ESL-TR-93/06-03

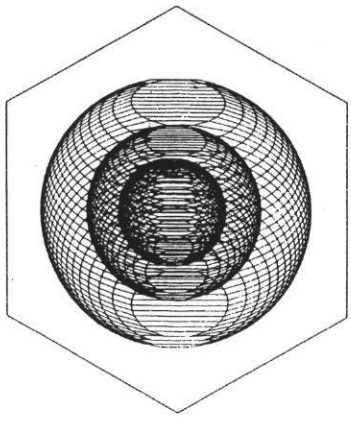
TEXAS LoanSTAR MONITORING AND ANALYSIS PROGRAM

Report to

THE MONITORING AND ADVISORY REVIEW COMMITTEE

Presentations

June 2–3, 1993
Austin, TX



ENERGY SYSTEMS LABORATORY
Department of Mechanical Engineering
Texas Engineering Experiment Station
Texas A&M University System

PRESENTATIONS

Table of Contents

Agenda
MONITORING ANALYSIS AND REVIEW
COMMITTEE MEETING
Doubletree Hotel
Austin, Texas
June 2-3, 1993

Wednesday, June 2, 1993

7:30 - 8:30 a.m.	Continental Breakfast
8:00 - 8:30 a.m.	Opening Comments, Introductions, Energy Office
8:30 - 10:15 a.m.	LoanSTAR Overview, Economic Impact Comments
	Task 1: Energy Audits, Training, Audit Procedures in 1992-93 (Warren M. Heffington)
	Task 6: Improved Energy Audits (Jeff S. Haberl)
	Task A: Metering Hardware and Oversight of Data Acquisition Subcontractors (Dennis L. O'Neal)
	Task B: Calibration Laboratory (W. D. Turner)
	Feedback on Tasks 1, A, B
10:15 - 10:30 a.m.	Coffee Break
10:30 - 12:15 p.m.	Task C: Data Handling and Retrieval (Jeff Haberl, Robert Sparks)
	Task D: Analysis of Data and Software Development (Jeff Haberl, Robert Sparks)
	Feedback on Tasks C, D
12:15 - 1:30 p.m.	Sit-down Lunch
1:30 - 3:30 p.m.	Task D: Analysis of Data and Software Development (David Claridge and Kelly Kissock)
	Task E: LoanSTAR Technology Transfer (David Claridge, Jeff Haberl, Dan Turner)
	Feedback on Tasks D, E
3:30 - 3:45 p.m.	Coffee Break

3:45 - 4:00 p.m.	Ernie Freeman, U.S. Department of Energy - "Existing Buildings Research"
4:00 - 4:15 p.m.	Bill Mixon, Oak Ridge National Lab - "ORNL Commercial Retrofit Update"
4:15 - 4:30 p.m.	Margaret Fels, Princeton University - "A Study of the Effect of Humidity on PRISM Results"
4:30 - 4:45 p.m.	Todd Taylor, Battelle Pacific Northwest Laboratories - "Dip-Stick Audits"
4:45 - 5:00 p.m.	Vijay Reddy, Houston Lighting & Power - "HL&P DSM Programs"
5:00 - 5:15 p.m.	Grant Brohard, Pacific Gas & Electric - "Results of Date ACT^2"
5:15 - 5:30 p.m.	Hashem Akbari, Lawrence Berkeley Laboratory - "Use of Energy Management Systems for Building Energy Monitoring"
5:30 - 5:45 p.m.	Ren Anderson, NREL - "TBA"
5:45 - 6:00 p.m.	Bruce Hunn, University of Texas at Austin - "TBA"
6:00 - 6:30 p.m.	Break
6:30	Dinner

Thursday, June 3, 1993

7:30 - 8:30 a.m.	Sit-down Breakfast
8:30 - 10:15 a.m.	Future Directions Tasks 1, 6 Task A Task B Task C Task D Task E
10:15 - 10:30 a.m.	Coffee Break
10:30 - 12:30 p.m.	Wrap-up, Open Discussion
12:30 - 1:30 p.m.	Buffet Lunch in the Restaurant

Current Status

LoanSTAR Program

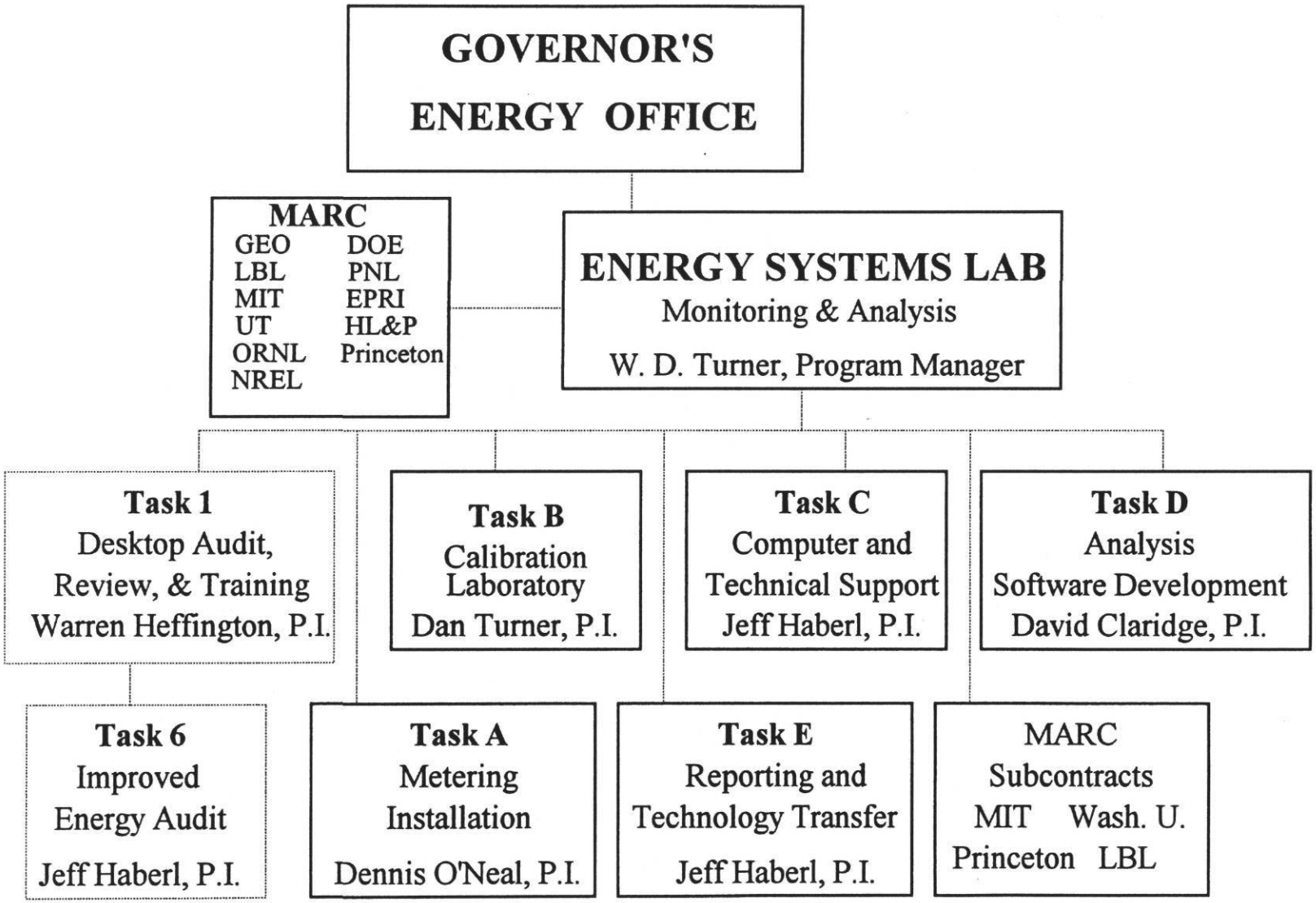
for

MARC Meeting

by

W. D. Turner

June 1993


GOVERNOR'S
ENERGY OFFICE
MARC
GEO
LBL
MIT
UT
ORNL
NREL
DOE
PNL
EPRI
HL&P
Princeton
ENERGY SYSTEMS LAB
Monitoring & Analysis
W. D. Turner, Program Manager
Task 1
Desktop Audit,
Review, & Training
Warren Heffington, P.I.
Task B
Calibration
Laboratory
Dan Turner, P.I.
Task C
Computer and
Technical Support
Jeff Haberl, P.I.
Task D
Analysis
Software Development
David Claridge, P.I.
Task 6
Improved
Energy Audit
Jeff Haberl, P.I.
Task A
Metering
Installation
Dennis O'Neal, P.I.
Task E
Reporting and
Technology Transfer
Jeff Haberl, P.I.
MARC
Subcontracts
MIT Wash. U.
Princeton LBL

LoanSTAR Personnel
May 1993

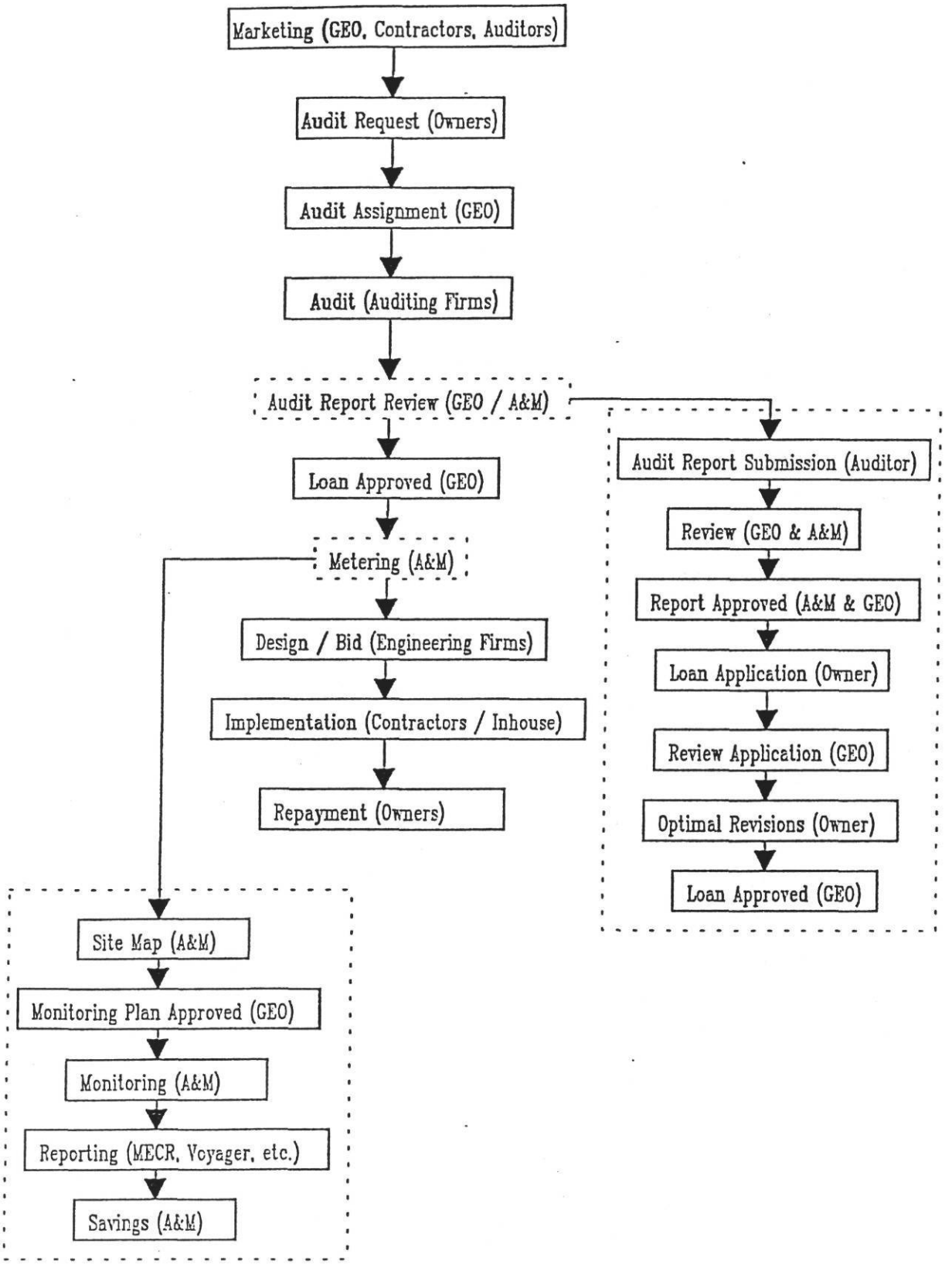
Faculty: W. D. Turner, D. O'Neal, D. Claridge, W. Heffington, J. Haberl, T. A. Reddy, N. Saman

