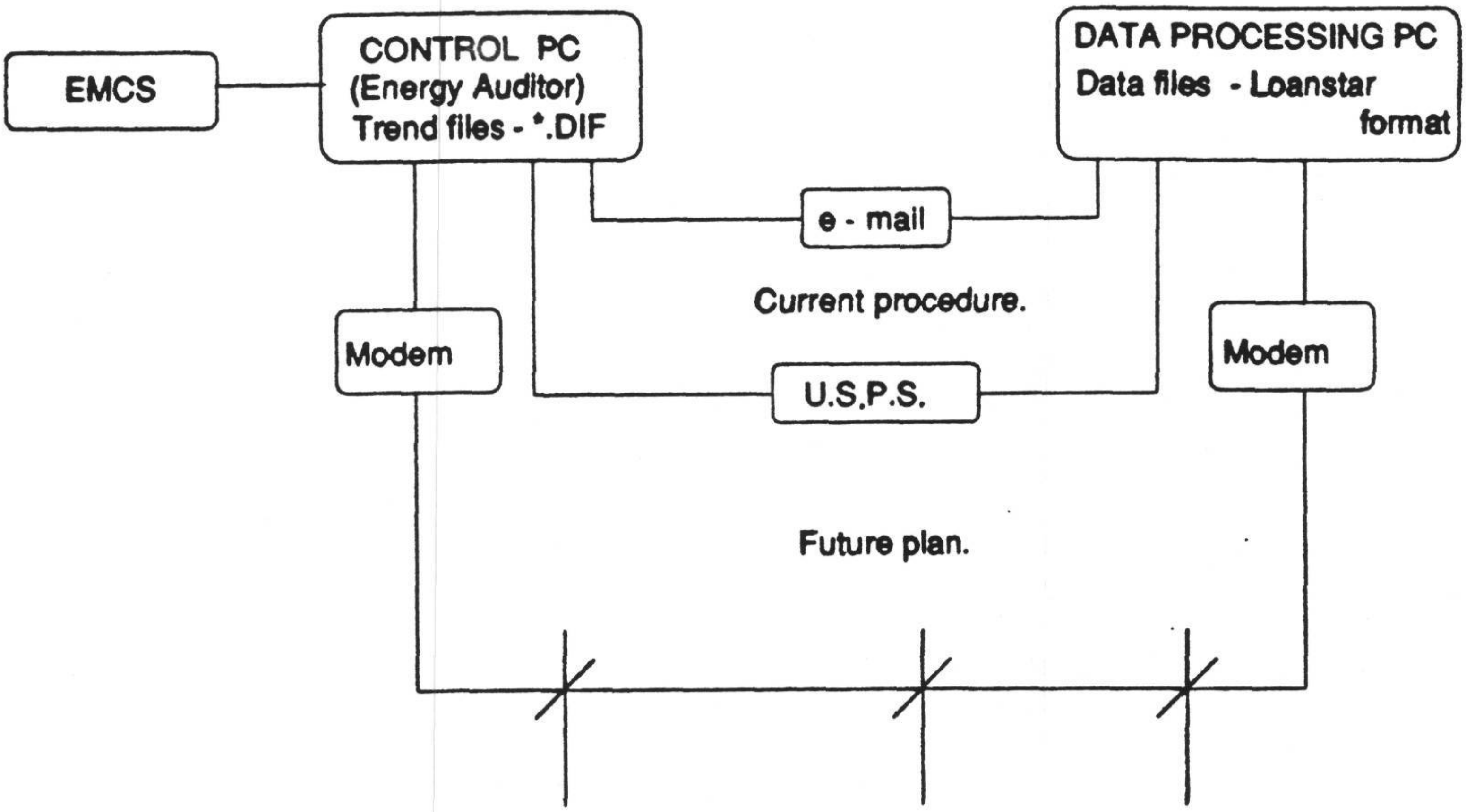
-> 4 sites selected
(TT, PVAM, TAMU, USDOE)

-> Working closely with 3 EMCS Companies (Honeywell, JCI, L&G,P).

-> Established prototypes with all three Companies.

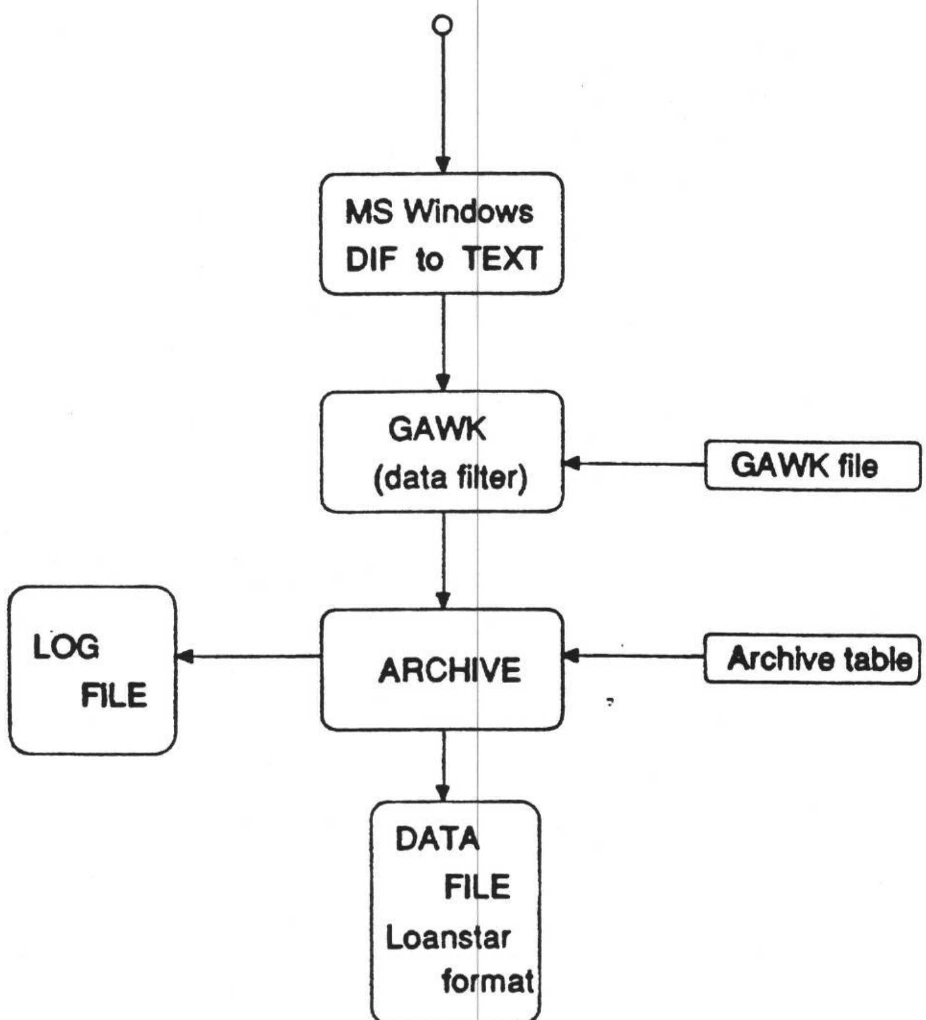
-> Draft Report underway.

Example: Texas Tech (Honeywell)

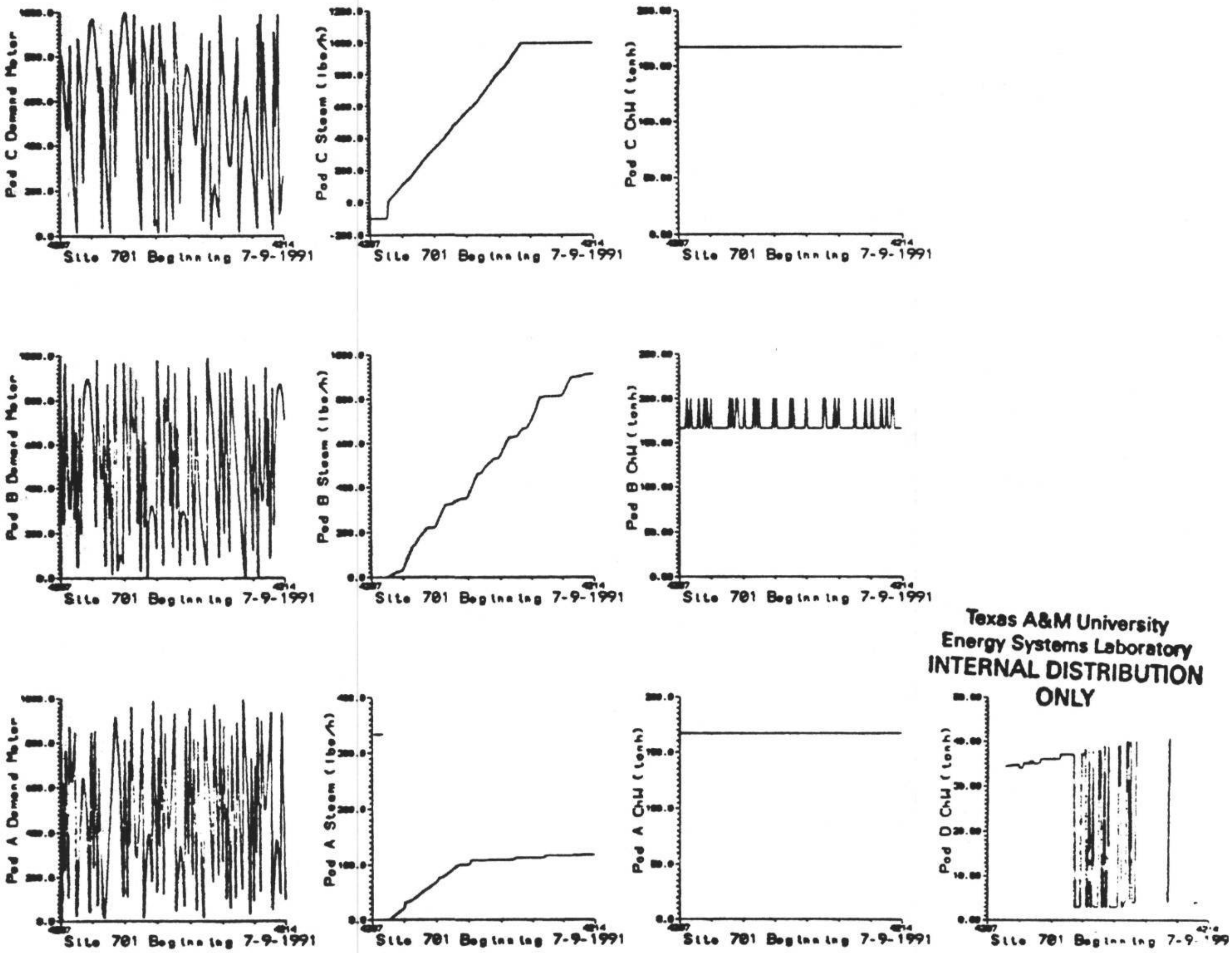


Texas Tech Data Processing Stream
(Flowchart)

Data from the HONEYWELL DELTA 1000 EMCS is converted into a DIF format by the Energy Auditor Software.



LoanSTAR
Inspection Plot for Texas Tech



Texas A&M University
Energy Systems Laboratory
INTERNAL DISTRIBUTION
ONLY

August, 1991. J.Haberl @ LoanSTAR MARC Meeting.

LoanSTAR Progress with EMCS Effort: (Joint Effort w/ LBL)

Value to LoanSTAR:

-> EMCSs can be used to monitor building energy usage date.

-> 3 EMCSs have been prototyped to "feed" into the LoanSTAR format.

-> In certain cases EMCSs may be a cost effective monitoring solution.

-> Each EMCS must be considered separately for unique problems.

TASK 2

BUILDING MONITORING ON THE LoanSTAR PROJECT: AGENCY UPDATE

DENNIS O'NEAL
JOHN BRYANT
KEITH BOLES

ENERGY SYSTEMS LABORATORY
TEXAS A&M UNIVERSITY

ADMINISTRATIVE CHANGES

- **MEET WITH TASK 5 PRIOR TO INITIAL SITE VISIT**
- **ISSUE AMENDMENT FOR SITE TO DASS EARLY IN LOAN CYCLE**
- **ADOPTED FORMAL PROCEDURE TO TRACK SITE METERING PROBLEMS**
- **EMPLOYED ADDITIONAL TASK 2 ENGINEER**

METERING PROJECTS MAY BE CATEGORIZED AS:

- **COMPLETED - ONLINE AND COLLECTING DATA**

- **UNDER CONSTRUCTION - SOME DEGREE OF COMPLETION**

- **NEW SITE - INITIAL VISIT COMPLETED**

COMPLETED SITES

SITE	# BLDGS	# POINTS
Texas A&M - ZEC	1	44
Capitol Complex	10	99
U.T. Austin	11	110
UTHSC - School of Health	1	11
UTHSC - San Antonio	2	12
Texas Dept. of Health	5	20
SP&GSC - Winters Complex	1	3
U.T. Arlington	3	44
Victoria I.S.D.	2	11

UNDER CONSTRUCTION

SITE	# BLDGS	# POINTS	
UTHSC - HOUSTON	1	58	95%
M.D. ANDERSON	1	48	95%
TEXAS TECH HSC	1	14	95%
U.T. MEDICAL BRANCH	5	21	80%
TEXAS A&M GALVESTON	4	6	15%
U.T. PAN AMERICAN	1	5	95%
S.W. TEXAS STATE U.	7	14	15%
TEXAS COLLEGE OF OSTEPATHIC MEDICINE	3	3	60%
U.T. DALLAS	3	3	30%
FT. WORTH I.S.D	2	9	60%
TEXAS STATE TECHNICAL INSTITUTE	6	16	25%
CORPUS CHRISTI Jr. COLLEGE	1	13	25%

NEW SITES

SITE	# BLDGS	# POINTS
U.T. ARLINGTON	5	40
DALLAS COUNTY	2	15
MIDLAND COUNTY	1	3

FUTURE PLANS

- **COORDINATE PRESENT/FUTURE METERING WITH DESIGN CONSULTANTS**

- **WORK CLOSELY WITH TASK 3 CALIBRATION FACILITY**

TASK 2

BUILDING MONITORING ON THE LoanSTAR PROJECT: LESSONS LEARNED

DENNIS O'NEAL
JOHN BRYANT
KEITH BOLES

ENERGY SYSTEMS LABORATORY
TEXAS A&M UNIVERSITY

THE LESSONS LEARNED OVER THE PAST TWO YEARS CAN BE SPLIT INTO FOUR GENERAL CATEGORIES

- **INSTRUMENTATION**

- **INSTALLATION**

- **MAINTENANCE**

- **ADMINISTRATION**

LESSONS LEARNED: INSTRUMENTATION

- **A BTU METER MAY PICK UP 60 H_Z NOISE FROM THE NOISY SURROUNDINGS.**

- **TWO DIFFERENT BRANDS OF THERMAL ENERGY METERS MOST LIKELY WILL NOT AGREE WITH EACH OTHER.**

- **A BTU METER THAT IS NOT FIELD SCALEABLE MAY BE SET WRONG AT THE FACTORY.**

- **THE MARKED POLARITY OF A CURRENT TRANSFORMER MAY BE OPPOSITE OF ITS ACTUAL POLARITY.**

- **THE OUTPUT OF A CURRENT TRANSFORMER MAY BE FAR DIFFERENT FROM ITS RATING.**

LESSONS LEARNED: INSTRUMENTATION (CONTINUED....)