Administrative: D. Greer, D. Rosenkranz, S. Swanson, D. Wallace

Technical: C. Boecker, C. Bohmer, J. Bryant, K. Milligan, R. Chambers, R. Lopez, R. Sparks, J. Houcek, A. Britton, D. Nutter, D. Willis, S. Katipamula, A. Athar, D. Ruch, K. Kissock, M. Liu, J. Wang, F. Scott

Graduate Students: J. Backer, K. Mitchell, J. Robinson, B. Munger, A. Nafis, A. Kulandaivelu, A. Baranowski, M. Abbas, T. Bou Saada, R. Beasley, Y. Liu, A. Dhar, G. Bailey, X. Wu, J. Mahoney, F. Dorhofer, N. Muraya, J. Eggebrecht

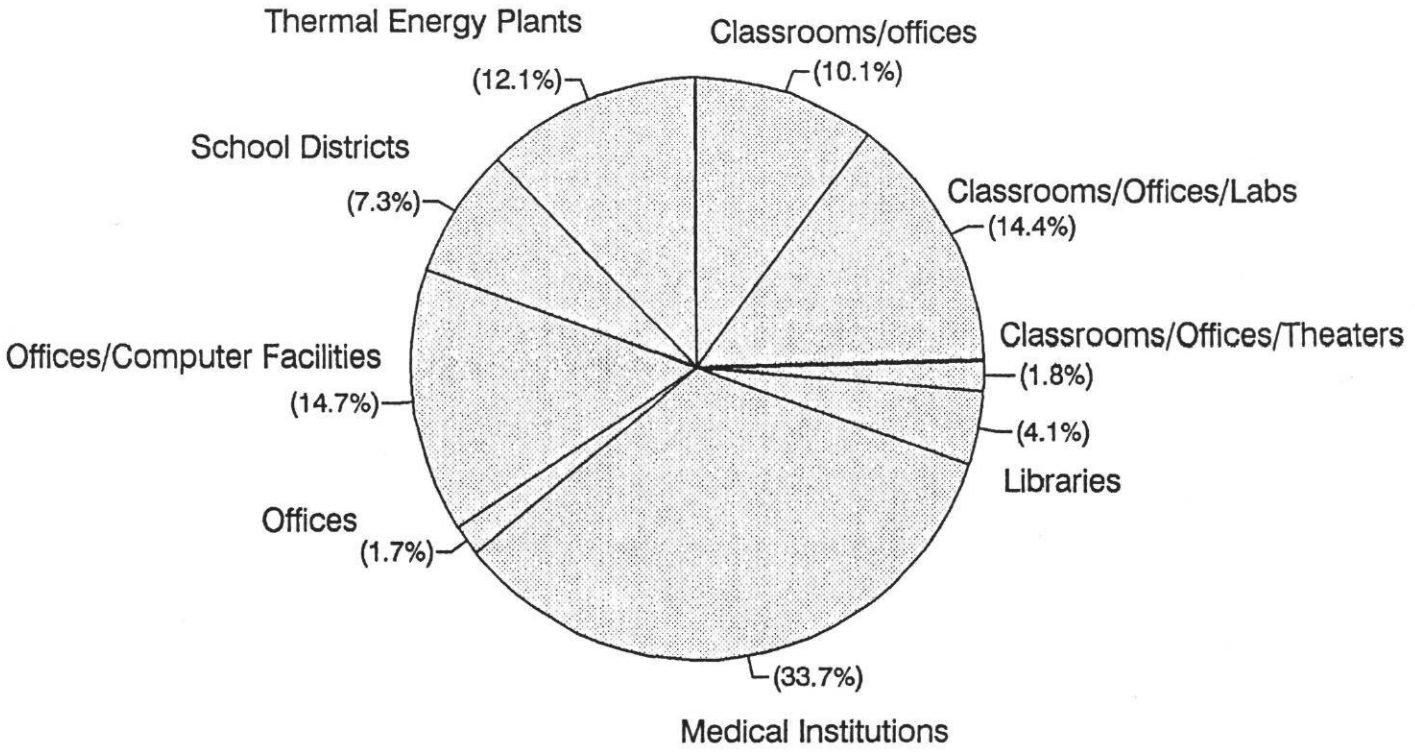
Undergraduate Students: M. Castillo, B. Broyles, J. Steele, J. Rife, S. Gregorcyk


Marketing (GEO, Contractors, Auditors)
Audit Request (Owners)
Audit Assignment (GEO)
Audit (Auditing Firms)
Audit Report Review (GEO / A&M)
Loan Approved (GEO)
Metering (A&M)
Design / Bid (Engineering Firms)
Implementation (Contractors / Inhouse)
Repayment (Owners)
Audit Report Submission (Auditor)
Review (GEO & A&M)
Report Approved (A&M & GEO)
Loan Application (Owner)
Review Application (GEO)
Optimal Revisions (Owner)
Loan Approved (GEO)
Site Map (A&M)
Monitoring Plan Approved (GEO)
Monitoring (A&M)
Reporting (MECR, Voyager, etc.)
Savings (A&M)

Percent Area by Functional Use

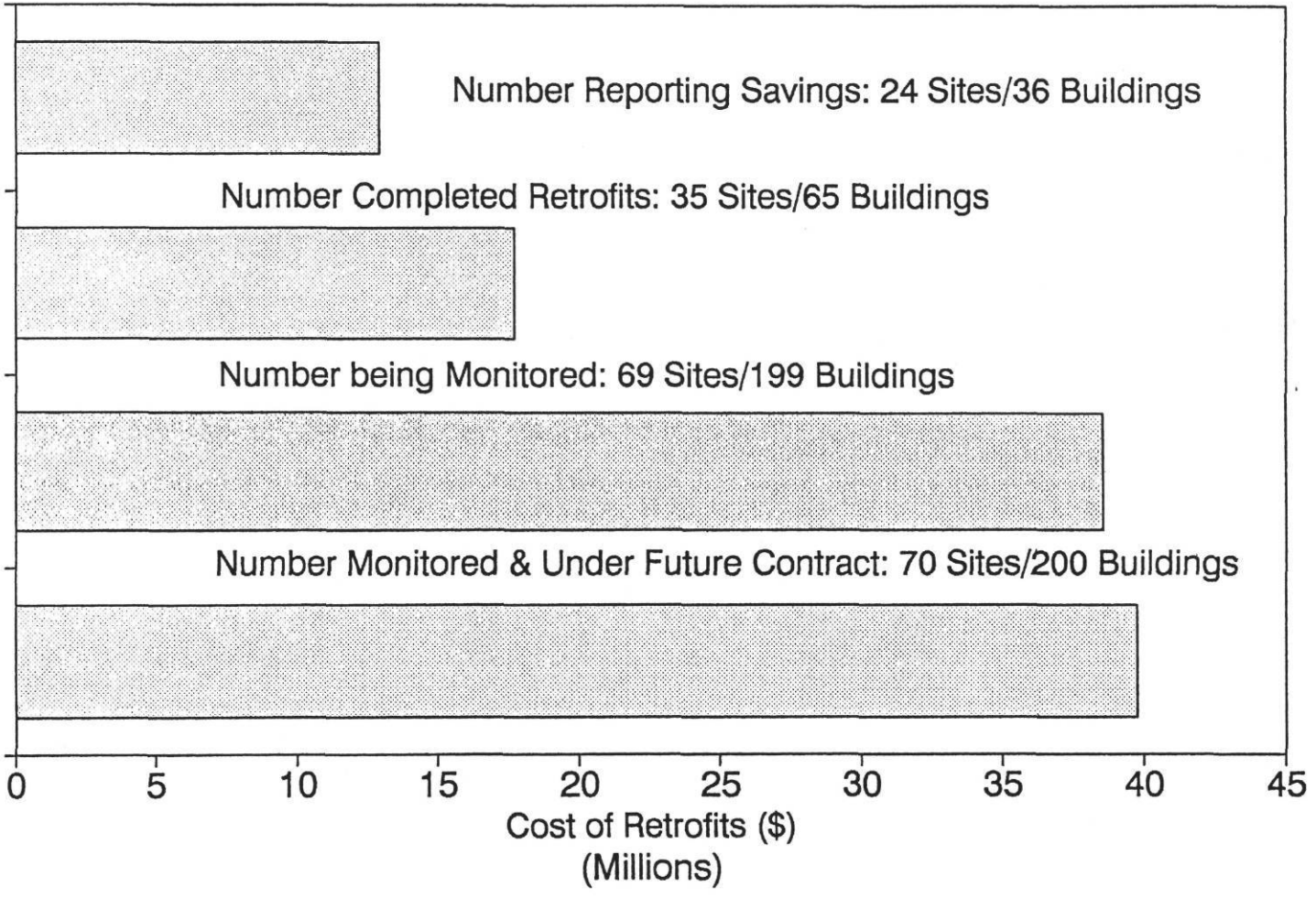
Buildings Monitored as of April, 1993

Total Area Monitored Under LoanSTAR Program: 18.27 Million sq.ft.