- **SOME RELATIVE HUMIDITY SENSORS ARE TEMPERATURE DEPENDENT**

- **RELATIVE HUMIDITY INSTRUMENTATION MAY FAIL TO PERFORM ADEQUATELY AFTER ONLY A FEW MONTHS OF OPERATION**

- **THE DATA LOGGER MANUFACTURER WILL NOT TELL YOU ABOUT AN UNDOCUMENTED CALIBRATION PROCEDURE FOR HIS DATA LOGGER UNTIL YOU ASK.**

LESSONS LEARNED: INSTALLATION

- THE FLOW RATE IN A PIPE MAY BE OUTSIDE THE USEFUL RANGE OF THE FLOW METER.

- ASBESTOS INSULATION MAY BE ON THE PIPING WHERE THE THERMAL METERING INSTRUMENTATION IS TO BE INSTALLED.

- THE CONTRACTOR MAY NOT COMPENSATE FOR THE LEAD LENGTH WHEN RTDs ARE INSTALLED.

- THE DIAMETER OF THE PIPE IN WHICH THE FLOW METER IS INSTALLED MAY BE DIFFERENT FROM THAT TOLD YOU BY THE FACILITY MANAGER OR INDICATED BY THE SCHEMATICS.

- IF A TEMPERATURE PROBE CAN BE REACHED BY A PERSON FROM THE FLOOR, THE PROBE WILL BE USED AS A CHIN-UP BAR, STEP LADDER, OR SOME OTHER AIDE.

LESSONS LEARNED: INSTALLATION (CONTINUED....)

- IF A TEMPERATURE PROBE IS NO LONGER FUNCTIONING, IT MAY BE BECAUSE IT NO LONGER EXISTS.

- IF MULTIPLE VOLTAGES ARE AVAILABLE IN THE BUILDING, THEN THE POTENTIAL TRANSDUCER MAY BE CONNECTED TO THE WRONG REFERENCE VOLTAGE.

- IF CTs ARE CONNECTED TO A SECONDARY LINE, THEN THEY PROBABLY WILL NOT BE SCALED CORRECTLY.

- DATA ACQUISITION BOARDS ON A DATA LOGGER CAN SUBSTITUTE AS EXPENSIVE FUSES.

LESSONS LEARNED: INSTALLATION (CONTINUED....)

- **THE DATA LOGGER PROBABLY WILL NOT BE PROGRAMMED CORRECTLY WHEN DATA COLLECTION FIRST BEGINS.**

LESSONS LEARNED: MAINTENANCE

GENERAL RULE: EXPECT THE INSTRUMENTATION TO FAIL AT SOME POINT IN THE PROGRAM.

- **MODEMS**
- **INSERTION FLOW METERS**
- **CURRENT TRANSFORMERS**
- **ASPIRATING FAN**
- **BATTERY**

LESSONS LEARNED: ADMINISTRATION

- **EXPECT DELIVERY TIMES ON INSTRUMENTATION AND EQUIPMENT TO BE 30 TO 45 DAYS LONGER THAN EXPECTED.**
- **COORDINATE WITH LOCAL UTILITIES AS EARLY AS POSSIBLE.**
- **DEVELOP A NOTEBOOK FOR EACH SITE TO DOCUMENT INSTALLED MONITORING SYSTEM.**
- **DEVELOP TIGHT DEADLINES FOR THE INSTALLATION COMPLETION AND A THOROUGH CHECKOUT PROCEDURE.**
- **COORDINATE WITH HOST AGENCY FOR SMOOTH INSTALLATION AND MAINTENANCE.**

LESSONS LEARNED: ADMINISTRATION (Continued....)

- **COMMUNICATE WITH THE RETROFIT CONTRACTOR OR EXPECT SOME DESTRUCTION OF YOUR MONITORING EQUIPMENT.**

CALIBRATION LABORATORY

TASK 3 - CALIBRATION LABORATORY

PERSONNEL: DAN TURNER, PI
DENNIS O'NEAL
JEFF HABERL
MELVIN GLASS, PE
CLINT FINSTAD
FRANK SCOTT
DON COONROD

TASK 3

Purpose

To support the field monitoring program and the and the communications subsystems task

- **trouble shoot sensors with problems in field**

- **provide facility to test new sensors and/or systems prior to field installation**

- **help develop metering system acceptance procedures**

- **develop portable calibration capability**

CALIBRATION LABORATORY
at the Texas A&M
Energy Systems Laboratory

TEMPERATURE (-40F to +500F)	**HUMIDITY** (10 to 90% RH)
HYDRAULIC PRESSURE (0 to 500 PSI)	**AIR PRESSURE** (0 to 24 in.W.G.)
LIQUID FLOW (1 to 650 GPM)	**AIR FLOW** (0 to 10 in.W.G.) (0 to 8,000 CFM)
ELECTRICAL (120-480VAC,0-200A) (0-40,000 W,0-100%PF)	**LIGHTING** (1 to 10,000 fc)
ROTATIONAL SPEED (0 to 3,600 RPM)	**SOLAR** (1 to 2,000 W/M2)

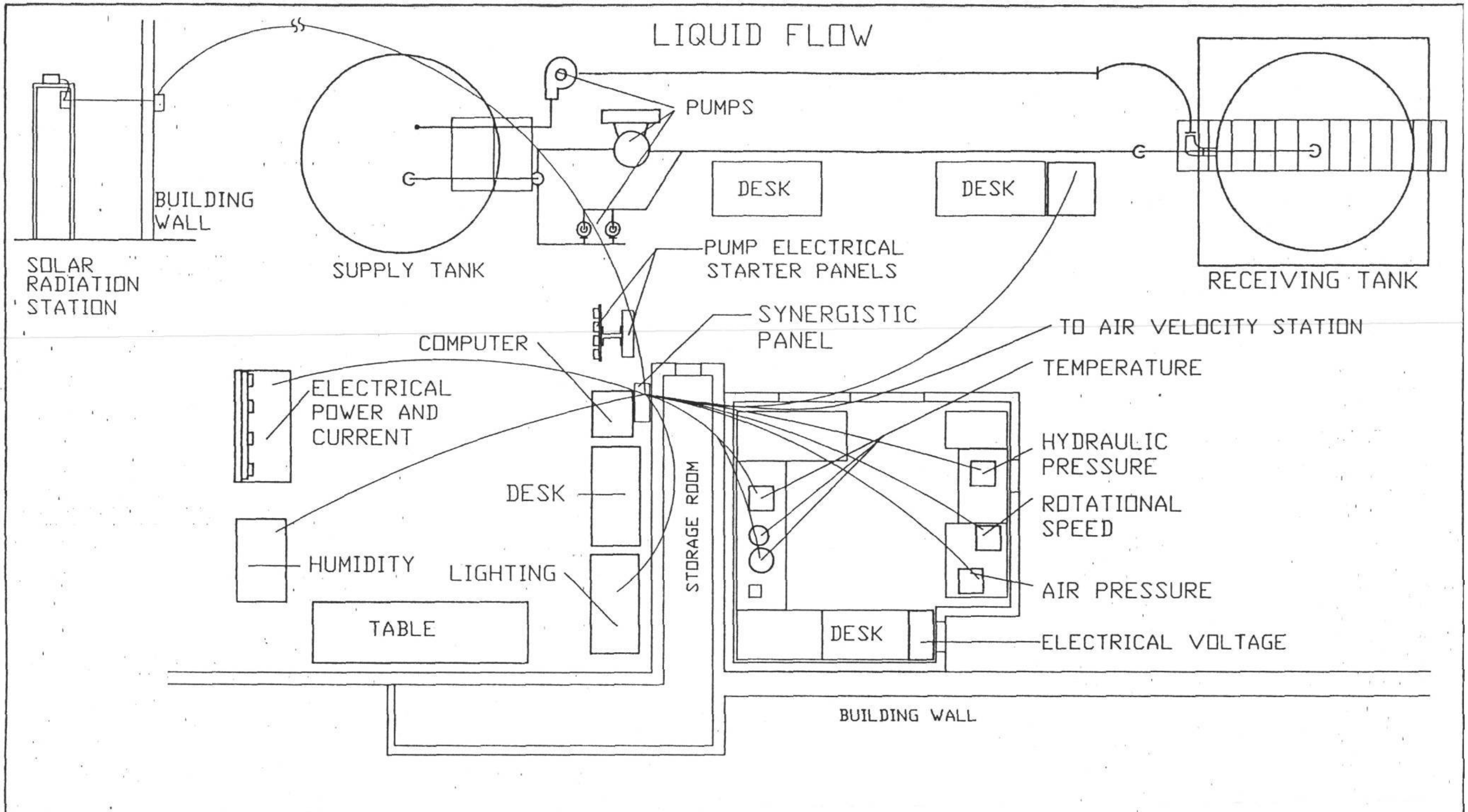


FIGURE CALIBRATION FACILITY LAYOUT

FIGURE 3 - Typical Temperature-Humidity Test for Nominal 80%

Relative Humidity Test

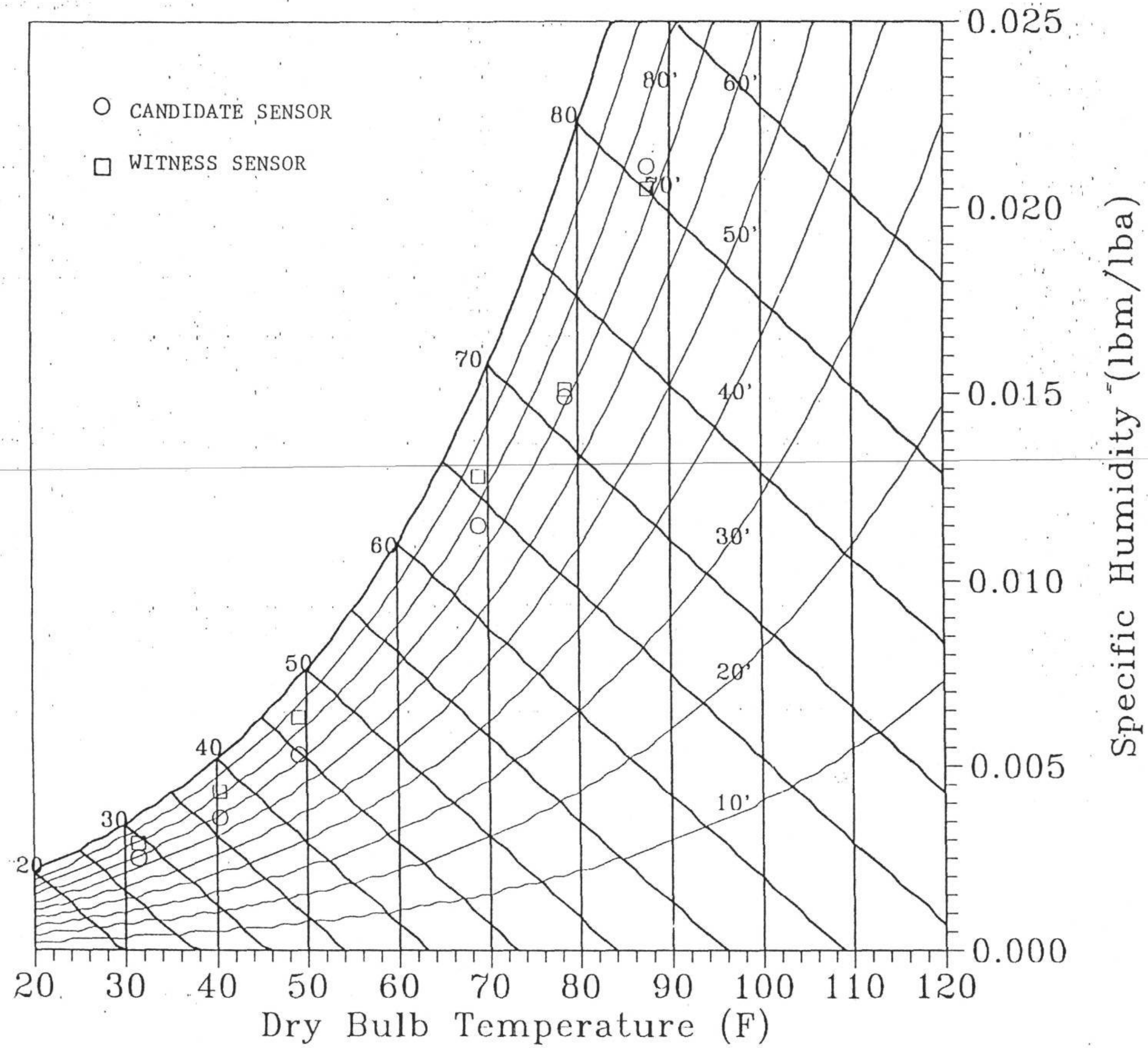
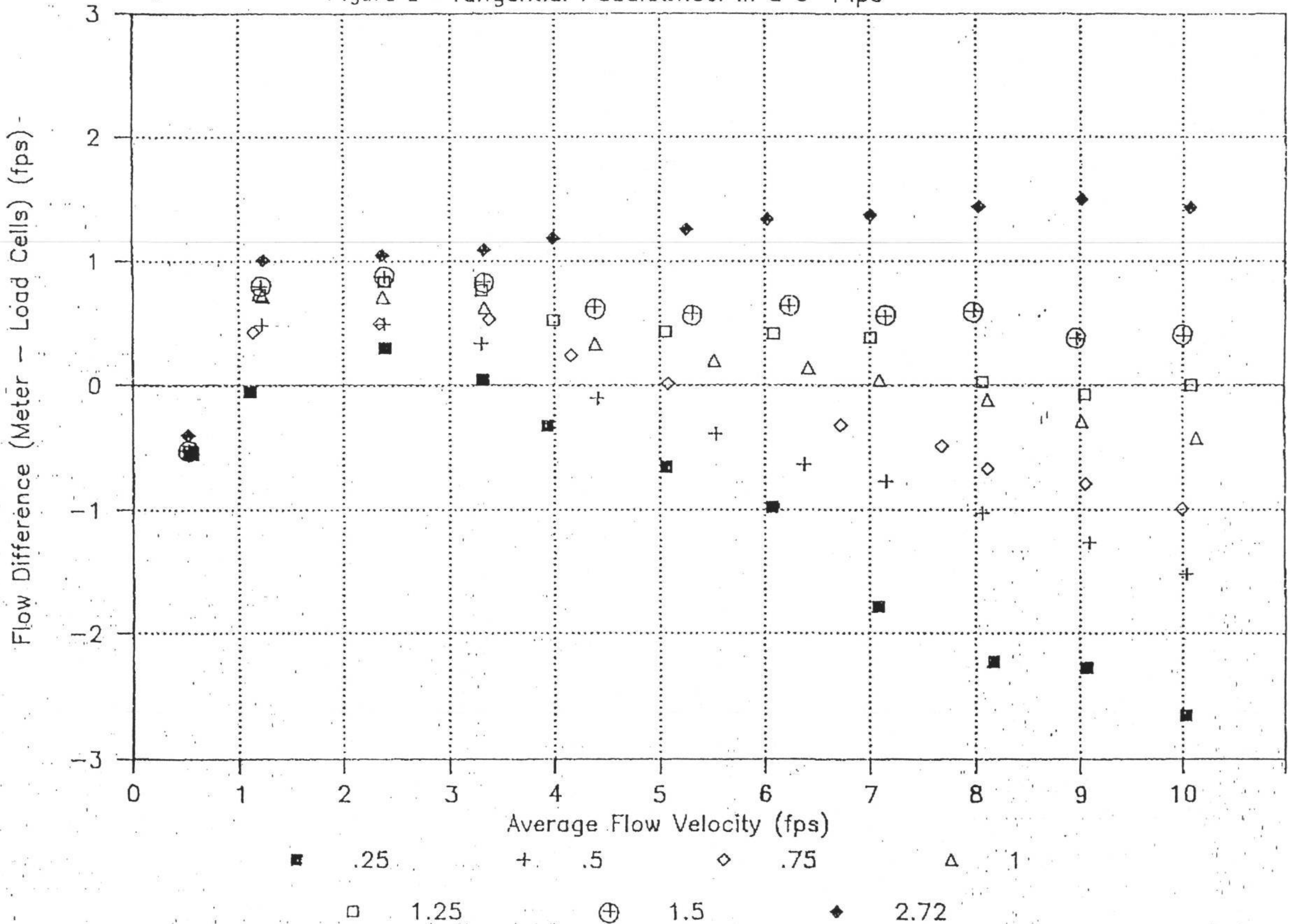


Figure 2 - Tangential Paddlewheel in a 6" Pipe



FUTURE PLANS

° Automatic data collection, using two (2) C-180's for data collection

° Expand flow loop to add 8" & 10" pipe sizes and increase the capacity to 1200 gpm

° Complete the lighting/illumination station

° Install new instrumentation for electrical test stand

° Develop portable calibration procedures and kit for field checkout

° Develop detailed test procedures for each station

Texas LoanSTAR Monitoring and Analysis Program

Flowmeter Calibration

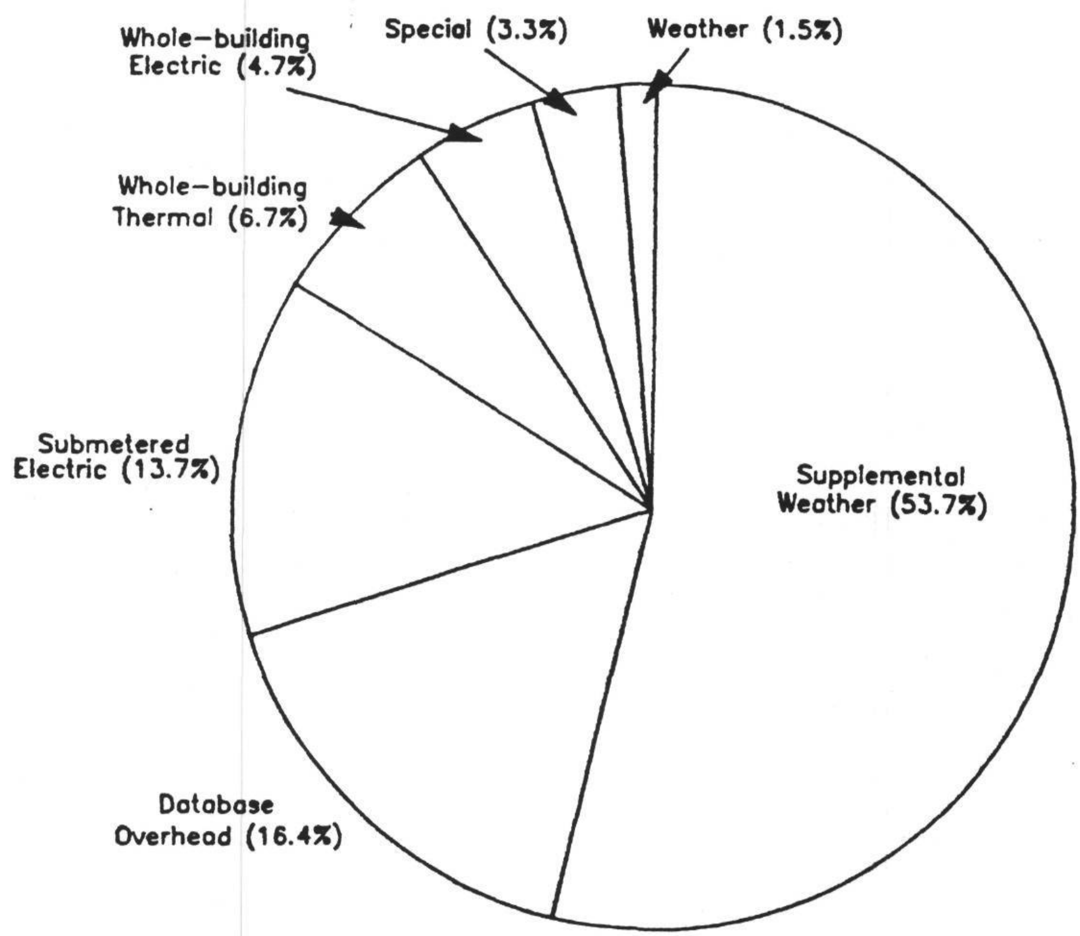
Progress Report

Jeff S. Haberl
W.Dan Turner
Mel Glass
Clint Finstad
Frank Scott

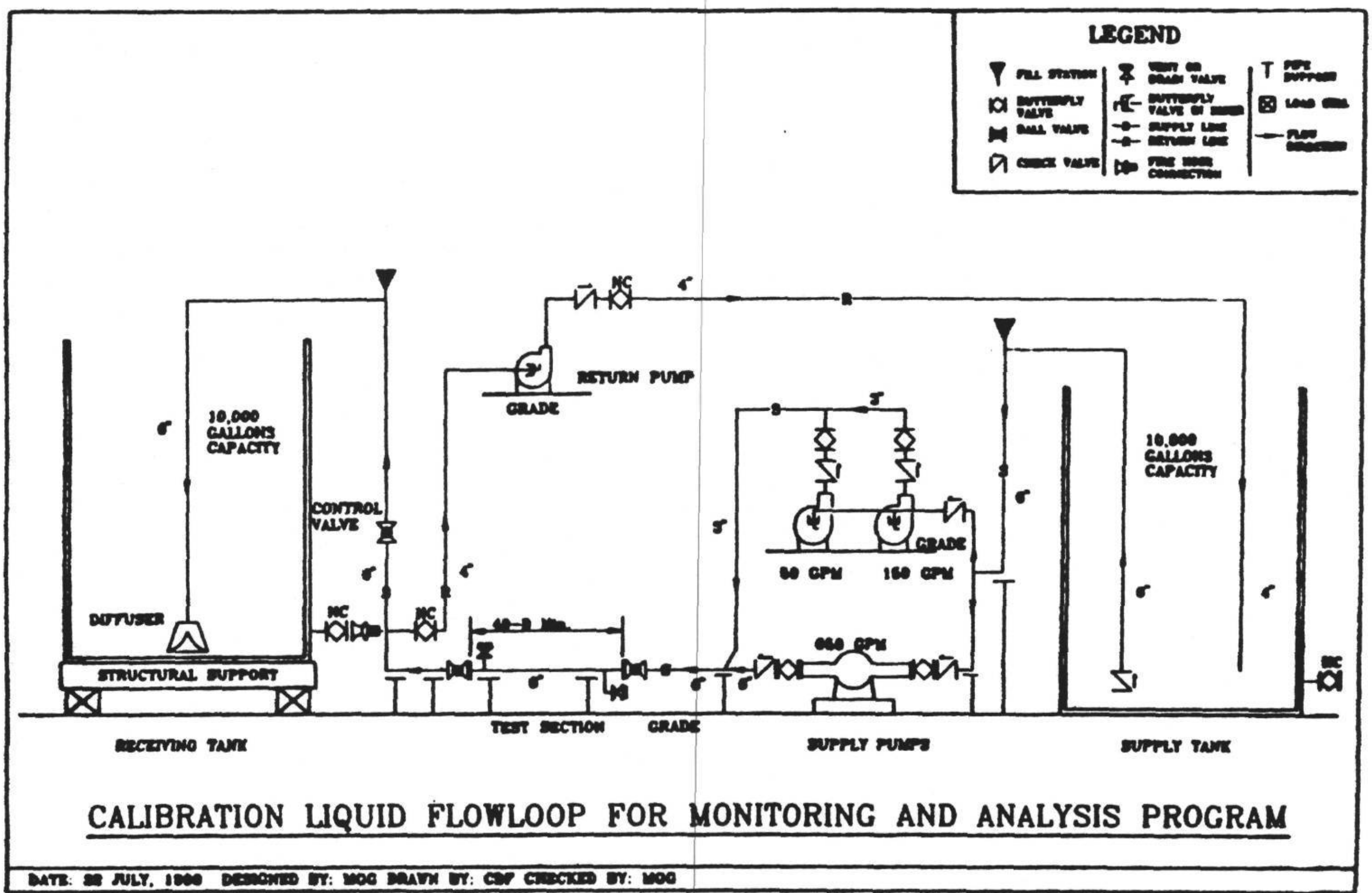
Don Coonrod
Coonrod Manufacturing & Services

August 1991

Importance of liquid flow measurement: (whole-building thermal meas.)