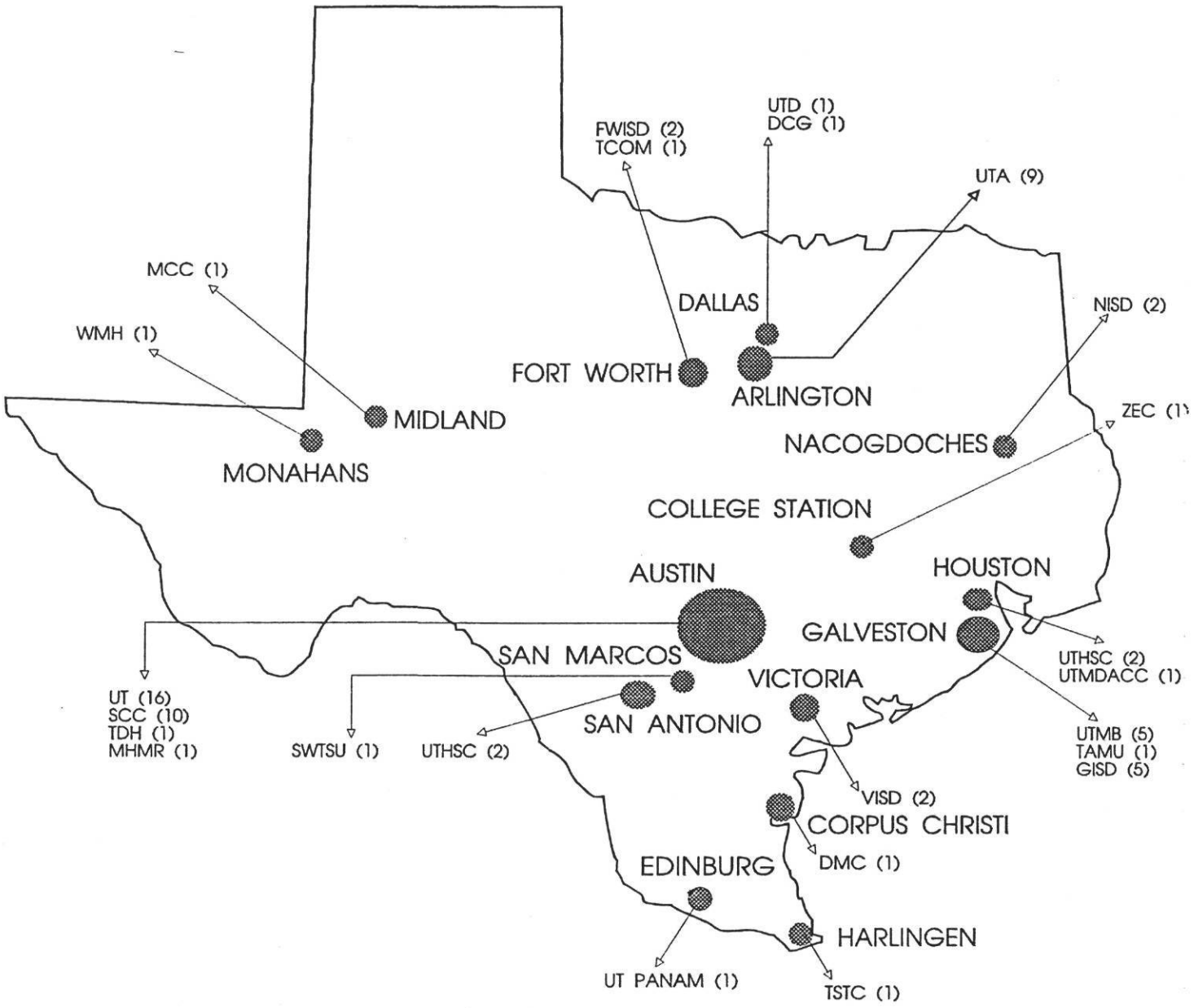


Estimated Cost of Retrofits

As of May, 1993

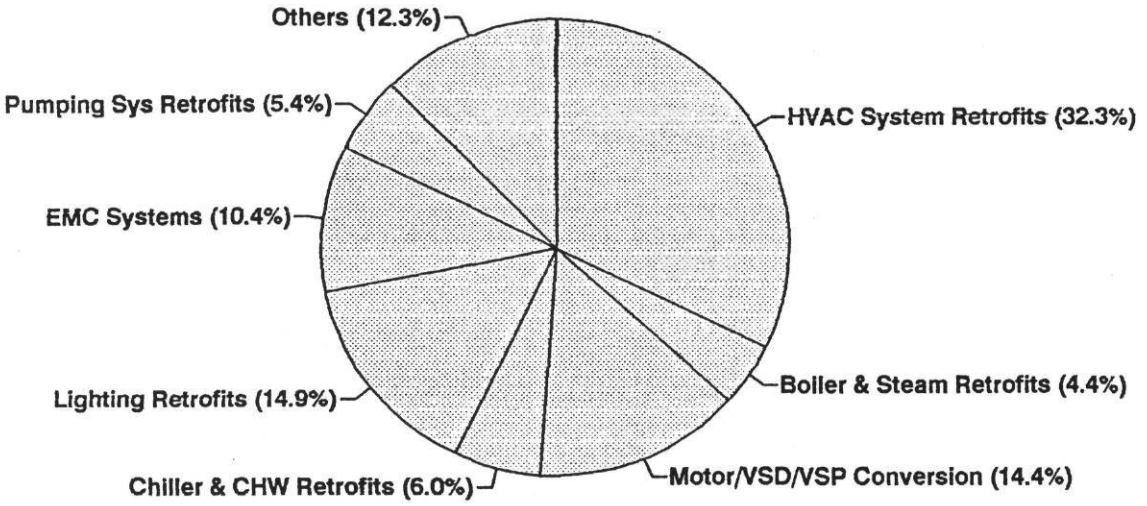


SITES MONITORED UNDER LOANSTAR PROGRAM AS OF MAY 1993



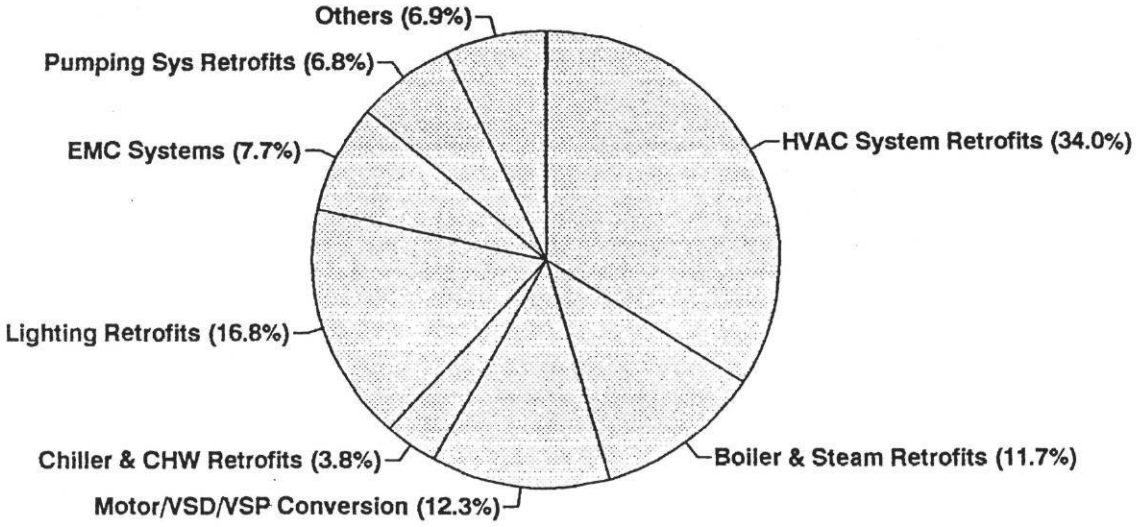
Audit Estimated Retrofit Cost

69 Sites/199 Buildings Monitored as of May 1993
Total Estimated Retrofit Cost: $32.5 Million



Audit Estimated Cost Savings

69 Sites/199 Buildings Monitored as of May 1993
Annual Cost Savings: $9.6 Million



Summary of ECRM's for Buildings Being Monitored as of May 1993

ECRM Recommendations	Impl. Cost $	% of Total Imp. Cost	Cost Savings $	% of Total Cost Savings	Simple Payback Yrs
HVAC System Retrofits	$10,504,625	32.3	$3,256,227	34.0	3.2
Boiler & Steam Retrofits	$1,439,646	4.4	$1,116,516	11.7	1.3
Motor/VSD/VSP Conversion	$4,679,163	14.4	$1,172,166	12.3	4.0
Chiller & CHW Retrofits	$1,936,886	6.0	$362,643	3.8	5.3
Lighting Retrofits	$4,841,987	14.9	$1,605,062	16.8	3.0
EMC Systems	$3,368,158	10.4	$736,918	7.7	4.6
Pumping Sys Retrofits	$1,752,647	5.4	$655,057	6.8	2.7
Others	$3,997,383	12.3	$662,291	6.9	6.0
Totals	$32,520,495	100	$9,566,880	100	3.4

Energy Conservation Identified in Buildings Monitored Under LoanSTAR Program as of May 1993

Purchased Utility Category	Site Energy	Site Energy** (million Btu/yr)	Source Energy* (million Btu/yr)	Fractional Site Energy Savings (%)	Fractional Source Energy Savings (%)
Electricity	113,282,528 (kWh/yr)	386,520	1,314,077	26.6	52.9
Natural Gas	305,274 (MCF/yr)	314,432	314,432	21.7	12.7
Steam/Hot Water	318,237 (million Btu/yr)	318,237	424,316	21.9	17.1
Chilled Water	35,986,682 (Ton-hr/yr)	431,840	431,840	29.8	17.4
Totals		1,451,029	2,484,666	100	100

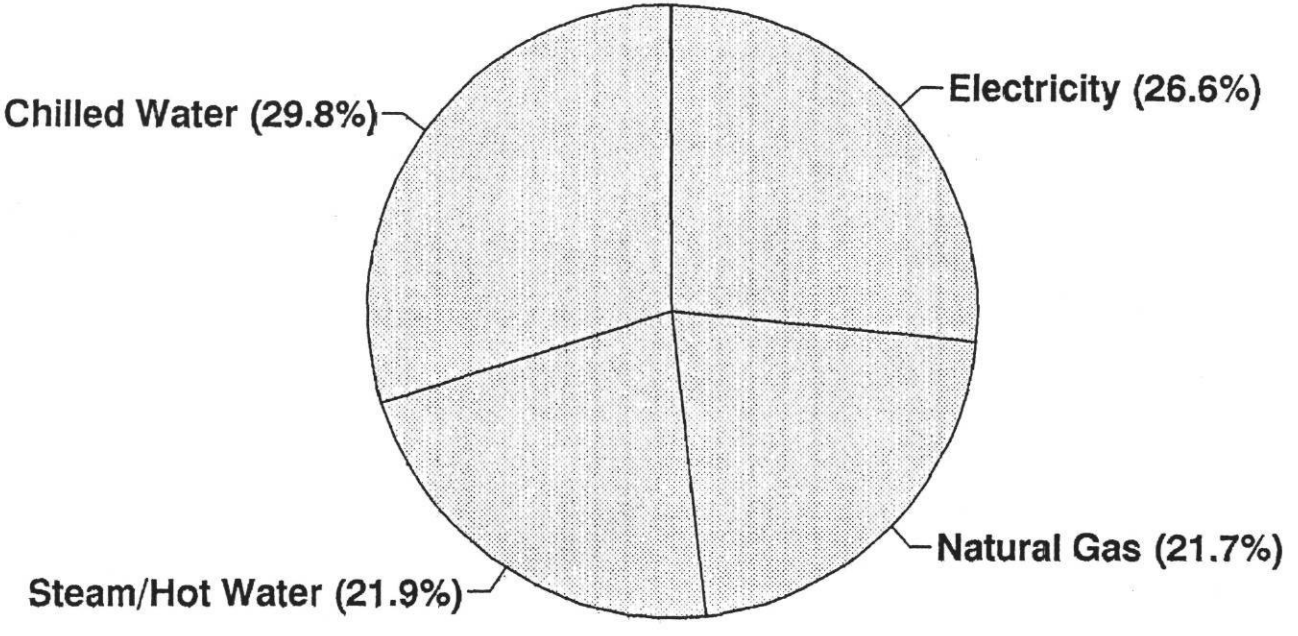
** Btu savings calculated on the basis of site Btus (i.e. 3,412 Btu/kWh, 1,030,000 Btu/MCF and 12,000 Btu/ton-hr)

* Btu savings calculated on the basis of source Btus (i.e. 11,600 Btu/kWh, 1,030,000 Btu/MCF, boiler efficiency of 75% and 12,000 Btu/ton-hr)

AUDIT ESTIMATED ENERGY SAVINGS

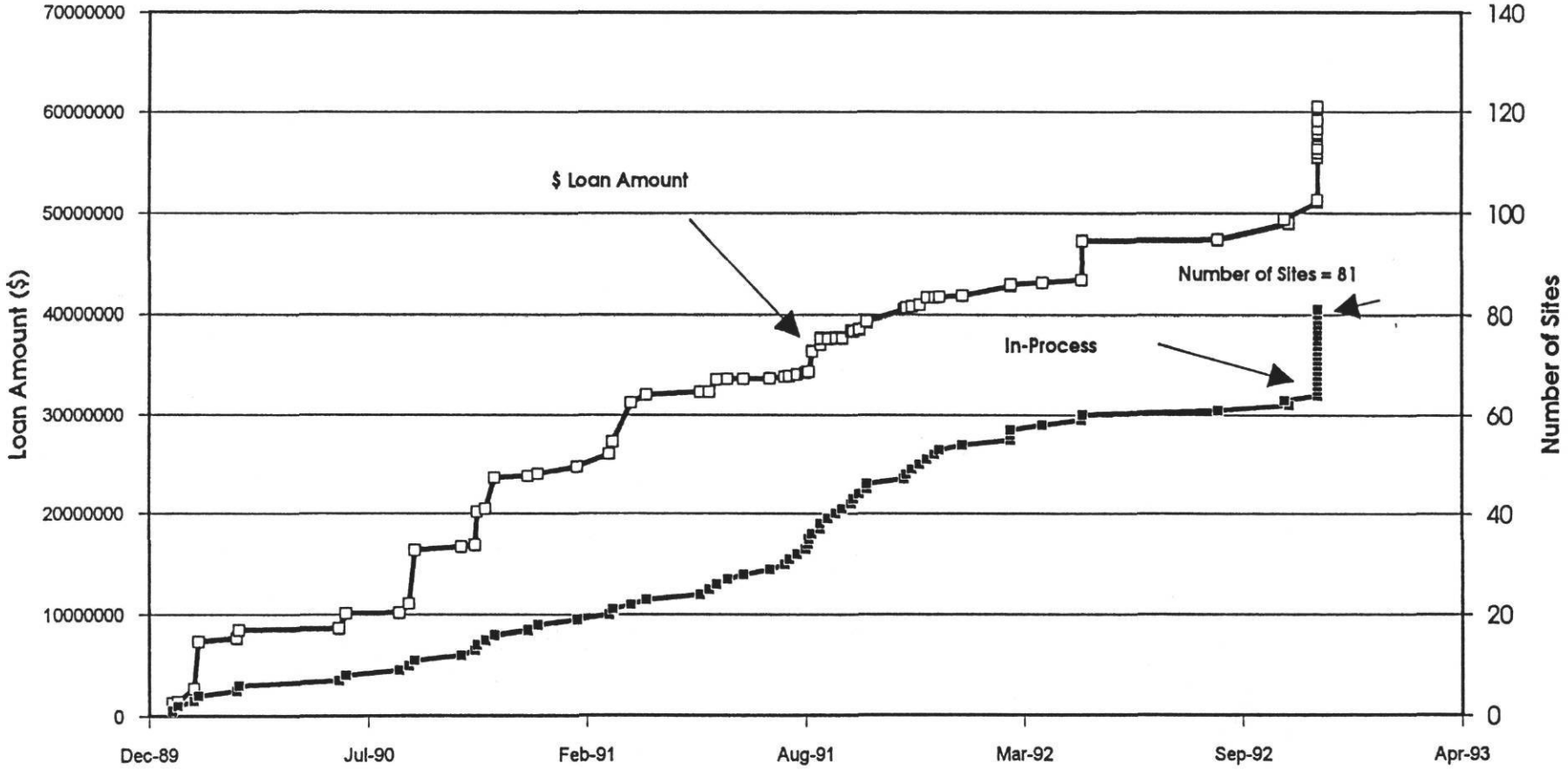
69 Sites/199 Buildings Monitored as of May 1993

Site Energy Savings: 1.45 Trillion Btu/yr

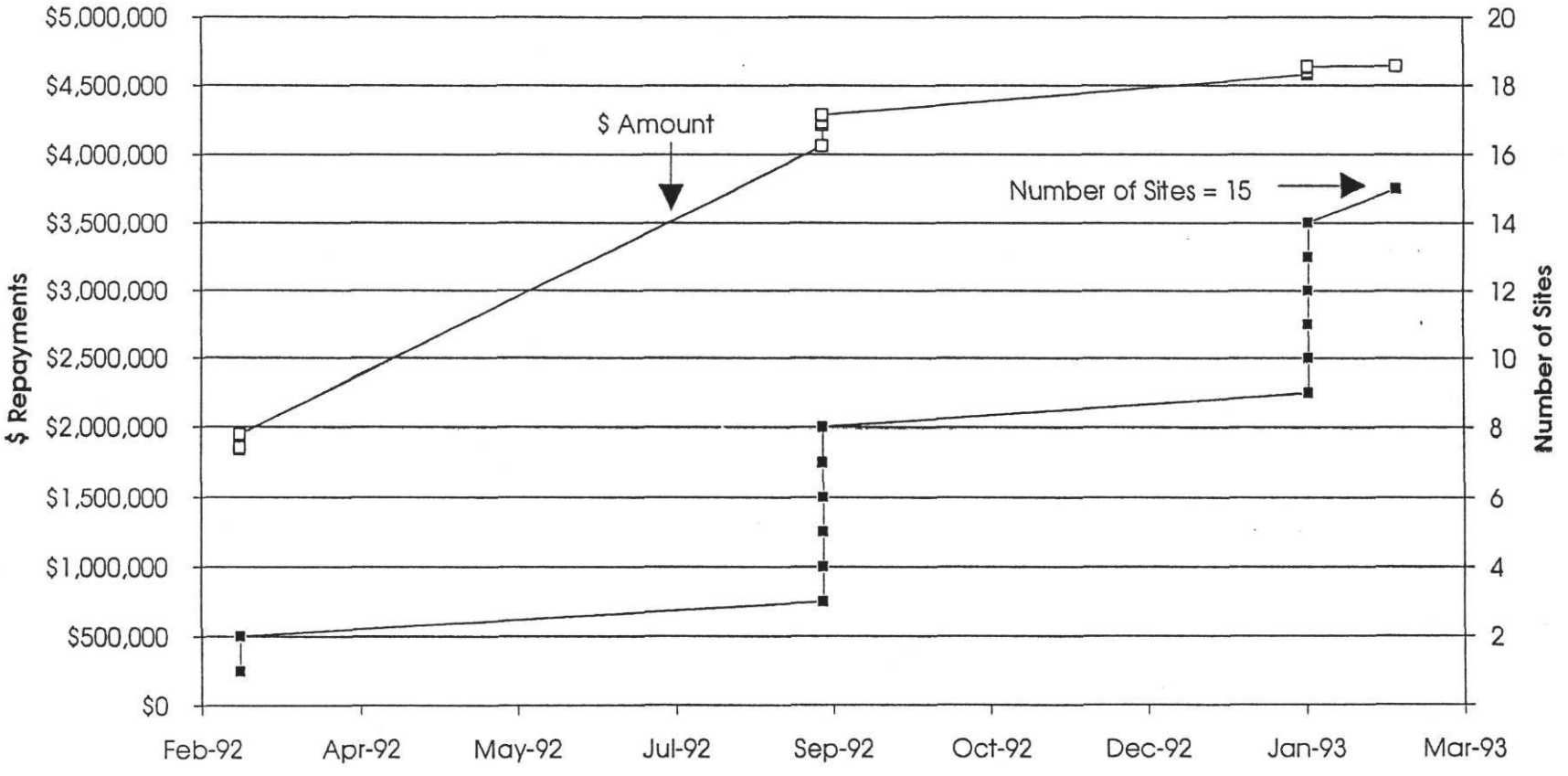


Btu savings calculated on the basis of site Btus (i.e. 3,412 Btu/kWh, 1,030,000 Btu/MCF & 12,000 Btu/ton-hr)

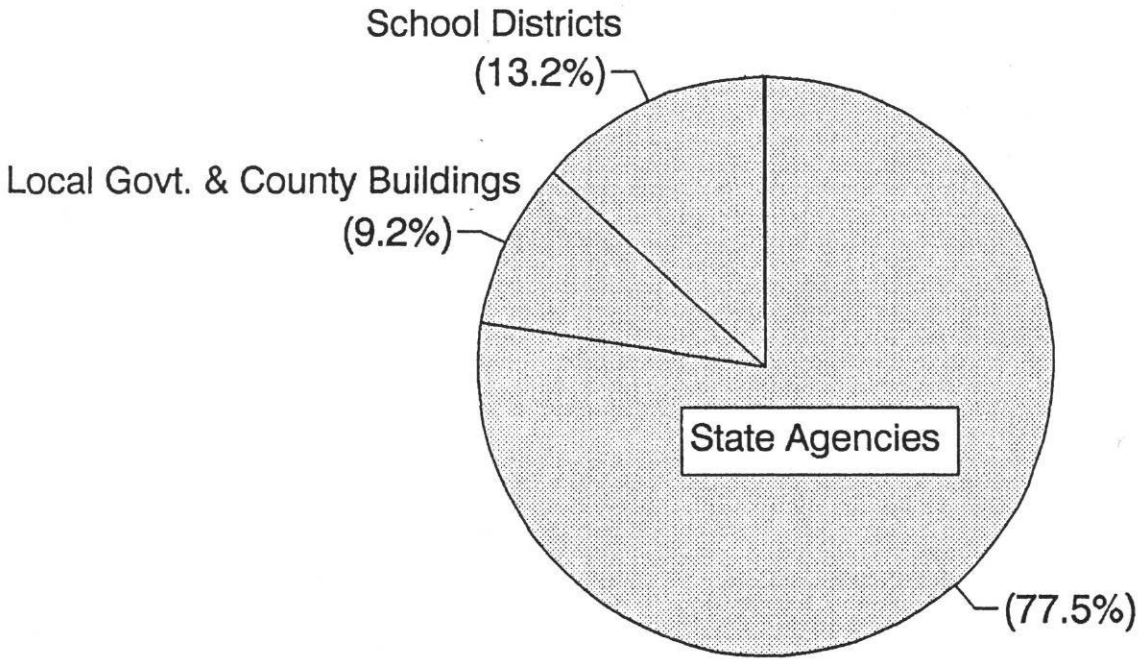
Cumulative Loan Amount Executed & In-Process as of April, 1993



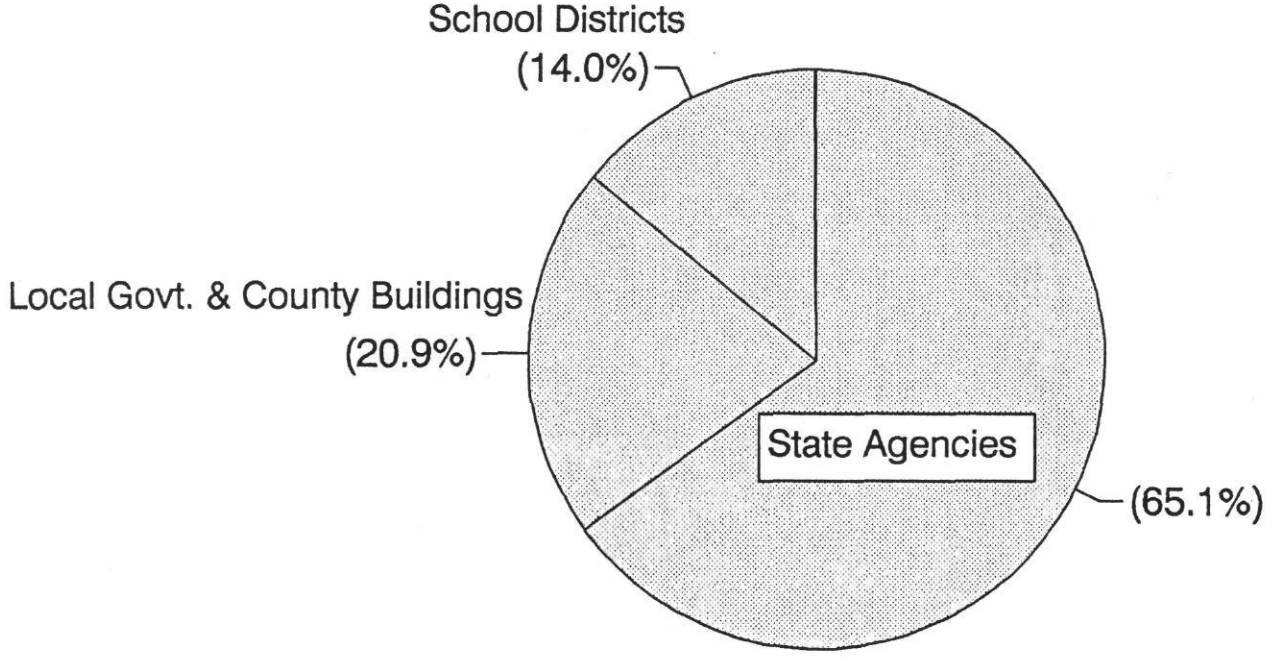
Total Cumulative Repayments of Loans as of April, 1993



LOANS EXECUTED AS OF MAY, 1993
Total Loan Amount: $49,738,000

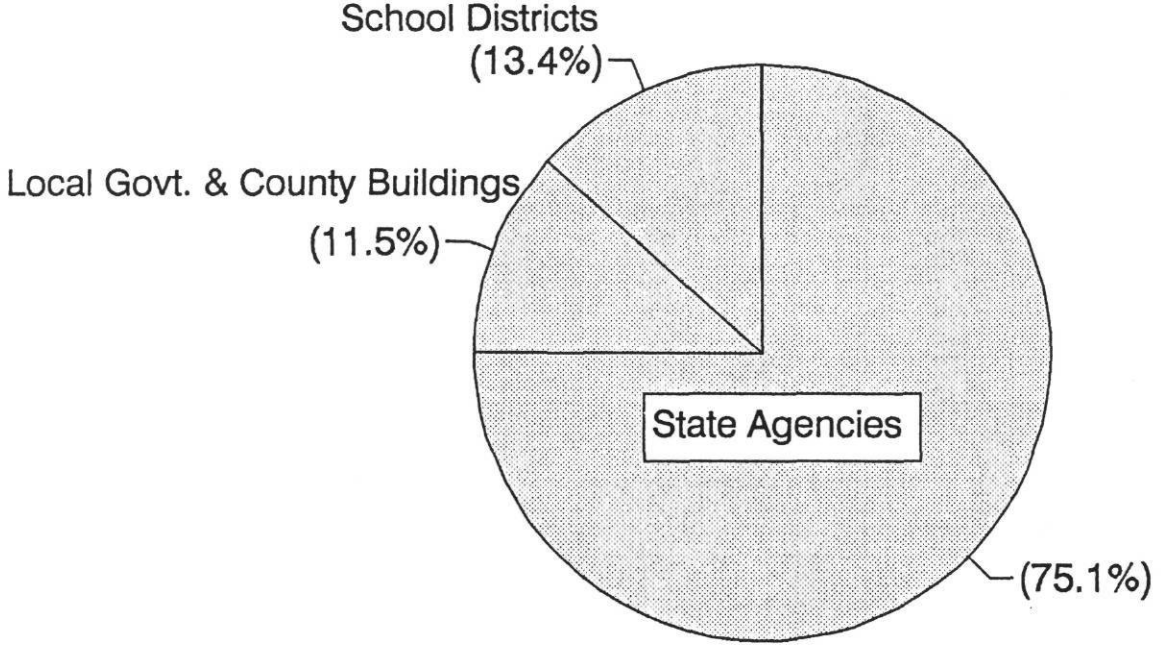


LOANS IN PROCESS AS OF MAY, 1993
Total Loan Amount: $11,840,000



LOANS EXECUTED & IN PROCESS

Total as of May, 1993: $61,578,000



LoanSTAR ENERGY AUDITING: UPDATE AND CHANGES (TASK 1)