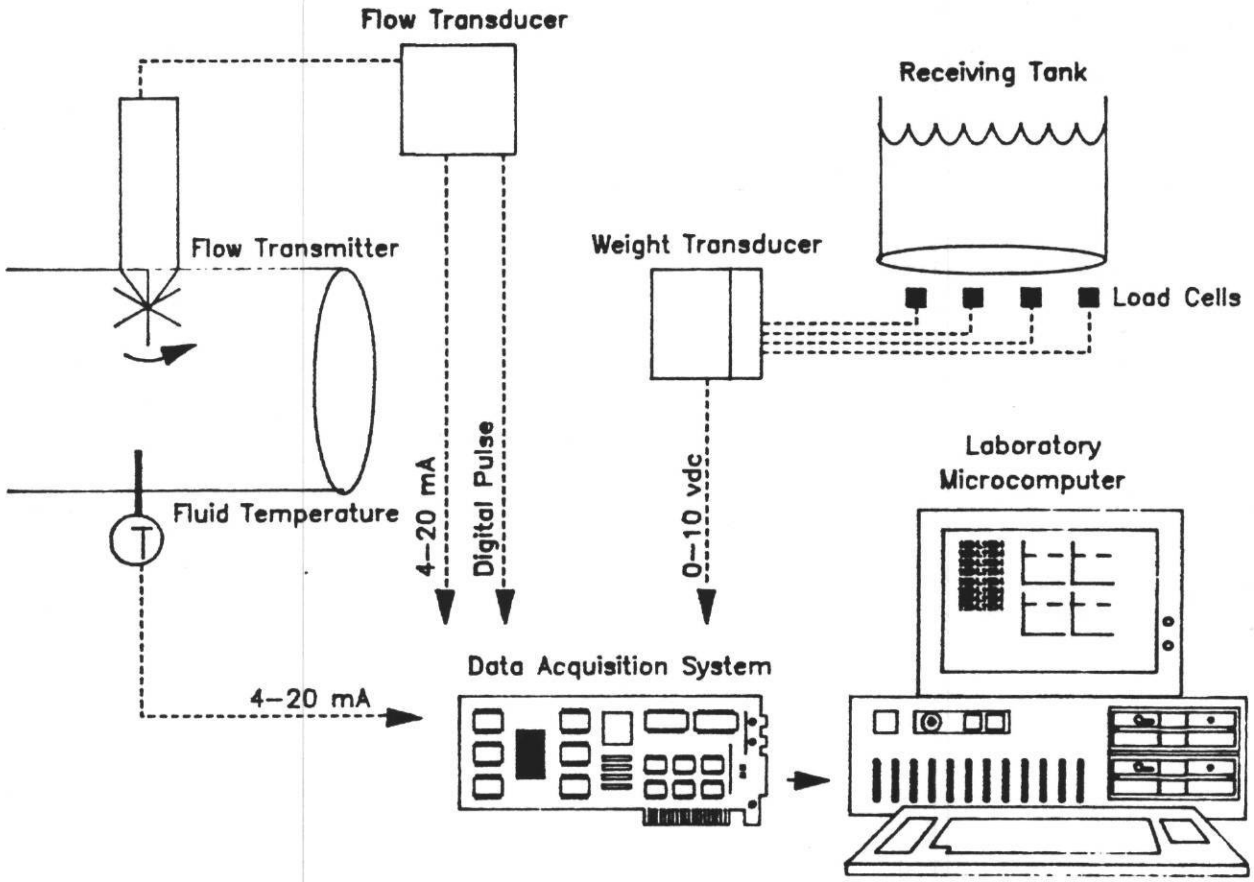


Liquid Flow Loop Diagram

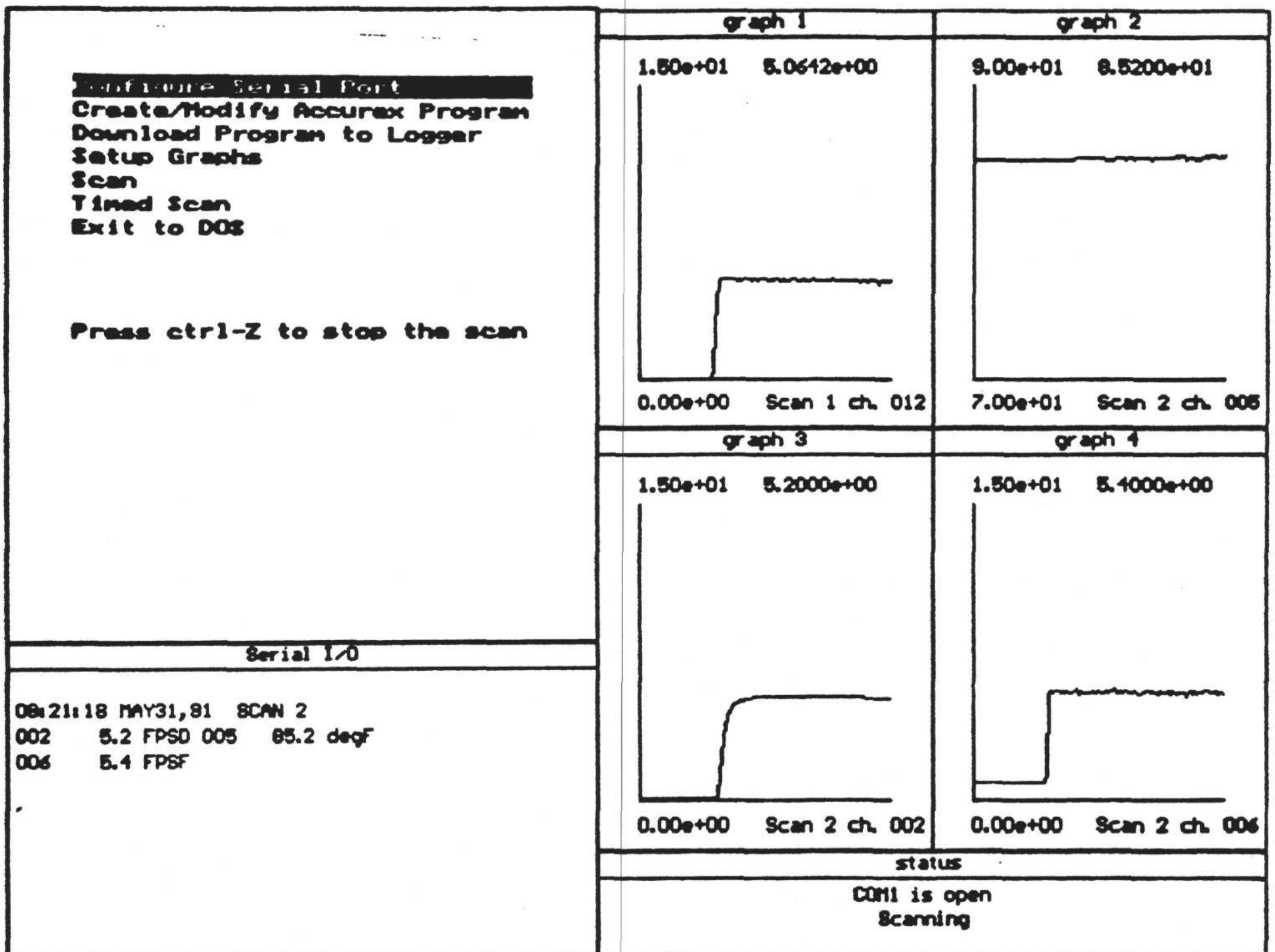


August, 1991. J.Haberl @ LoanSTAR MARC Meeting.

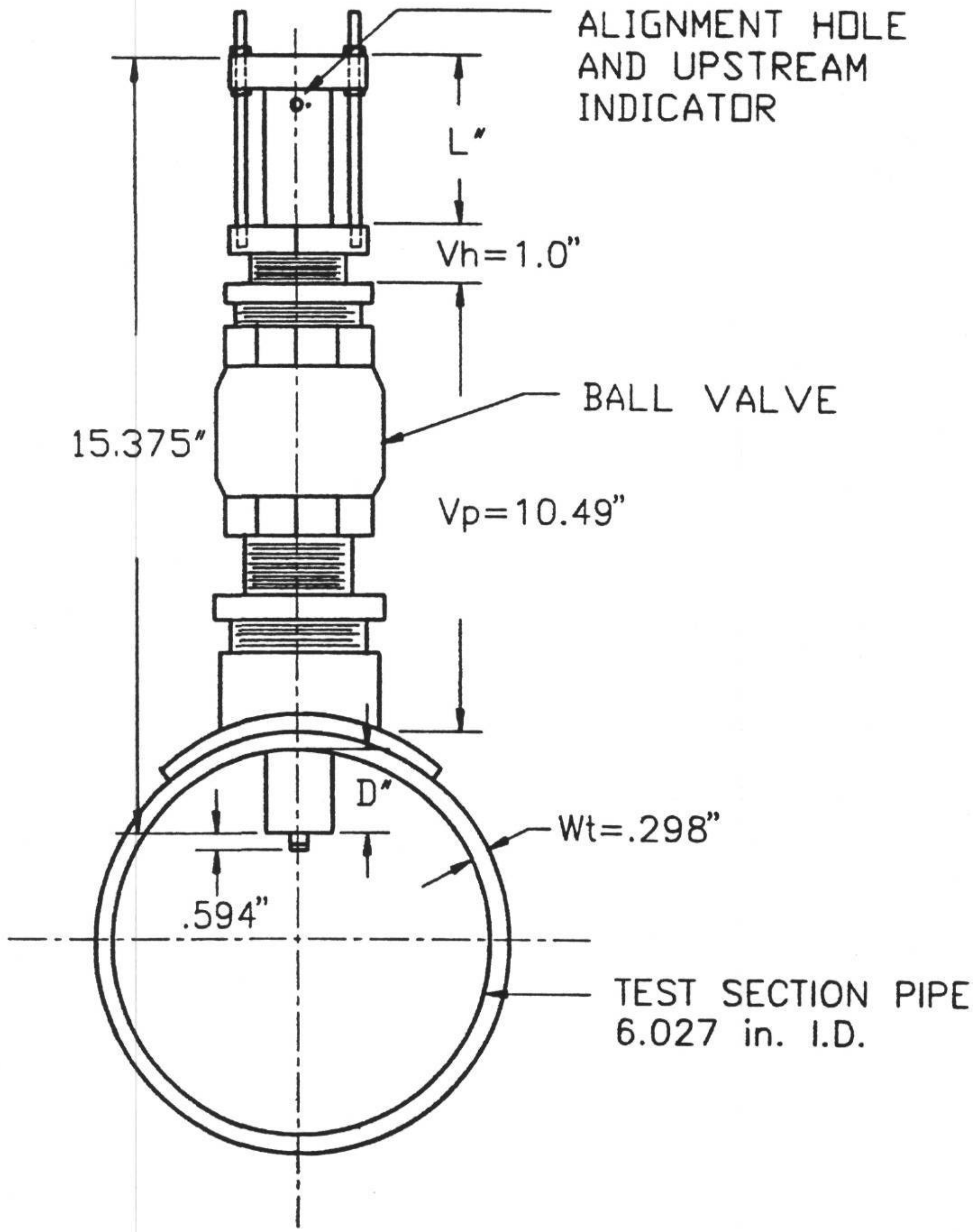
Liquid Flow Loop Electronics



Example Real Time Display



Insertion-type Paddlewheel Flowmeter

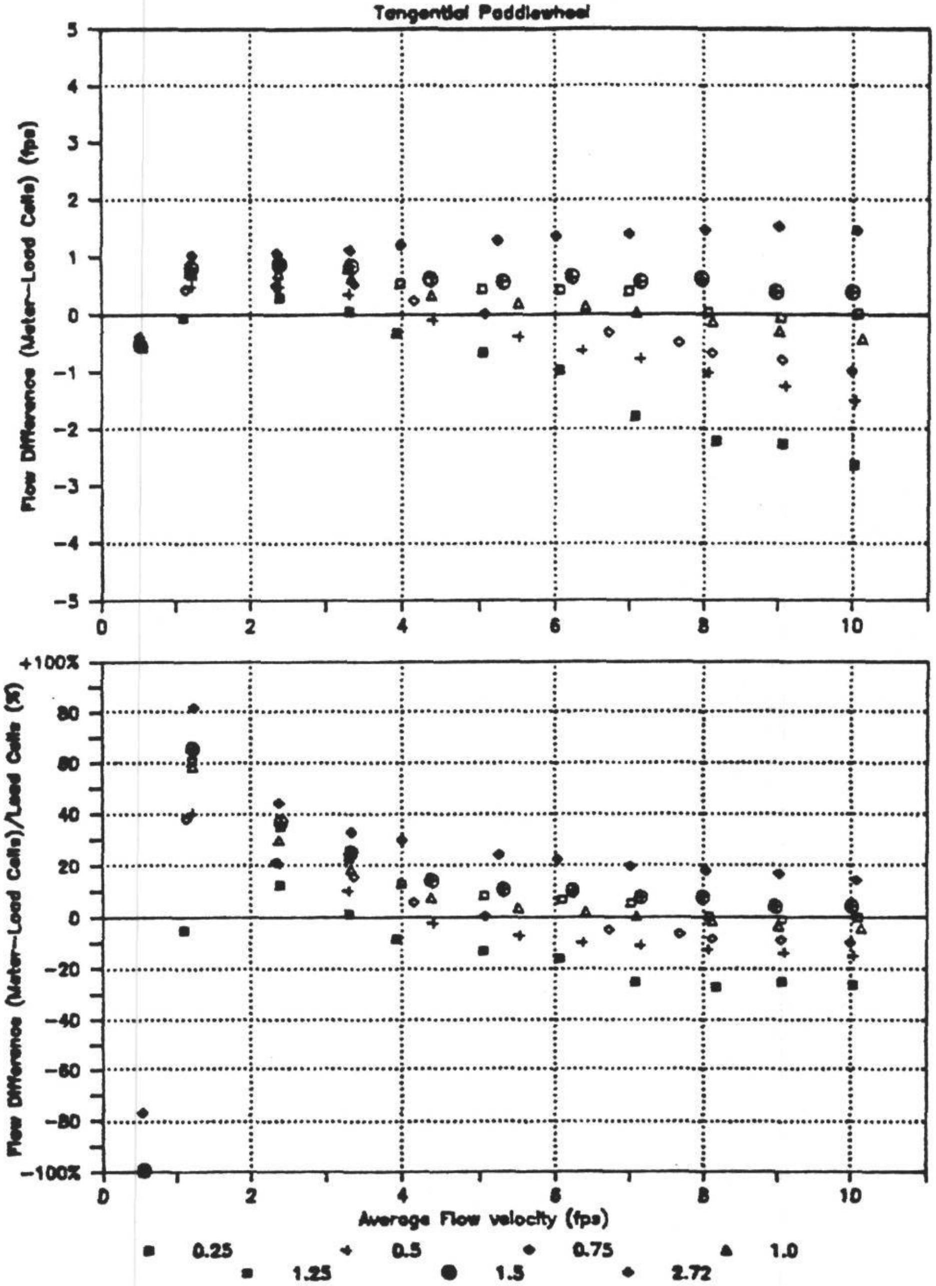


Preliminary
Depth of Insertion Test Results
(Table)

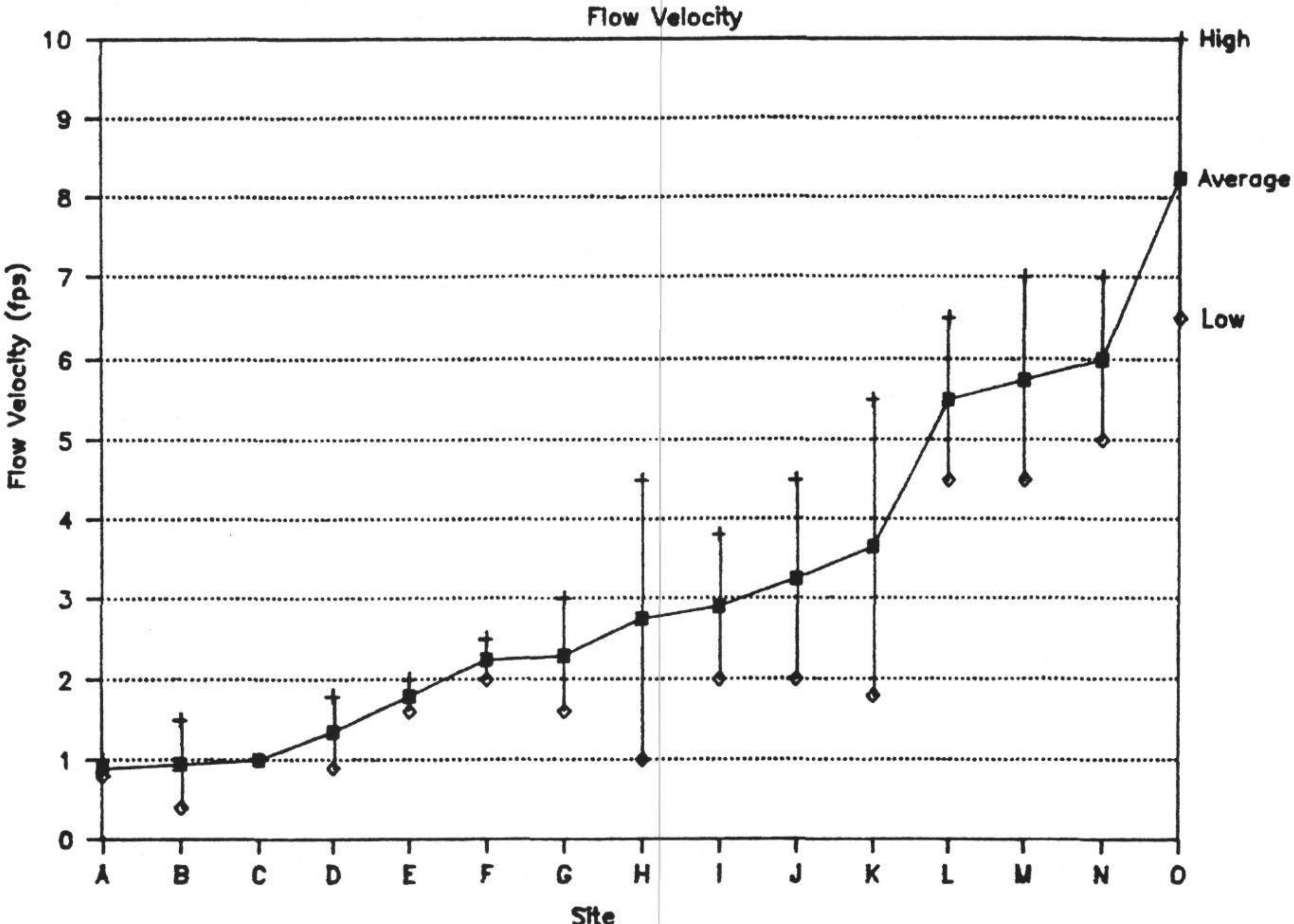
Flow Trial	Load Cells Flow	Load Cells Sdev/Flow	Doppler Flow	Doppler Sdev/Flow	Paddle Flow	Paddle Sdev/Flow	Reynolds Number
.5	.55	8.2%	*	*	.00089 **	306.4%	30,000
1	1.14	6.4%	1.02	29.4%	1.83	4.0%	62,500
2	2.34	3.0%	2.08	11.7%	2.97	2.3%	128,200
3	3.38	3.8%	3.11	6.9%	3.9	3.1%	184,800
4	4.15	3.1%	4.23	4.1%	4.39	2.7%	227,200
5	5.08	2.8%	5.26	2.8%	5.09	3.5%	277,900
6	6.18	2.6%	6.38	2.4%	6.04	2.2%	338,200
7	7.01	2.2%	6.92	7.7%	6.75	1.9%	383,600
8	8.11	3.1%	7.34	8.0%	7.49	2.8%	444,000
9	9.06	3.3%	8.42	2.9%	8.24	3.1%	495,900
10	9.99	3.9%	8.92	13.0%	9.10	3.6%	546,700

NOTE:
(*) The Doppler flow meter was unavailable for this trial.
(**) The paddlewheel appeared to stop rotating at this low velocity.