Presented By:
Warren M. Heffington

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

June 2, 1993

- **Role of Energy Systems Laboratory (Task 1)**
  - Provide thorough review of detailed energy analysis reports
  - Provide auditor training
  - Streamline and update audit process
- **Review Personnel**
  - Three staff engineers
    (Saman, Nutter, Britton - two are P.E.s)
  - One cost estimator (Tiner - P.E.)
  - One water/wastewater specialist (Stallard)
  - Several graduate students (3/8 FTE)

- **Reports are reviewed for:**
  - Suitability of engineering recommendations
  - Compliance with audit agreements (screening report)
  - Compliance with audit guidelines
  - Compliance with audit format
  - Correctness of numbers

- **Basis for LoanSTAR loans**
  - Energy audits by private consultant engineering firms
  - Presently 27 firms under contract to EO for audits
  - About 14 are active
  - Each energy audit report shows:
    - Implementation costs - basis for amount of loan
    - Calculated annual savings - basis for payback of loan
- **Following are data and observations**
  - From completed audit reports
  - By report reviewers (also with independent audit experience)

- **LoanSTAR Audit Results**
  - 1/89 - 5/93
  - Dependent results for capital-intensive projects known as ECRMs
  - Reviewed by ESL
    - $73.1 million investment costs
    - $20.5 million annual savings
    - 3.6 year simple payback
    - 70.0 million sq. ft.
    - 111 audit reports
    - 63% of the investment cost is for state agencies
    - 37% is for local governments and school districts

- **Two Types of Reports**
  - **Simplified**
    - Category I ECRMs - limited calculation projects using historical paybacks and estimate of implementation cost.
    - Category II ECRMs - SimpCalc or other simplified calculation procedure
  - **Detailed**
    - Category III ECRM - detailed calculations and documentation required

LoanSTAR Results from Simplified and Detailed Audits (Reviewed by ESL, 1/92 - 5/93)

	Investment Cost		Annual Savings	Payback
	million $	% of Total	million $/yr	Yrs
Simplified	6.7	25	1.8	3.7
Detailed	20.0	75	4.7	4.3
Total	26.7	100	6.5	4.1

LoanSTAR Audit Results from Simplified Reports (Reviewed by non-ESL Personnel)

- $3.1 million investment cost
- 0.89 million annual savings
- 3.5 year simple payback
- 4.0 million sq. ft.
- 20 audit reports

Major LoanSTAR Funding Opportunities*

	Investment Cost		Annual Savings	Payback
	million $	% of Total	million $/yr	Yrs
TECCP (ESL)**	30.5	29	10.9	2.8
Detailed (ESL)	66.4	62	18.7	3.6
Simplified (ESL)	6.7	6	1.8	3.7
Simplified (Non-ESL)	3.1	3	0.89	3.5
Total	106.7	100	32.3	3.3

*Not complete.

**TECCP was originally $42.8 million in investment costs and $19.9 million in annual savings with 2.2 year payback.

- **LoanSTAR "Dipstick" ECRMs**
  - $250,000 investment cost
  - $120,000 annual savings
  - 2.1 year simple payback
  - Used in 4 reports
  - Types of projects
    - Energy-efficient Motors (1)
    - Incandescent to Fluorescent (2)
    - Incandescent exit lamps to 9-W Fluorescent (1)
    - Time clock shut down of HVAC equipment (1)
    - 40-W to 34-W Fluorescent (1)

- **Simplified LoanSTAR Report Problems (noted by ESL)**
  - 9 of 21 reports have major problems
  - Major problem is cost savings or implementation cost change in review of 5% or more

Report	Change in Cost Savings, %	Change in Implement-ation Cost, %	Comment
Cypress-Fairbanks ISD	-35	+17	
Dallas ISD			no lighting data
Mesquite ISD		+60*	Other major problems
County of El Paso	-6	-14	
City of New Braunfels		+7	
Nolan County	+40		
SWCID			OK (17.4 year payback project required some discussion)
Mercedes ISD	+35	-5	not sealed
Howard County	-7	-28	
Matagorda County	-10	-25	not sealed

*The displayed investment costs changed by 60%. The actual investment cost in the first version was obscured by poor communication and unacceptable reporting practices.

TASK A

BUILDING MONITORING ON THE LoanSTAR PROJECT: AGENCY UPDATE

Dennis O'Neal
Chuck Bohmer
John Bryant
Curtis Boecker

Monitoring Analysis and Review Committee Meeting
June 2-3, 1993
Austin, Texas

FUNCTIONS OF TASK A

- Determine metering requirements at each site
- Oversee installation of equipment
- Maintain monitoring equipment

UPDATE SINCE LAST MARC MEETING

- 15 new buildings on line
- Maintenance is still an important part of Task A
    - Flow Meters
    - Data Loggers
    - Electrical Components
    - Pressure Transducers

UPDATE (CONTINUED)

- Equipment database expanded
- Continued integration with Task B in the Calibration Laboratory
    - Calibration of all existing flow research flow meters during summer 1992
    - Recalibration of RH transducers
    - Calibration of new flow meters for new installations

SITES COMPLETED SINCE MAY 1992

SITE	# BLDGS	# POINTS
• **NACOGDOCHES ISD**	2	16
• **GALVESTON ISD**	5	30
• **UT AUSTIN**	3	28
• **CAPITOL COMPLEX CHW METERING**	5	10

POST RETROFIT ADDITIONS

SITE	# BLDGS	# POINTS
• GALVESTON ISD	5	5
• UT PAN AMERICAN	1	2
• TSTC HARLINGEN	1	6
• DELMAR COLLEGE	1	10
• NACOGDOCHES ISD	1	1
• UT MEDICAL BRANCH GALVESTON	5	5
• UT AUSTIN	1	4
• TEXAS DEPT. OF HEALTH	1	1

SITES UNDER CONSTRUCTION

SITE	# BLDGS	# POINTS
• UT ARLINGTON	8	40
• CAPITOL BUILDING CAPITOL EXTENSION	2	11

NEW SITES THAT MAY SOON START CONSTRUCTION

SITE	# BLDGS
• TEXAS A&M/COLLEGE STATION	3
• TEXAS WOMAN'S UNIVERSITY	4
• EL PASO COMMUNITY COLLEGE	3

MANY EQUIPMENT PROBLEMS HAVE BEEN RESOLVED

TYPE OF EQUIPMENT	# INSTALLED	TOTAL # OF PROBLEMS	# OF PROBLEMS LAST YEAR	# PROBLEMS FIXED
INSERTION FLOWMETERS	55	20	6	20
PRESSURE TRANSDUCERS	7	5	1	4
BTU METERS	52	9	6	8
CTs	1700+	3	0	3
DATA LOGGERS	72	13	8	13
MODEMS	60	5	3	5
HUMIDITY SENSORS	12	3	1	3
GAS METERS	30	5	2	5
CONDENSATE METERS	30	5	2	5
PHONE LINES	60	20	10	20
WEATHER STATIONS	6	10	4	8

TYPICAL METERING PROBLEMS

- Phone lines down during bad weather
- Gas company meters non-functional (poor response time for repairs - up to 3 months)
- Retrofit contractors damage or disable metering equipment
- Electronic metering components fail (data loggers, Btu meters, communications boards)
- Signal wires broken by contractors
- Physical failure of equipment

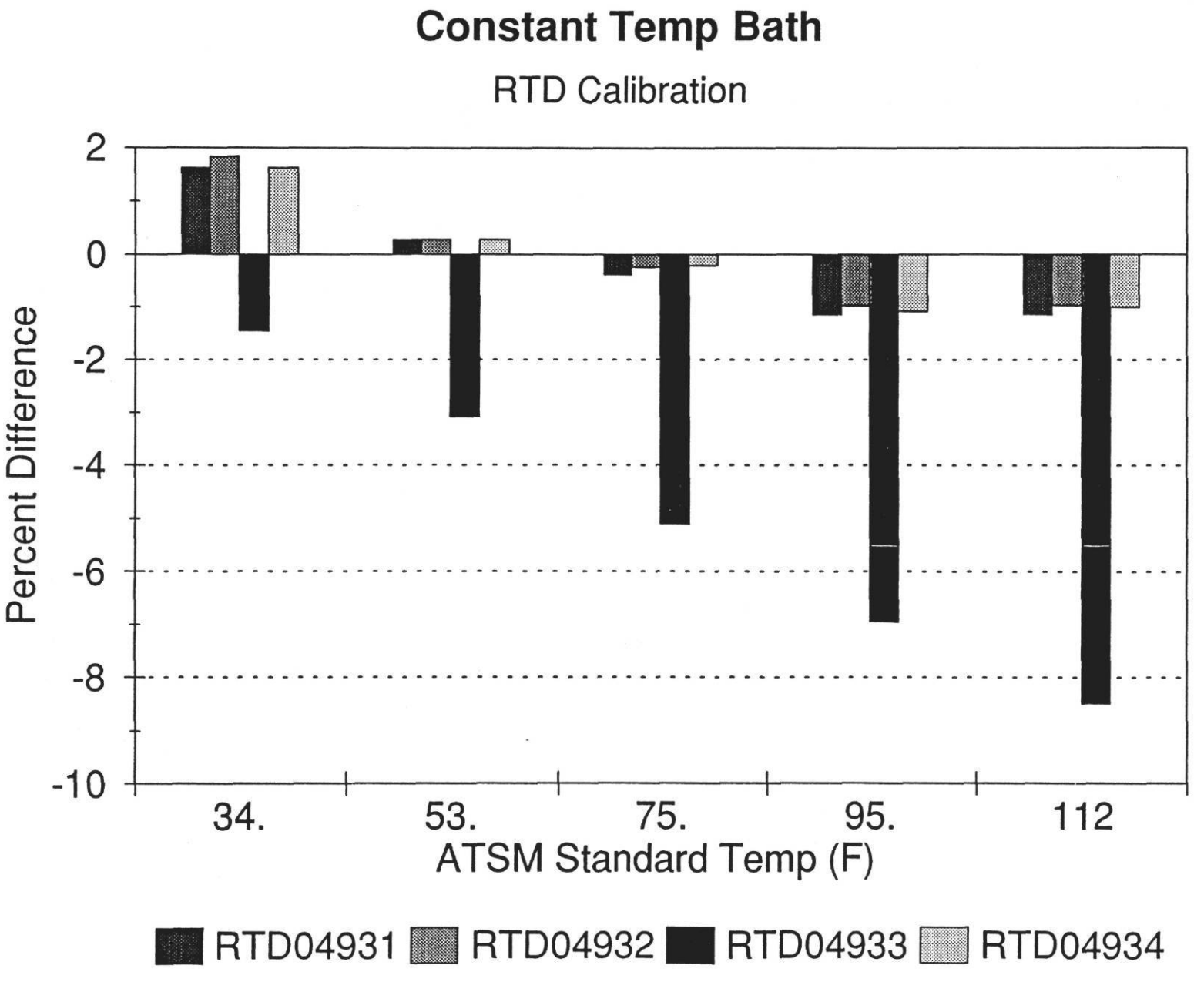
TASK B

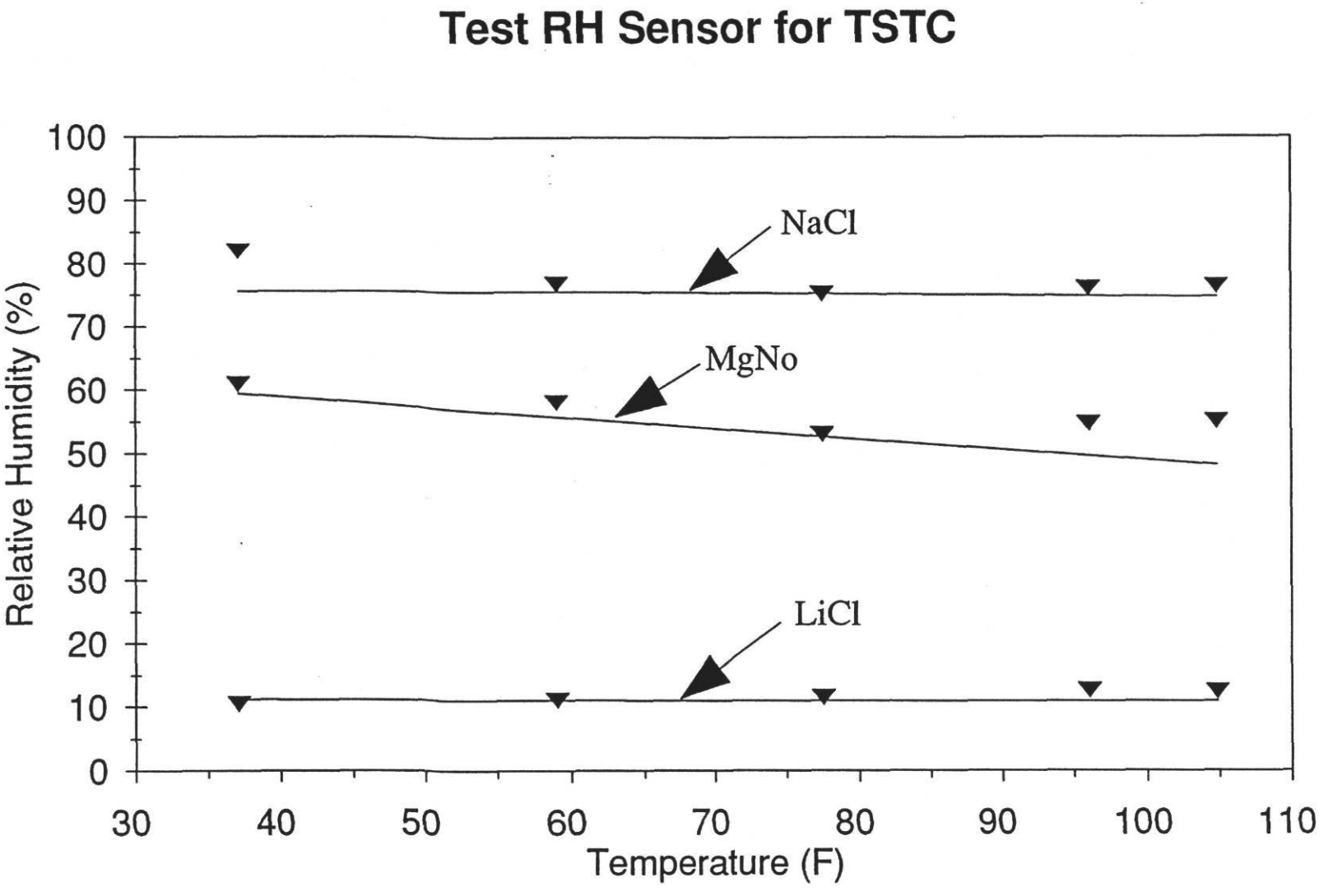
CALIBRATION LABORATORY

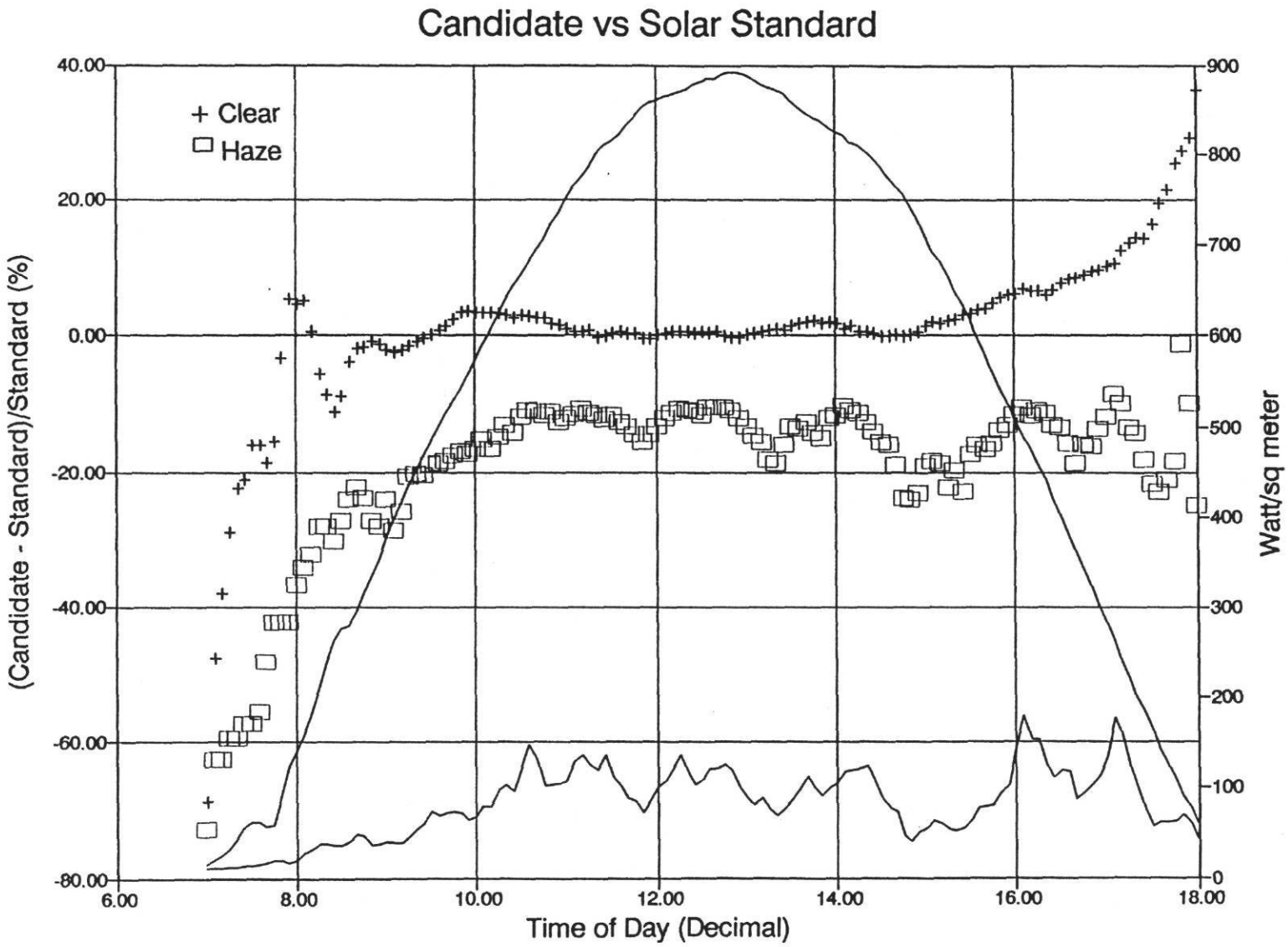
Dan Turner, P. I.
Dennis O'Neal
Jeff Haberl
Chuck Bohmer
John Bryant
Kelly Milligan
Jay Robinson

CALIBRATION LABORATORY SUPPORT ACTIVITIES

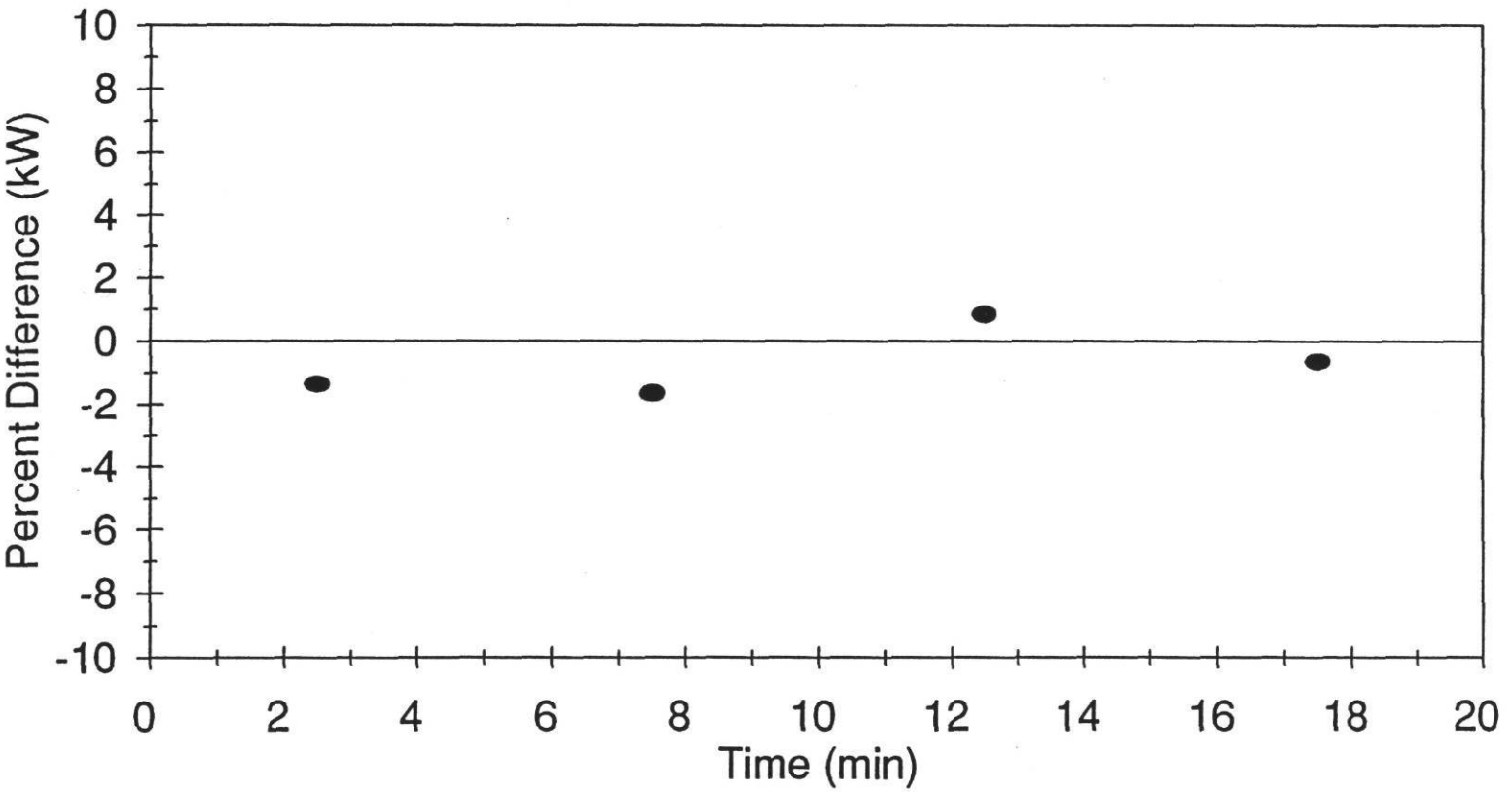
- CALIBRATION OF SENSORS (Temperature and Relative Humidity) FOR WEATHER STATIONS IN TEMP-HUMIDITY CHAMBER
- CALIBRATION OF SOLAR RADIATION SENSOR FOR WEATHER STATIONS
- TESTING AND VERIFICATION OF ACCURACY OF NEW C180-E LOGGER VS. C180-A1 LOGGER
- SENT EPPLEY PSP's AND PYRHELIOMETER TO EPPLEY FOR RECALIBRATION
- PURCHASED PORTABLE CALIBRATION INSTRUMENTATION FOR FIELD CHECKS AND USE AT LAB
- IN-HOUSE REPAIR OF DK BTU METERS AND SYNERGISTICS DAS MOTHER BOARDS
- PROVIDED VALUABLE FIELD STAFF SUPPORT TO TASK A


Constant Temp Bath
RTD Calibration
Percent Difference
2
0
-2
-4
-6
-8
-10
34.
53.
75.
95.
112
ATSM Standard Temp (F)
RTD04931
RTD04932
RTD04933
RTD04934


Test RH Sensor for TSTC
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
NaCl
MgNo
LiCl
30
40
50
60
70
80
90
100
110
Temperature (F)


Candidate vs Solar Standard
+ Clear
Haze
(Candidate - Standard)/Standard (%)
Watt/sq meter
Time of Day (Decimal)
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
900
800
700
600
500
400
300
200
100
0
6.00
8.00
10.00
12.00
14.00
16.00
18.00

Accuracy of MagnaLab CT's tested with Ohio Semitronics Precision Watt Xducer



1993 MARC MEETING UPDATE ON THE FLOW LOOP

- The orifice plates were tested and performed to within
  ±2% of the Load Cells. This gave confirmation to the previous tests and gave an adequate secondary standard.