Preliminary
Depth of Insertion Test Results (Graphs)



Preliminary
Impact on LoanSTAR Sites



-> Tangential paddlewheels appear to be a cost effective metering technology for >3 fps flow regime.

-> LoanSTAR sites with >3 fps should not be significantly effected by the new constants.

-> LoanSTAR sites with <3 fps should increase the savings from variable speed retrofits.

-> Other monitoring with old meter constants should consider issuing new meter constants.

Liquid Flow Calibration

Future Work.

-> Develop LoanSTAR meter constants
(6, 8, 10, 12" pipes).

-> Adjust historical data.

-> Reissue new constants for existing meters.

-> Investigate alternative metering technologies for
low flow velocities (1/2 to 3 fps).

-> Recalibrate LoanSTAR flowmeters.

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

PROGRESS REPORT

Warren M. Heffington, P.E.

Staff Engineers

Angela Britton
Doug Tiner, P.E.
Darin Nutter
Aamer Athar

Graduate Students

Norman Muraya
Niranjan Hiras
S. Thamilseran
Ben Nuboer (Mansoor Parvaiz)

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

AUDITS RESULTS

(All values except simple paybacks are millions.)

		ECRMs			M&Os		Combined		
	Building Area Audited (SF)	Invest. Cost ($)	Annual Savings ($/yr)	Simple Payback (yr)	Invest. Cost ($)	Annual Savings ($/yr)	Invest. Cost ($)	Annual Savings ($/yr)	Simple Payback (yr)
TECCP[1]	35.3	42.8	19.9	2.2	0.1	1.4	42.9	21.3	2.0
LoanSTAR[2]	17.4	24.8	7.2	3.4	neg	0.1	24.8	7.3	3.4
Total	52.7	67.6	27.1	2.5	0.1	1.5	67.7	28.6	2.4

1 TECCP - Texas Energy Cost Containment Program, 1984 and 1986.

2 LoanSTAR - January 1989 - July 1991.

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

TABLE 3

ENERGY CONSERVATION IDENTIFIED IN LOANSTAR AUDITS

Purchased Utility Category	Site Energy Savings	Source* Energy Savings (million Btu/yr)	Fractional Source Energy Savings (%)
Electricity	136,186,131 (kWh/yr)	1,579,759	64
Natural Gas	605,448 (MCF/yr)	623,611	25
Steam/Hot Water	93,456 (million Btu/yr)	124,608	5
Chilled Water	12,932,192 (Ton-hr/yr)	155,186	6
Total		2,483,165	100

* Btu savings calculated on the basis of 11,600 Btu/kWh, 1,030,000 Btu/MCF, and 12,000 Btu/ton-hr.

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

TABLE 4

SUMMARY OF ECRM's FOR BUILDINGS RECEIVING LOANSTAR AUDITS

ECRM Recommendations	Implementation Cost (million dollars)	Fractional Implementation Cost (%)	Annual Cost Savings* (million dollars)	Fractional Cost Savings (%)	Simple Payback (Years)
Lighting Retrofits	8.6	33	2.7	35	3.1
Chiller & CHW Retrofits	4.3	17	0.9	11	4.9
Motor/VSD/VSP Conversion	3.3	13	1.0	13	3.3
HVAC System Retrofits	3.1	12	0.8	11	3.6
Others	2.3	9	0.7	9	3.3
EMC Systems	2.1	8	0.5	7	3.9
Boiler & Steam Retrofits	1.4	5	1.0	12	1.5
Pumping System Retrofits	0.8	3	0.2	2	4.8
Total	25.9	100	7.8	100	3.3

* Independent values.

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

TABLE 5

TOTAL ENERGY CONSUMPTION, UTILITY COST AND SAVINGS. ENERGY AND COST VALUES ARE IN MILLIONS OF UNITS.

	Electrical kwh/yr	Natural Gas MCF/yr	Steam Btu/yr	Chilled Water Ton-hr/yr	Other Btu/yr	Total Source Energy Btu/yr	Total Utility Cost $/yr
Consumption	562	2.08	486,000	68.3	3,165	9,970,000	46.2
Savings (%)	24	29	19	19	--	25	16

TABLE 6

FRACTIONAL COMPARISON OF SOURCE ENERGY TYPES AND COST

	Consumption (%)	Cost (%)
Electricity	65.4	66.7
Natural Gas	21.5	14
Chilled Water	8.2	11.5
Steam	4.9	7.8
Other	<0.1	<0.1

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

COST OF AUDITS

- **1986 TECCP**

  COST - $0.050/SF

TYPICAL BLDG. AREA FRACTION	**- 63%**
COMPLEX BLDG. AREA FRACTION	**- 37%**
FRACTION OF IMPL. COST	**- 3%**
FRACTION OF ANNUAL SAVINGS	**- 7%**

- **LOANSTAR**

  COST - $0.081/SF

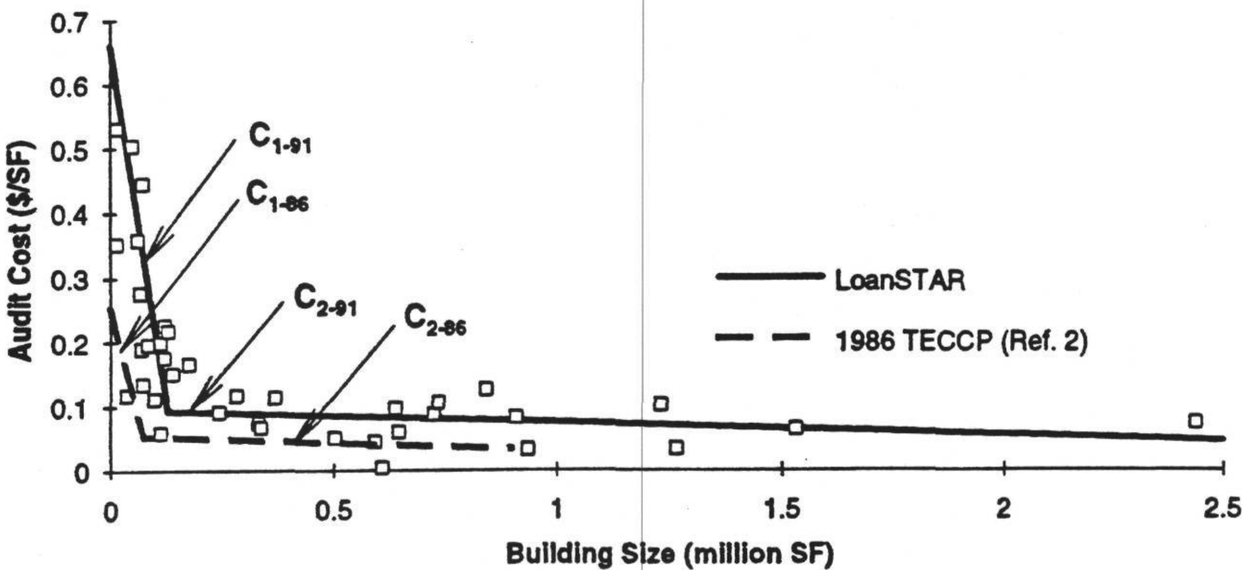
SIMPLE BLDG. AREA FRACTION	**- 8%**
TYPICAL BLDG. AREA FRACTION	**- 83%**
COMPLEX BLDG. AREA FRACTION	**- 9%**
FRACTION OF IMPL. COST	**- 6%**
FRACTION OF ANNUAL SAVINGS	**- 21%**

- **BLDG. TYPES**

  SIMPLE - WAREHOUSES, GYMS, PKG. GARAGES
  TYPICAL - OFFICES, CLASSROOMS
  COMPLEX - MEDICAL FACILITIES, PHYSICAL PLANTS

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

Figure 1. Audit Cost as a Function of Building Size. The data points are for the 38 LoanSTAR reports with available audit cost data (January 1989 - July 1991).



TASK 1. AUDIT REVIEW AND ASSIGNMENTS

CHANGES IN THE AUDIT PROCESS

- **ELIMINATE M&Os.**

- **ELIMINATE INDEPENDENT CALCULATIONS OF ECRMs.**

- **PROVIDE FOR DIFFERING LEVELS OF ECRMs:**

  - **CAT 1 - "DIPSTICK" - BASED ON EQUIPMENT QUANTITY ESTIMATES AND HISTORICAL PAYBACKS.**

  - **CAT 2 - SIMP CALC - SPREADSHEET CALCULATIONS DEVELOPED UNDER CONTRACT TO GEO.**

  - **CAT 3 - PRESENT ECRMs.**

TASK 1. AUDIT REVIEW AND ASSIGNMENTS

TABLE 8

PROPOSED CATEGORY I ECRMs AND HISTORICAL PAYBACKS

ECRM	Payback (Years)
Delamping	1
Repair Steam Traps	2
Photocells on Exterior Lights	3
Time Clock Shut Down of Equipment	3
Incandescent to H.P. Sodium	4
Incandescent to Screw-in Fluorescent	2
Energy-Efficient Fluorescent Lamps	2

Advanced Customer Technology Test for Maximum Energy Efficiency

Project Overview

Project Overview for the
LoanSTAR Monitoring and Advisory Review Committee
August 20, 1991
Austin, TX
Presented by Merwin Brown, PG&E R&D

Summary

- The Advanced Customer Technology Test (ACT^2) for Maximum Energy Efficiency project is a major R&D program of field experiments. The purpose of ACT^2 is to scientifically test the hypothesis, proposed by many energy efficiency experts and environmentalists, that substantial energy efficiency improvements can be achieved among utility customers at costs competitive with supply. The strategy of ACT^2 is to demonstrate in selected customers' businesses and homes integrated packages of modern end-use technologies optimized for maximum energy efficiency. A significant benefit of ACT^2 will be a scientific characterization of the cost-effective maximum potential for end-use energy efficiency technology.
- One of many unique features of this project is the high-level steering committee that provides overall guidance and review for the design and conduct of the field tests. It is composed of representatives of Lawrence Berkeley Laboratory, Natural Resources Defense Council, Rocky Mountain Institute, and PG&E. Other national and international environmental and energy efficiency experts provide advice and review on an ad hoc basis. The Internal Review Committee, composed of representatives from the various PG&E departments involved in customer energy efficiency, provides Company perspective, advice and review for overall project management and scope.
- PG&E is the project manager of this multi-year effort, and is providing the initial three years of funding of $10 million. These funds will be used to install the energy-saving packages in a number of residential, commercial, industrial, and agricultural sites to be made available by qualifying PG&E customers willing to serve as hosts for the tests.

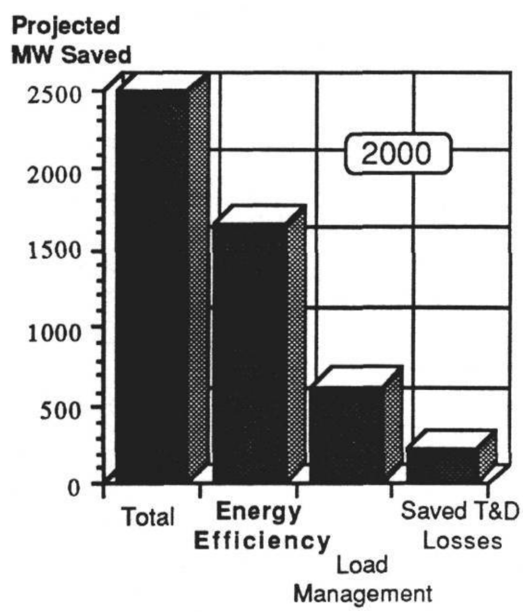
6/19/91

PG&E's
Commitment to Environmental Quality:
"A Cleaner, Healthier Environment"

- Increase customer **energy efficiency**
- Rely on **energy efficiency** as a resource

ACT² for Maximum Energy Efficiency PG&E

- **The Commitment: "Cleaner, healthier environment"**
  - Conduct business in environmentally sensitive manner
  - Sound environmental policy and sound business practice go hand in hand
  - Pursue both for benefit of customers, shareholders, employees, and communities PG&E serves
- **Elements of the Commitment Related to ACT²**
  - Customer Efficiency
    - Promote and implement energy efficiency by customers
    - Focus R&D on improving energy efficiency technologies
    - Work with environmental, consumer and other groups to monitor and improve programs
  - Electric Resource Plan
    - Place primary reliance on energy efficiency
    - 1650 MW by 2000
  - Collaborative
    - Utility earns by sharing savings
    - Provides funding for ACT²



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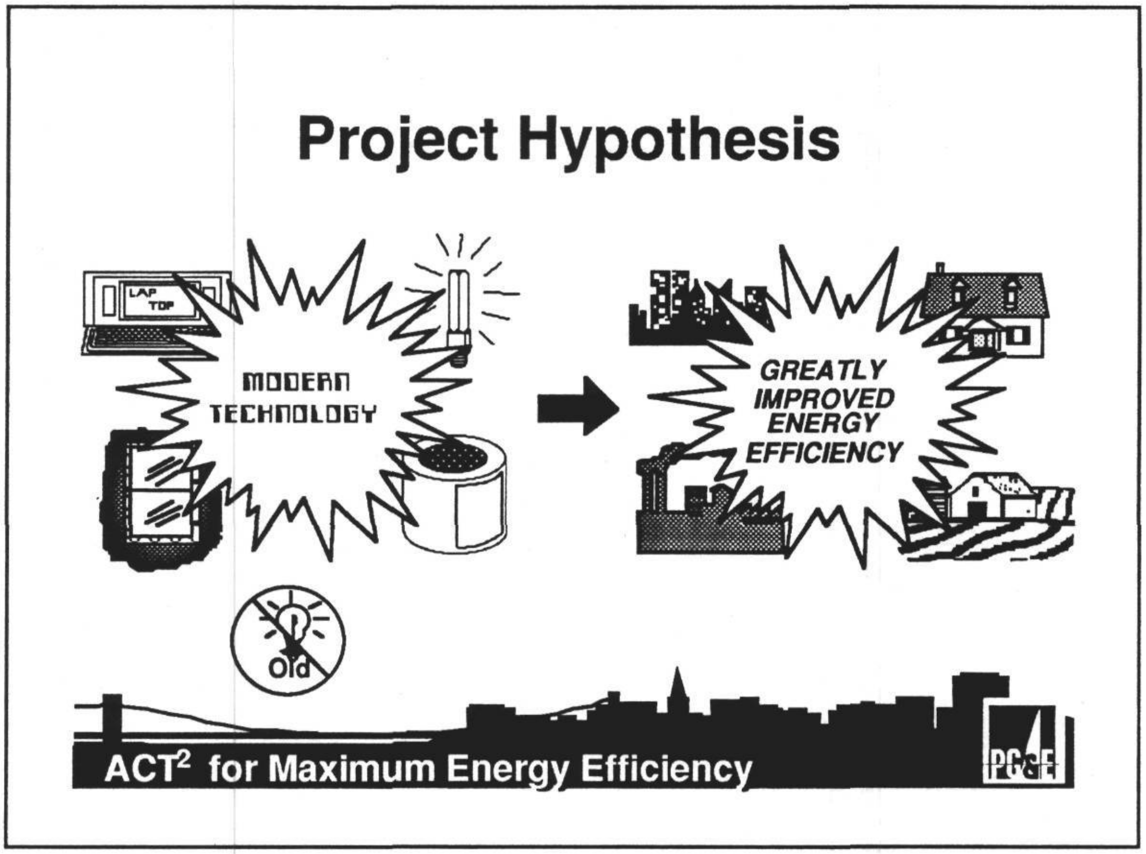
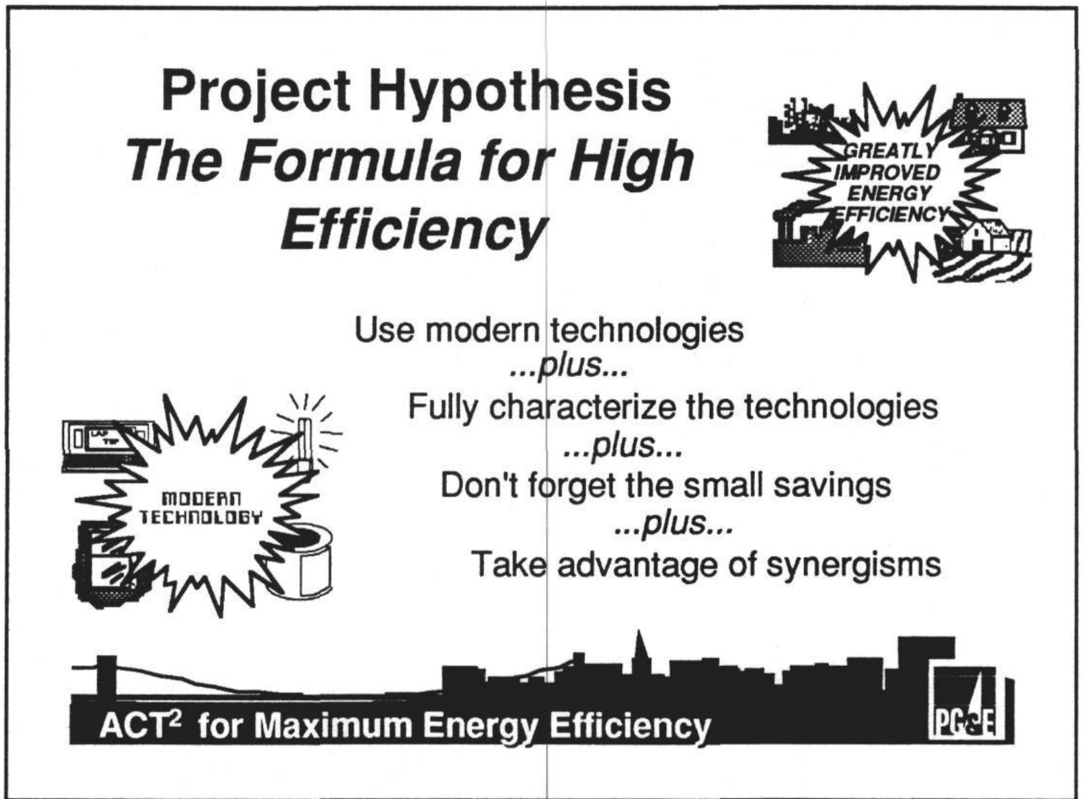


Growing concerns in the US about the environment, dependence on imported oil, and global competition have spurred a renewed push for energy efficiency. New energy-saving technologies, like high efficiency lighting, adjustable speed drive motors, modern office equipment and selective coatings on glass, are fostering projections that:
Substantial energy savings (perhaps as high as 75%) can be achieved in buildings, or industrial and agricultural processes, at economic costs through the use of modern customer end-use technology systems. One implication is that considerable environmental benefit can be had if the investment associated with supply were expended instead on energy efficiency.



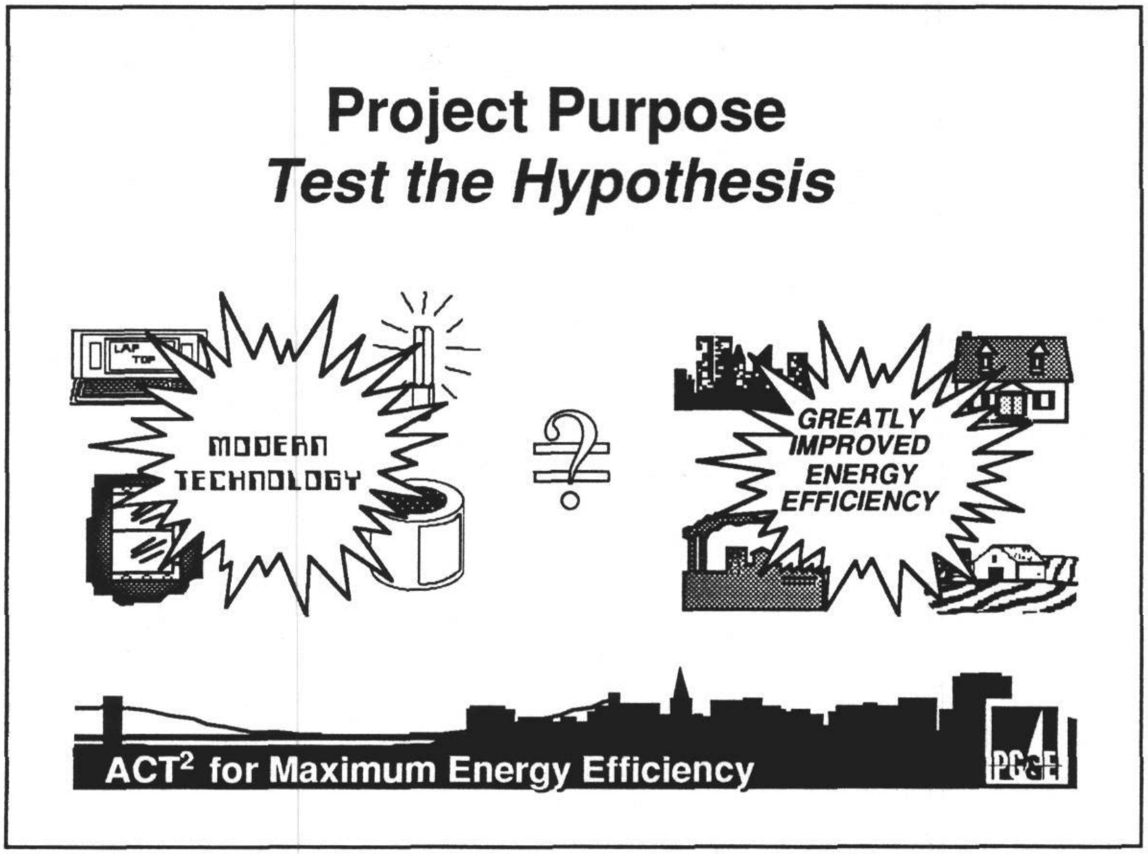
<u>Modern Technologies</u>: Most of the best electricity-saving technologies are less than 1 year old. Using 5-year-old technology results in half the savings at 3 times the costs*.

<u>Full Characterization</u>: Accounting for extra cost savings resulting from the use of some new technologies, provides economic opportunity for additional energy saving measures. For example, many new high efficiency lighting technologies have much longer operating lives leading to significant reductions in lamp replacement costs. These savings can be used to purchase other energy saving improvements.

<u>Small Savings</u>: Including many small savings, like improved exit signs and lap top computers, as well as a few big ones often doubles the total savings*.

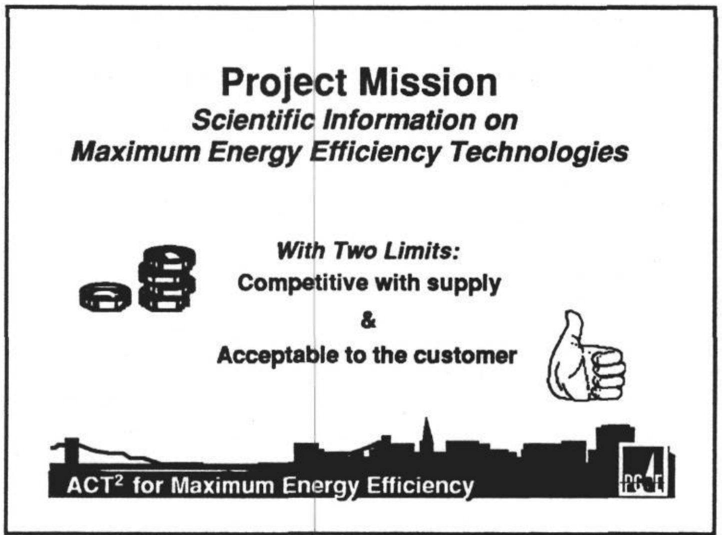
<u>Synergisms</u>: Detailed, whole-system engineering often reveals multiple benefits from single expenditures, thus reducing severalfold the total costs of integrated retrofit packages*. For example, new, special glazings can let in light while keeping out the heat, thereby reducing the needs for lighting and space cooling. High efficiency lighting can reduce further the demand for space cooling, resulting in smaller, cheaper HVAC units.

* Taken from Amory Lovins' "Why Do Assessments of Potential Electric Savings Differ?"

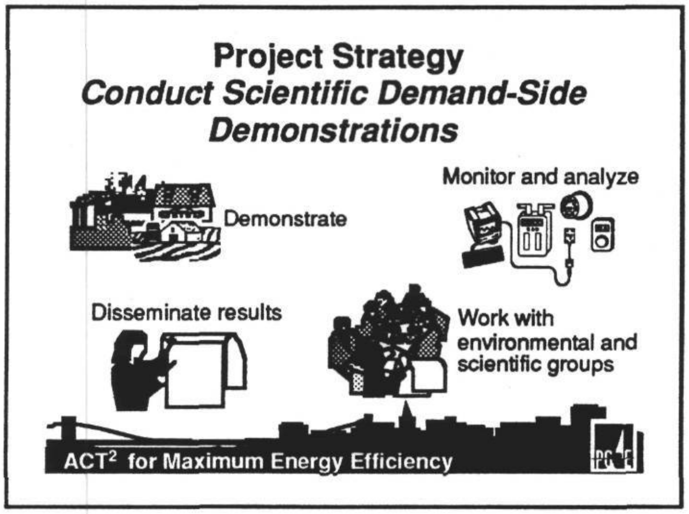


Projections of substantial energy savings possible from advanced end-use technologies have been substantiated only in part by the performance of individual technologies, in some instances, measured only under laboratory conditions. Little has been done to scientifically field test these advanced technologies as integrated systems designed to maximize energy efficiency in customer buildings or processes, where the effects of component interactions on technical performance, life-cycle economics and customer acceptance can be measured. The purpose of the ACT^2 for Maximum Energy Efficiency project is to test the hypothesis implied in the above projections that **substantial energy savings can be achieved in buildings, or industrial and agricultural processes, at economic costs through the use of modern customer end-use technology systems.**

By conducting this test, the project will attempt to determine the technical potential for energy efficiency in our customers' homes and businesses. This information will help planners to project to what degree the company can rely on energy efficiency to meet load and to contribute to earnings.



- Project Mission:
  - **To provide scientific field test information, for use by PG&E and its customers, on the maximum energy savings possible, at or below projected competitive costs, by using modern high-efficiency end-use technologies in integrated packages acceptable to the customer.**
- *Scientific field test information* **means** evaluation of data objectively collected in experiments at customer sites having suitable experimental control. The data will consist of measurements of energy use, economic and technical performance, and observations of user behavior.
- *For use by PG&E and customers* **means** of value to PG&E marketing, supply and corporate planners in making DSM strategic decisions and projections, and to customers in making decisions to deploy these technologies. Value to the public at large is also a conditional goal.
- *Maximum energy savings* **means** the greatest possible electrical KWhrs and gas therms saved, as compared to a conventional control site, within the economic and acceptance constraints.
- *Projected competitive costs* **means** utility life cycle costs that may not now be competitive but can be reasonably shown to have prospects of becoming competitive with utility supply costs.
- *Modern high-efficiency end-use technologies* **means** state-of-the-art, high-efficiency lighting, appliances, HVAC, controls, and similar end-use technologies, for the business or home.
- *Integrated packages* **means** combinations of end-use technology systems and envelope designed to take advantage of synergisms and characterizations that produce maximum energy savings.
- *Acceptable to the customer* **means** no deterioration in health, safety, convenience, comfort, productivity or aesthetics when compared to a control. The new technologies should be "transparent" to the user.



- The project is a **demand-side demonstration**, analogous to a supply-side demonstration, where a package of near-commercial advanced technologies is field tested to determine actual economic and technical performance, and user response.
  - *Demonstrate* by designing and installing, for each selected PG&E customer building or process, an integrated package of modern end-use technologies that maximizes energy savings at projected economic costs, and by testing performance under actual operating customer situations.
  - *Monitor and analyze*:
    - Capital, installation, and operating and maintenance costs.
    - Installation times and techniques
    - Energy use and savings
    - Device and system technical performance
    - User acceptance and site environmental quality
    - Site characteristics
  - *Disseminate results* by using a variety of methods and mediums to report on the evaluation of the data and lessons learned:
    - Written reports
    - Presentations
    - Forums
    - Testimonies
    - Tours
  - *Assure the credibility* of the results and their acceptance by scientific and environmental organizations by involving, as part of the project management team:
    - A top-level steering committee of renowned experts in energy efficient end-use technologies to advise on and review the overall project experimental and technology design.
    - Other national and international technical experts to advise on and review, on an ad hoc basis, the technologies and processes to be used.