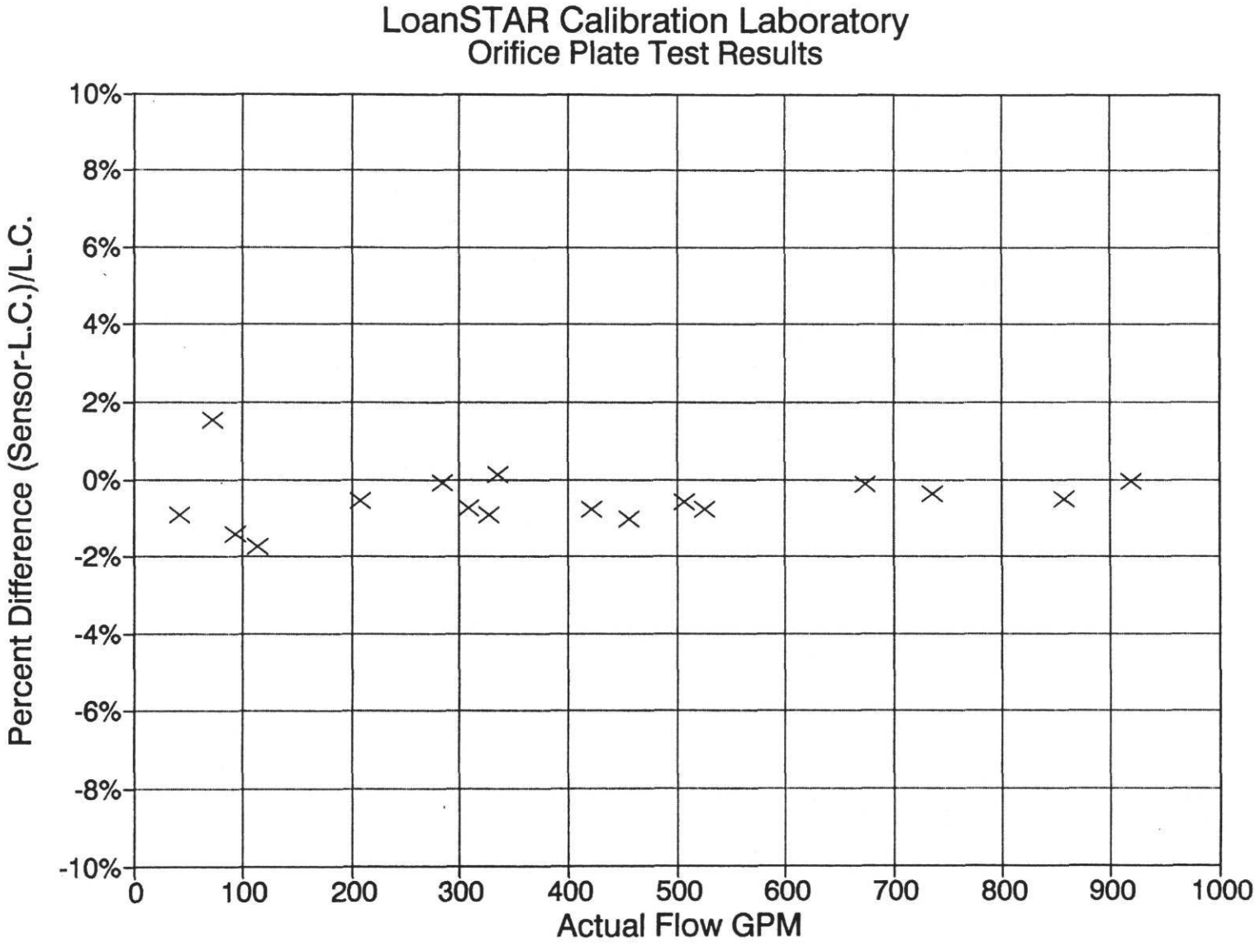
- Flow Research and Data Industrial meters were tested in the 10" test section.

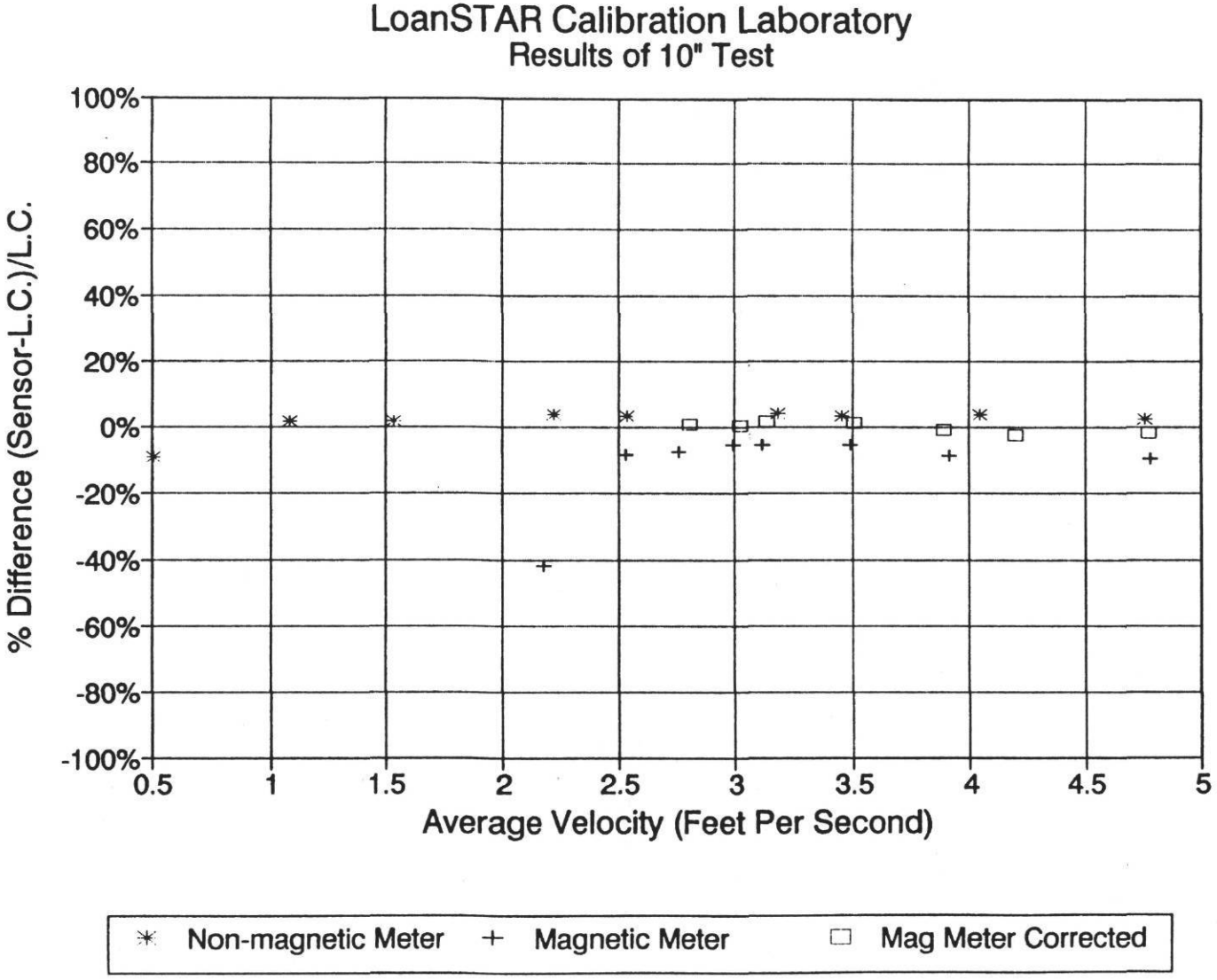
  – The DI was accurate to ±3%.

  – The FR was 7% low.

  – FR tests run with a corrected pulse per gallon (PPG) factor were within ±3%.

  – The EMCO (axial turbine) meter was accurate to ±3% of the flow rate.


LoanSTAR Calibration Laboratory
Orifice Plate Test Results
Percent Difference (Sensor-L.C.)/L.C.
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
0
100
200
300
400
500
600
700
800
900
1000
Actual Flow GPM


LoanSTAR Calibration Laboratory
Results of 10" Test
% Difference (Sensor-L.C.)/L.C.
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Average Velocity (Feet Per Second)
Non-magnetic Meter
Magnetic Meter
Mag Meter Corrected

- The 4" test section was constructed:

  - The Flow Research was tested at two different insertion depths 0.5" and 1.5"

  - At 0.5" ID, the meters recorded 28% low

  - At 1.5" ID the meters recorded ±4%

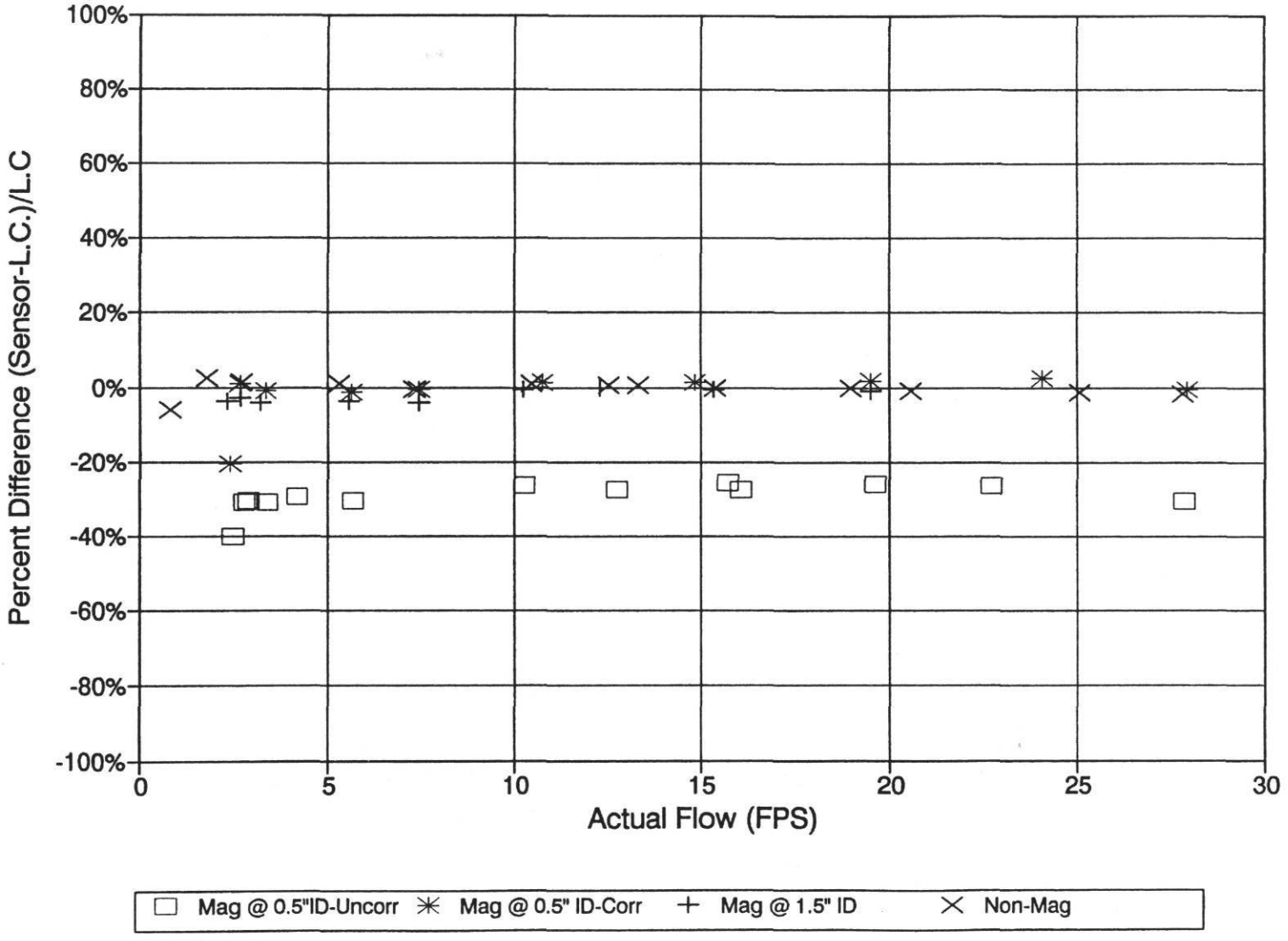
  - The DI recorded ±3% of the flow rate