Project Participants

PG&E **LBL**

Pacific Gas & Electric
Lawrence Berkeley Laboratory
Natural Resources Defense Council
Rocky Mountain Institute

NRDC **RMI**

ACT^2 for Maximum Energy Efficiency

PG&E

PG&E:

Fund and Manage Project
Serve on Steering Committee
Carl Weinberg

LBL:

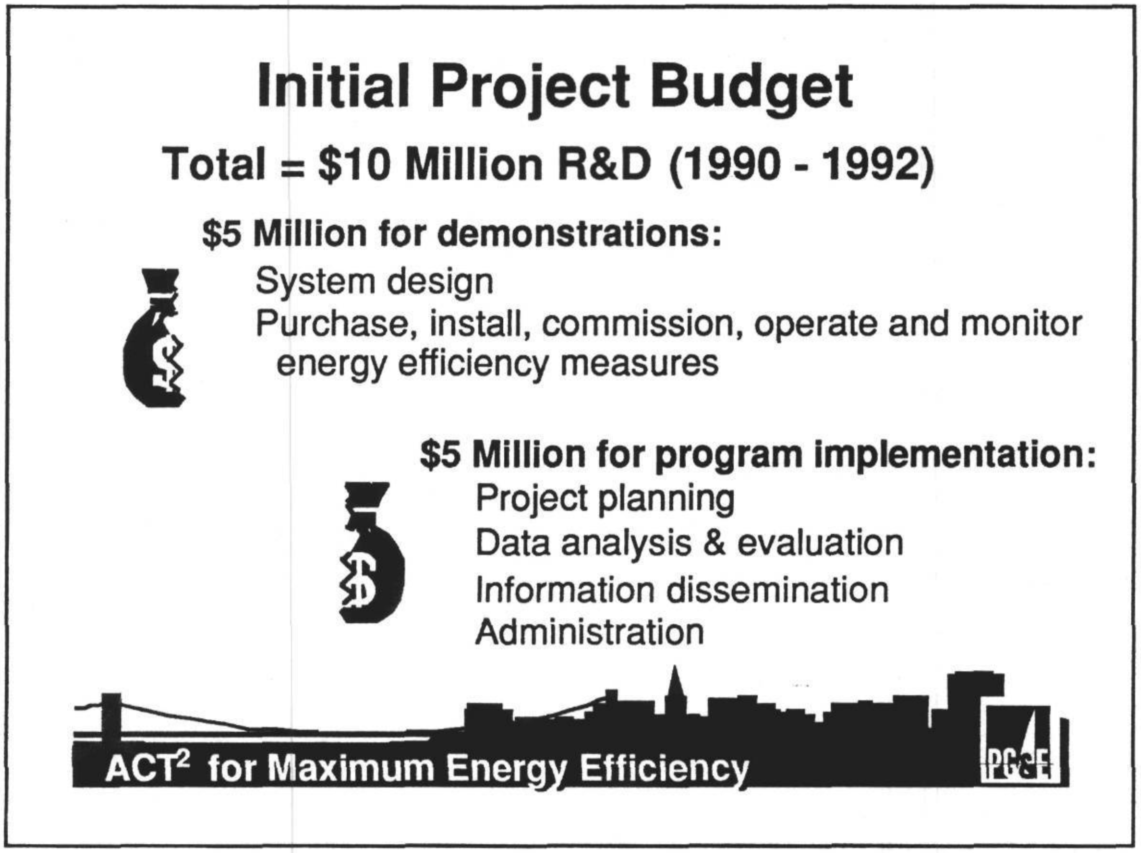
Serve on Steering Committee
Art Rosenfeld
Perform selected contract tasks

NRDC:

Serve on Steering Committee
Ralph Cavanagh

RMI:

Serve on Steering Committee
Amory Lovins



Funding

- $5 million was obtained by a California Public Utilities Commission (CPUC) resolution, December 18, 1989, that retained for this project a portion of the 1987-1989 R&D balancing account refund.
- Another $5 million was approved by the CPUC on August 29, 1990, as part of the Customer Energy Efficiency filing.

Budget

- Based on previous experiences with energy efficiency projects, a rule-of-thumb for budgeting has emerged:
  - 50% for demonstration design, installation, commissioning, operation and monitoring, and
  - 50% for project planning, administration, analysis and evaluation, and information dissemination

Project Deliverables and Benefits

- Information for planning and decision making
- Customer education and encouragement
- New design and measurement techniques
- Lessons learned from practical experience
- Guidance for future R&D

ACT^2 for Maximum Energy Efficiency

PG&E

Information for planning and decision making

Provide information to PG&E customers and planners on the technical potential for maximum energy efficiency, and the associated costs, by using modern, advanced end-use technologies.

Customer education and encouragement

Provide examples of modern energy-saving technologies operating successfully at customer sites, to inspire and encourage others to adopt these environmentally beneficial technologies.

New design and measurement techniques

Identify and develop integrated technology packages, and design and measurement techniques, that can maximize end-use energy savings at costs competitive with generation.

Lessons learned from practical experience

Provide hands-on learning about what to do, and what not to do, in designing, installing, commissioning and operating new energy saving technologies. Learn how to measure their performance and impacts. Reveal unforeseen benefits, e.g., improved productivity, and problems, e.g., deterioration of power quality.

Guidance for future R&D

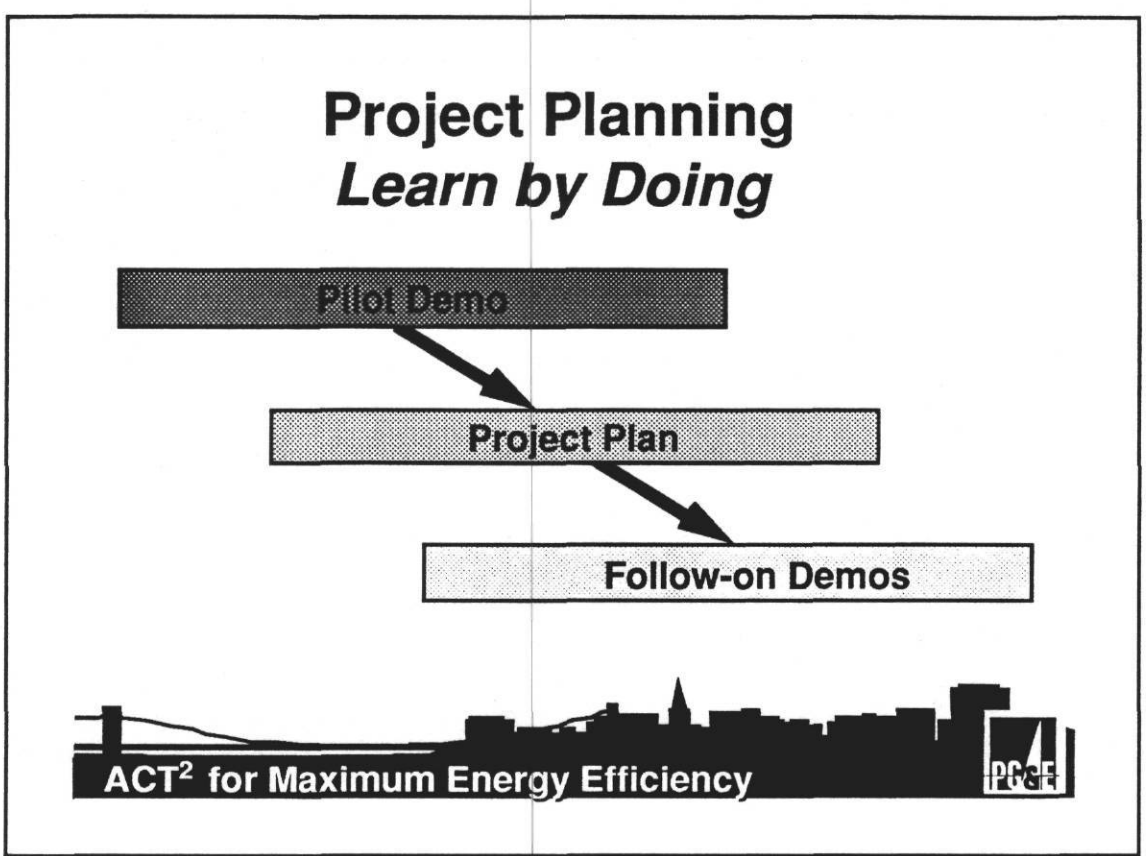
Provide guidance and direction for future energy efficiency R&D by PG&E and others

Project Committees & Forums

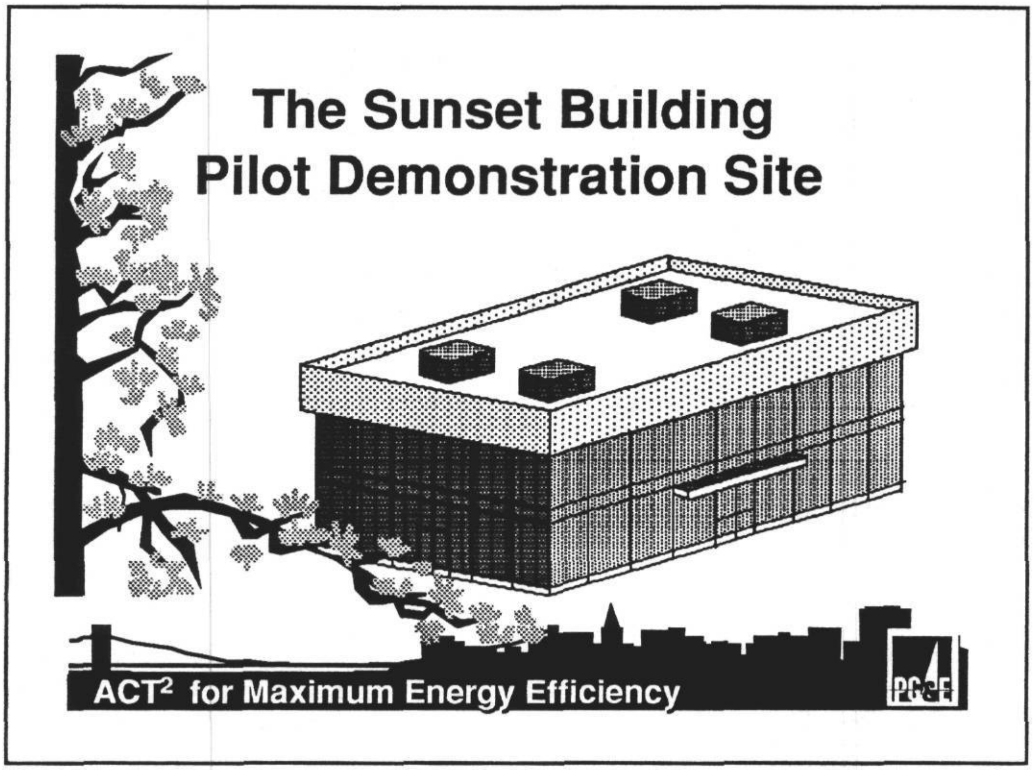
ACT^2 for Maximum Energy Efficiency

PG&E

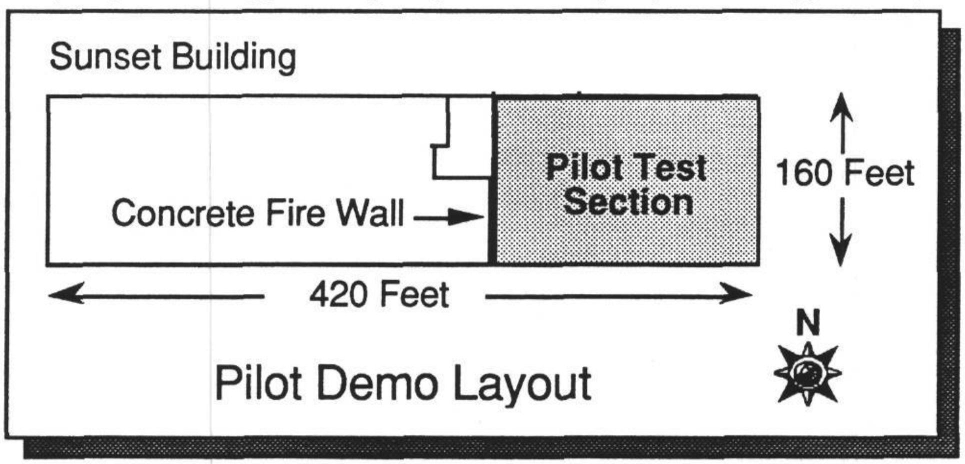
- **Advice and Review:**
  - Steering Committee: To guide PG&E, through advice and review, in the design and conduct of the project to help ensure valid results acceptable to scientific and environmental communities. Members, renowned for leadership in energy efficiency, represent the views of those communities.
    - Lawrence Berkeley Laboratory - Art Rosenfeld
    - Natural Resources Defense Council - Ralph Cavanagh
    - Rocky Mountain Institute - Amory Lovins
    - PG&E - Carl Weinberg
  - Internal Review Committee: To provide Company perspective, advice and review for overall project management and scope. Members are representatives involved in energy customer efficiency from the PG&E business units of Distribution, Electric Supply, ENCON and Gas Supply, and the departments of Corporate Planning and R&D.
  - Technical Advisory Network: A collection of national and international technical and human behavior experts to provide advice and review technologies on an *ad hoc* basis.
- **Forums to obtain comment and educate:**
  - Regulators: California regulators, NARUC, *etc.*
  - Utilities: EPRI, GRI, CURC, *etc.*
  - Trade Associations: ASHRAE, AEE, NEMA, APEM, *etc.*
  - *Etc.*

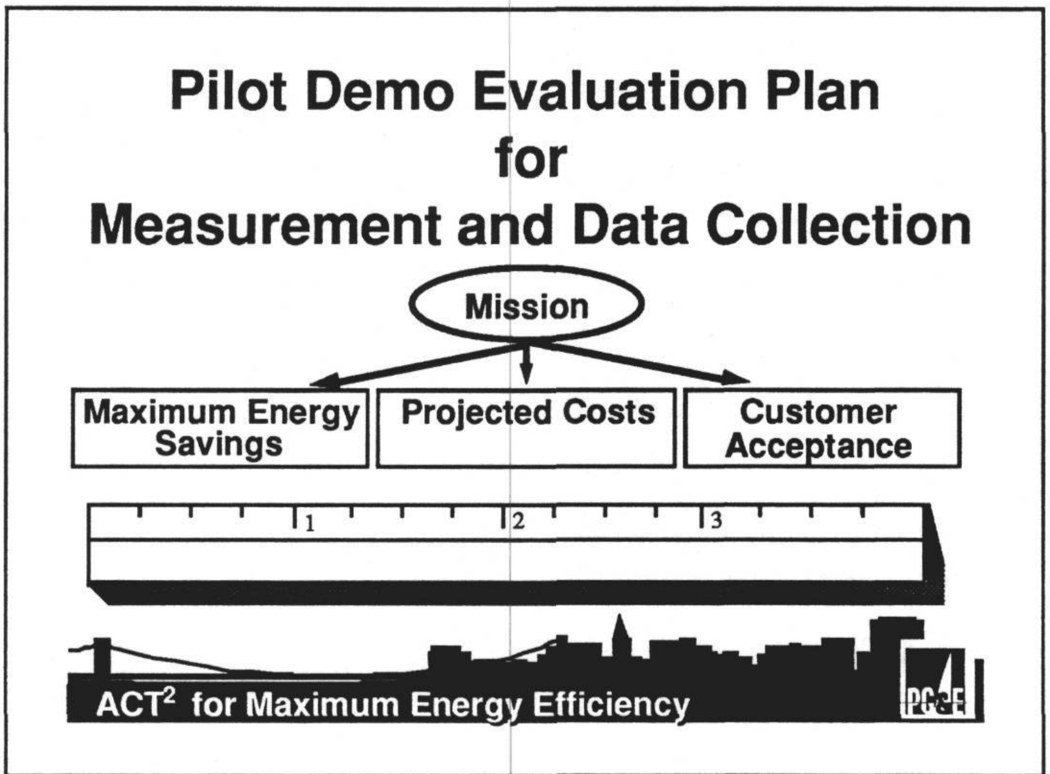


- INTENT:
  - To provide a "learn-by-doing" experience to guide the development of the project design, technology design methods, and measurement and monitoring techniques.
- APPROACH:
  - Project planning done in parallel to a pilot demonstration
  - Planning responsive to lessons learned in pilot demonstration
- RATIONALE:
  - Need to minimize risk is great:
    - The amount of money - $ 10 million - in the project is large.
    - Hosts might be adversely affected by big mistakes.
    - Project will be very visible and too many mistakes could hurt future energy efficiency efforts.
  - Pilot Demo gets some hardware into the field early under tightly controlled circumstances.
  - Maximizes chances that the project plan will result in follow-on demos that are properly designed, operated and monitored.



- The Sunset Building is owned by a PG&E customer, but occupied primarily by PG&E employees. It is a typical low-rise, two-story modern commercial office building located in San Ramon, CA. The ACT^2 Project Team is located on the site, and therefore will observe daily the impacts of the pilot demo on the occupants.
- Location: First floor, from east end to fire wall
- Includes most of the PG&E R&D Department
- 21,688 sq. ft.(pilot)/134,400 sq. ft.(total) & 58,000 sq. ft.(conditioned)/42,000 sq. ft. (occupied)
- 374,191 KWh per year(pilot)/1,162,707 KWh per year(total)
- 8,633 therms per year(pilot)/21,512 therms per year(total)
- $43,721 per year energy costs(pilot)/$119,681 per year energy costs(total)



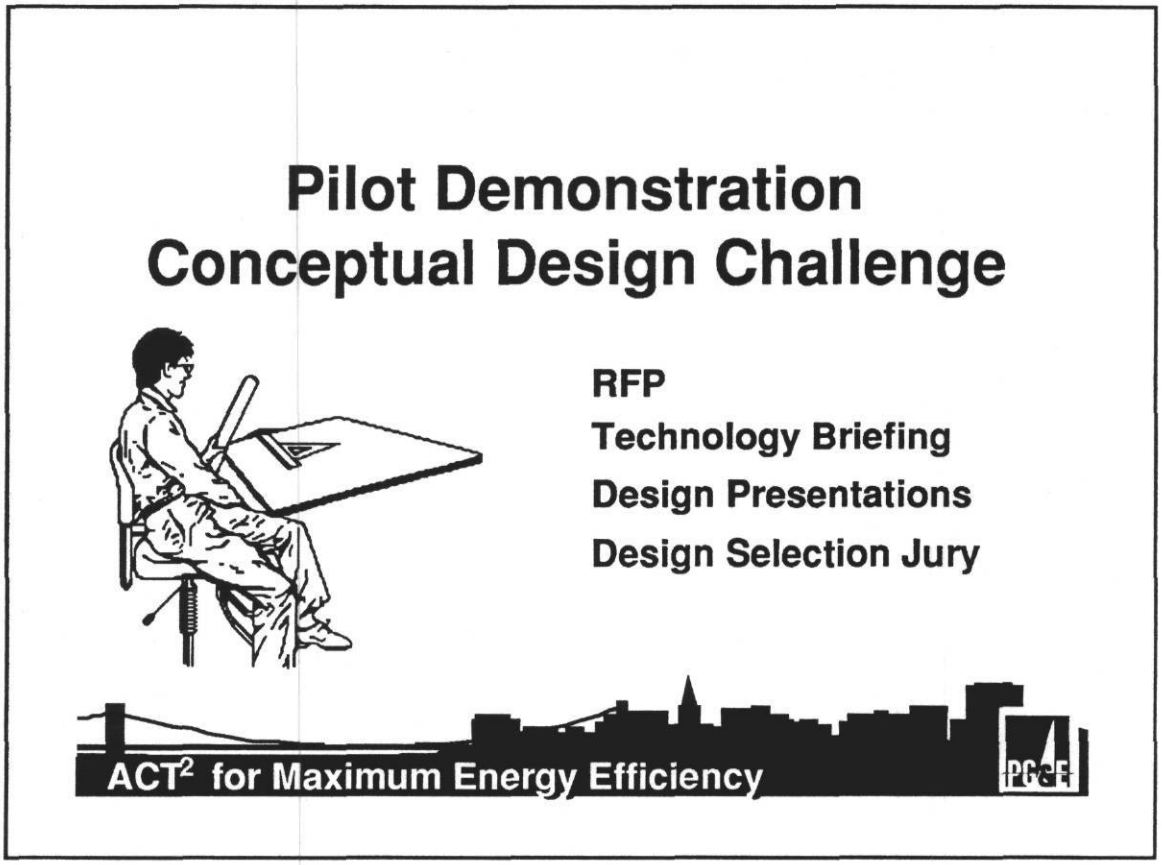


To achieve the mission, three main categories of information need to be obtained;

1. Maximum Energy Savings Possible
   - System KW, KWh, therms
   - Component energy use and efficiency
   - Power factor
   - Site characteristics (weather,etc.)

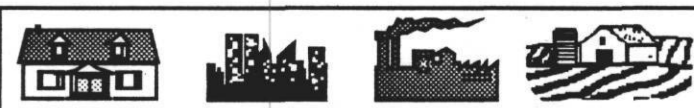
2. Projected Competitive Costs
   - Actual purchase, installation and O&M costs.
   - Projected costs

3. Customer Acceptance (Occupant Behavior)
   - Surveys on occupant acceptance
   - Indoor air quality
   - Lighting quality
   - Thermal comfort
   - Noise
   - Harmonic generation
   - Operation ease
   - Installation disruptions



- RFQ conceptual design issued
  - Most qualified firms selected
    - Firms prepare energy-efficient conceptual designs
      - Firms present conceptual designs
        - Jury selects best design, recommends changes
          - "Winning" firm completes design
            - RFP for installation issued

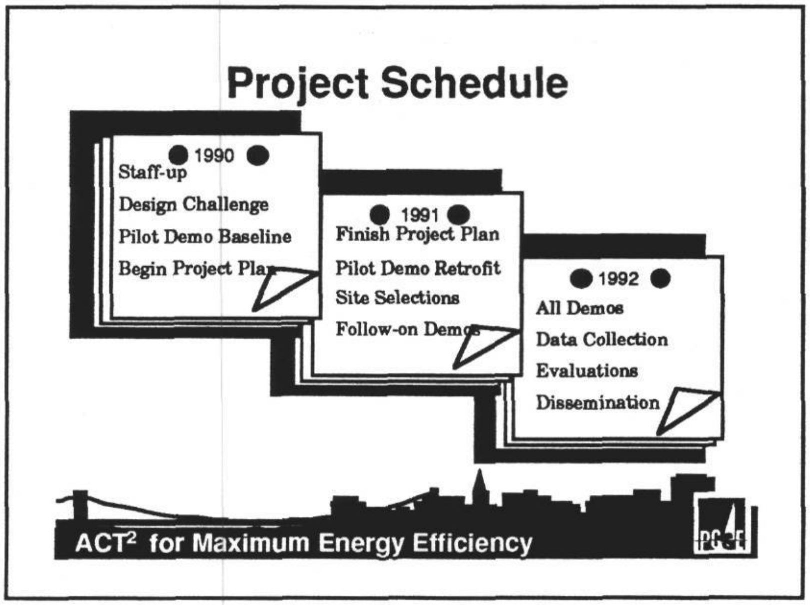
Suggested Follow-On Demonstration Types

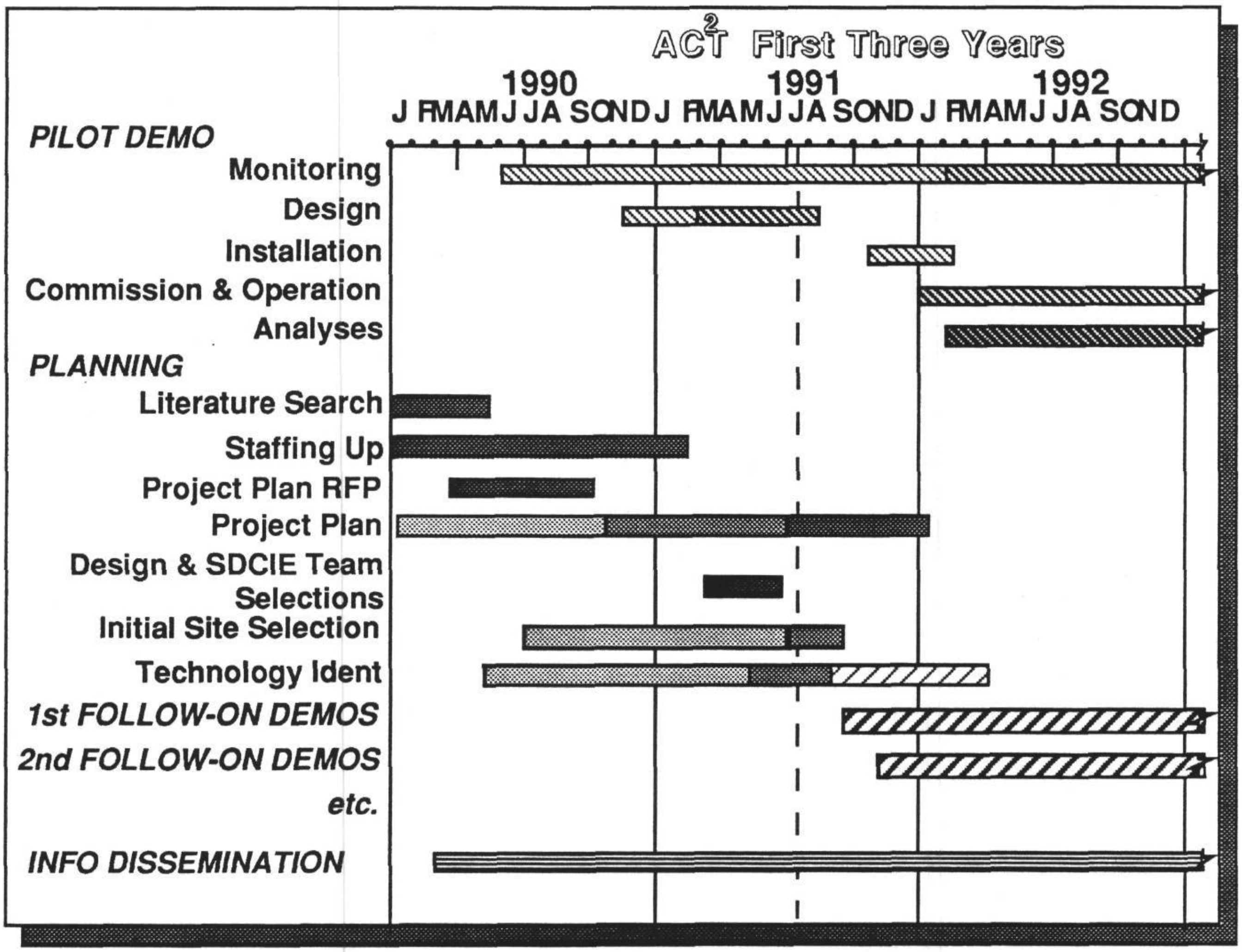


	Residential	Commercial	Industrial	Agricultural
New	Medium Income	Large Office Small Office		
Retrofit	Medium Income Load Survey* Apartment Building	Small Offices with Shops Supermarket	Drive Intensive Gas Intensive	Dairy Irrigation Pumping

**Load survey data has been collected for these homes*

- Demonstration types shown above were chosen, after consideration of a broad spectrum of PG&E customer segments and types, in order to focus the search for candidate hosts.
- In general these demonstration types were drawn either from customer segments having the most impact on energy demand overall, or having special needs for energy efficiency.
- Both new construction and retrofit demonstrations will be considered:
  - New construction demonstrations can incorporate innovative building designs and capture energy savings opportunities that would otherwise be lost.
  - Retrofit demonstrations represent a larger near term market for energy efficiency technologies than does new construction.
- Candidates will be identified through the corporate divisions, and selected based on the appropriate criteria and after discussions and agreement among all affected parties.


Project Schedule
1990
Staff-up
Design Challenge
Pilot Demo Baseline
Begin Project Plan
1991
Finish Project Plan
Pilot Demo Retrofit
Site Selections
Follow-on Demos
1992
All Demos
Data Collection
Evaluations
Dissemination
ACT² for Maximum Energy Efficiency


ACT² First Three Years
1990
1991
1992
J FMAMJ JA SOND J FMAMJ JA SOND J FMAMJ JA SOND
PILOT DEMO
Monitoring
Design
Installation
Commission & Operation
Analyses
PLANNING
Literature Search
Staffing Up
Project Plan RFP
Project Plan
Design & SDCIE Team Selections
Initial Site Selection
Technology Ident
1st FOLLOW-ON DEMOS
2nd FOLLOW-ON DEMOS
etc.
INFO DISSEMINATION

Texas LoanSTAR
Monitoring and Analysis Program

Task 6
Improved Energy Audit Process

Beginning: Fall 1991

Jeff S. Haberl

August 1991

Improved Energy Audit Process

Objectives:

1. Investigate use of dipstick audits (DOE/Battelle).

2. Incorporate demand data and other short term monitoring into auditor's work.

3. Investigate use of selected prescreening indices into audit.

4. Begin to use real savings to improve audit process (Task 2-5 Interaction).

Improved Energy Audit Process

Benefits:

-> Improves the accuracy and information content of LoanSTAR audits.

-> Improves and lengthens PRE data stream for LoanSTAR sites.

-> Accelerates technology transfer to/from LoanSTAR project to Texas A/Es.