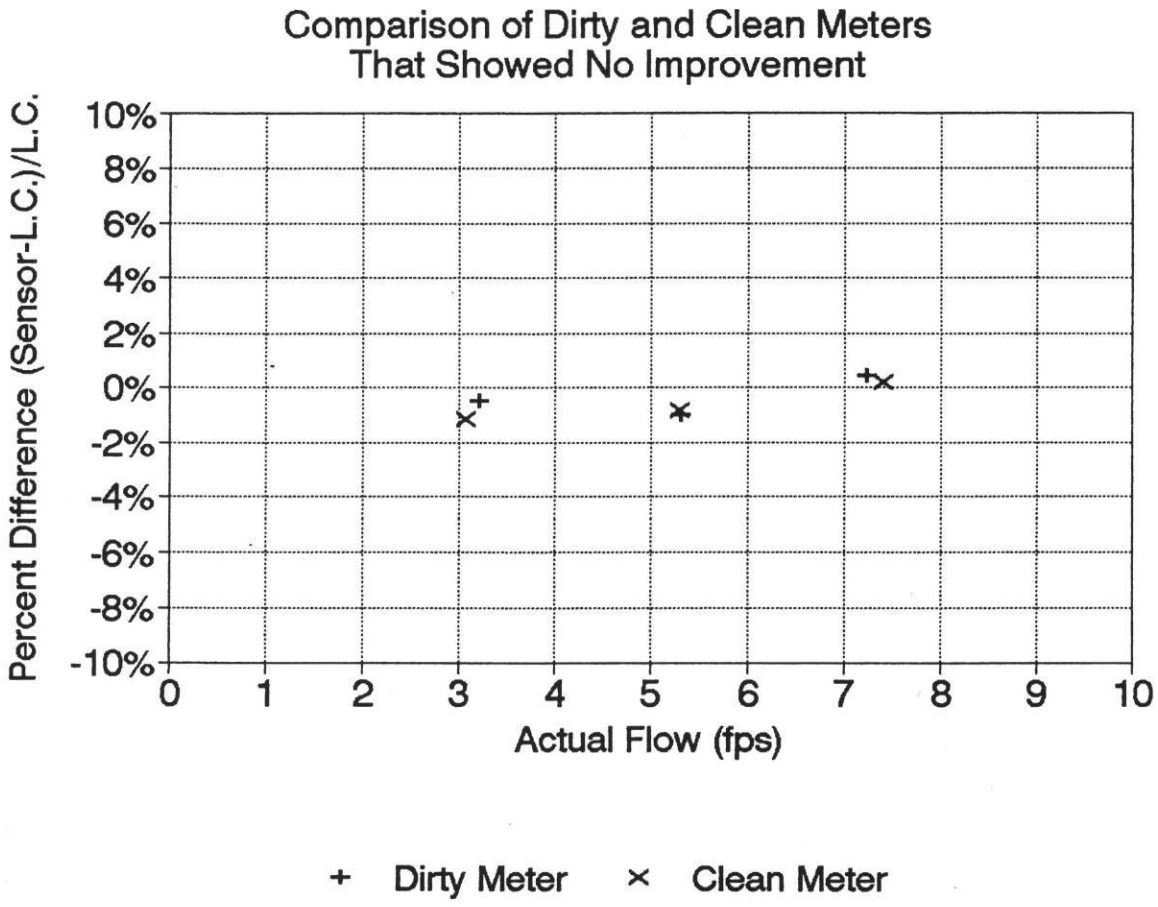
- Beginning at the end of last Summer and carrying into the Fall, meters were pulled from the field and "post-calibrated"

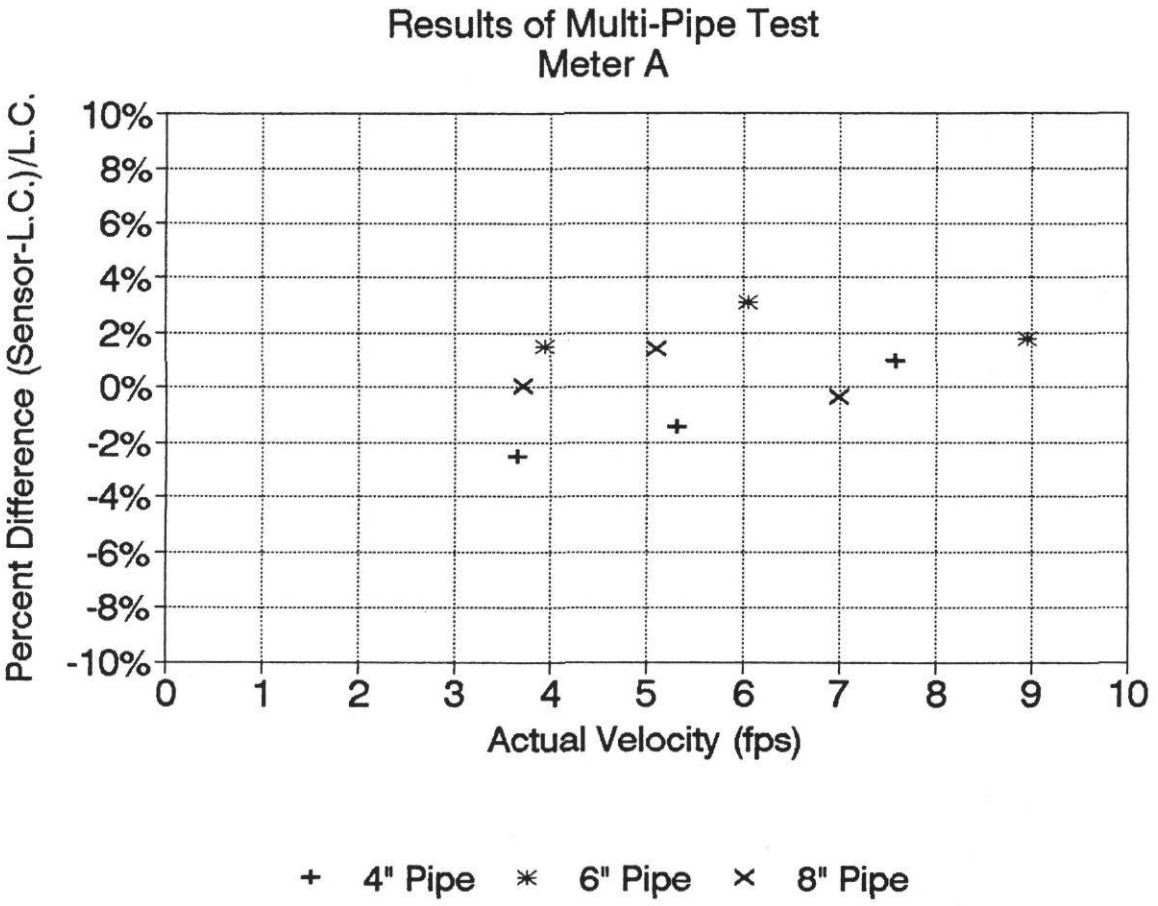
  - Results showed little degradation in meter performance due to field use.

  - It was determined that tests run in 4" pipe would translate to larger pipe sizes. This speeds up the testing process.

LoanSTAR Calibration Laboratory
4" Test Results




Comparison of Dirty and Clean Meters
That Showed No Improvement
Percent Difference (Sensor-L.C.)/L.C.
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
0
1
2
3
4
5
6
7
8
9
10
Actual Flow (fps)
+ Dirty Meter
× Clean Meter


Results of Multi-Pipe Test
Meter A
Percent Difference (Sensor-L.C.)/L.C.
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
0
1
2
3
4
5
6
7
8
9
10
Actual Velocity (fps)
+ 4" Pipe
* 6" Pipe
× 8" Pipe

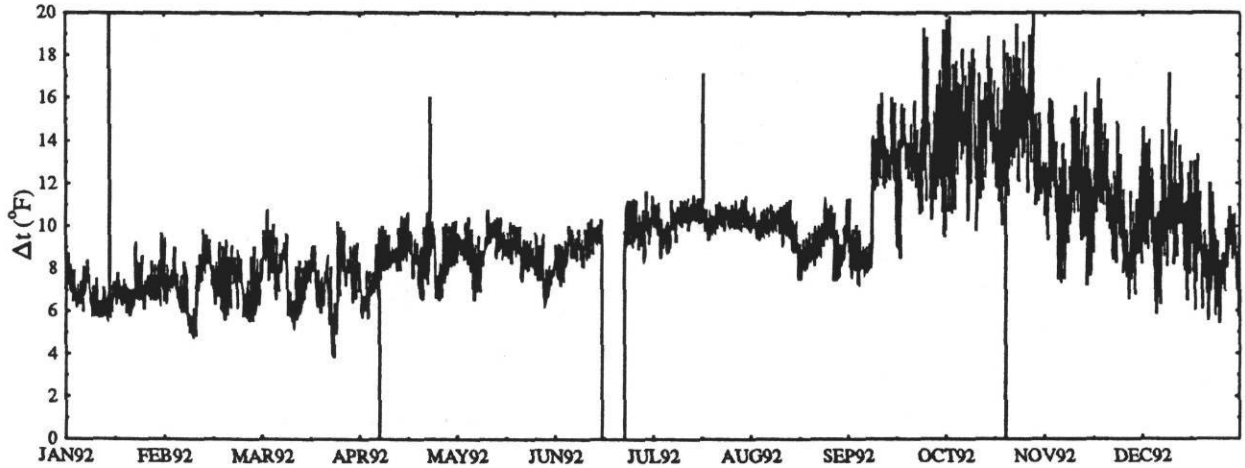
Conclusions

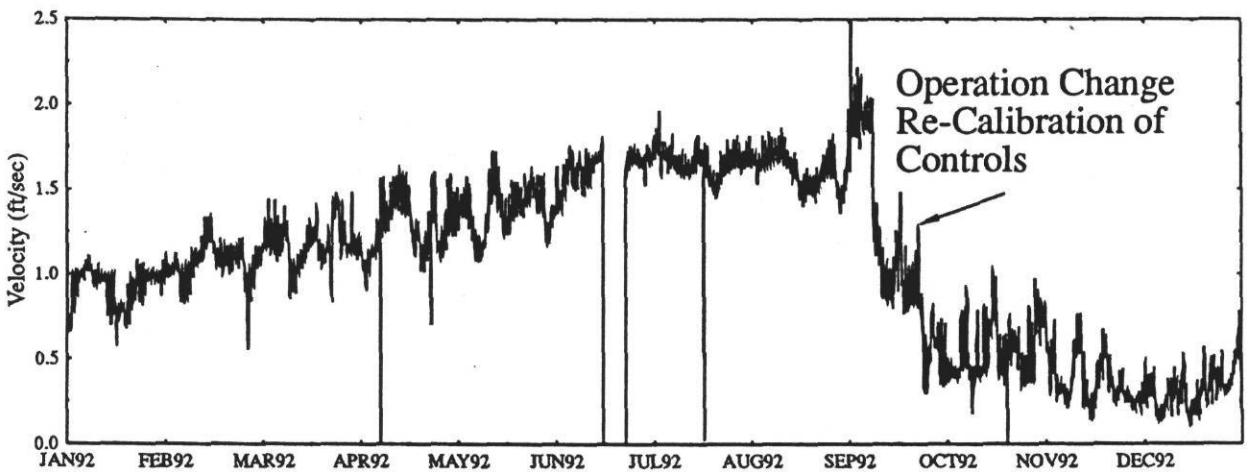
1. After two years of use, the meters perform nearly as well as a new meter.

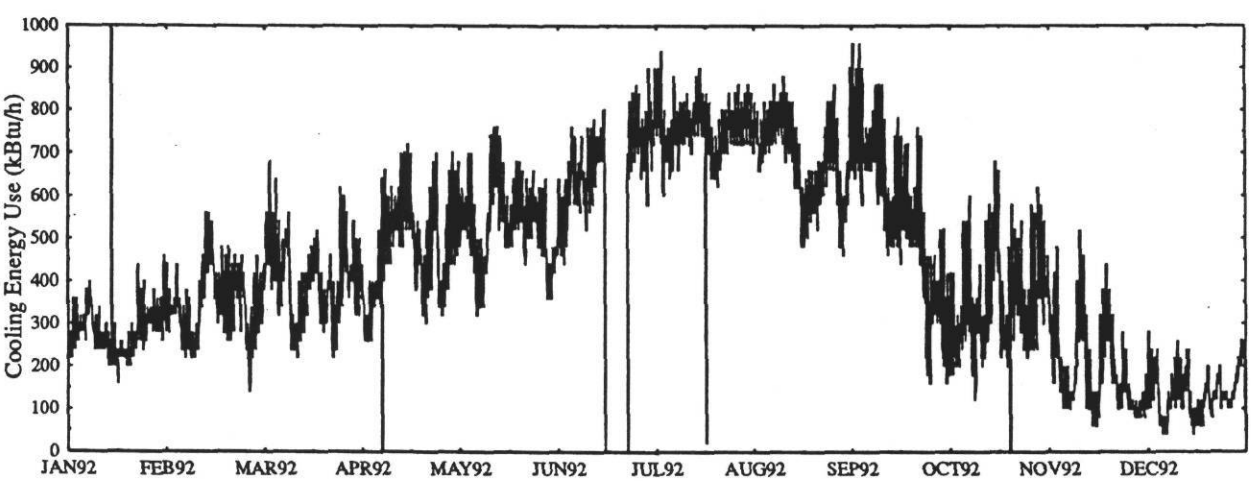
2. Testing and Re-calibration can be performed in 4" pipe and the results extended to larger pipe sizes.

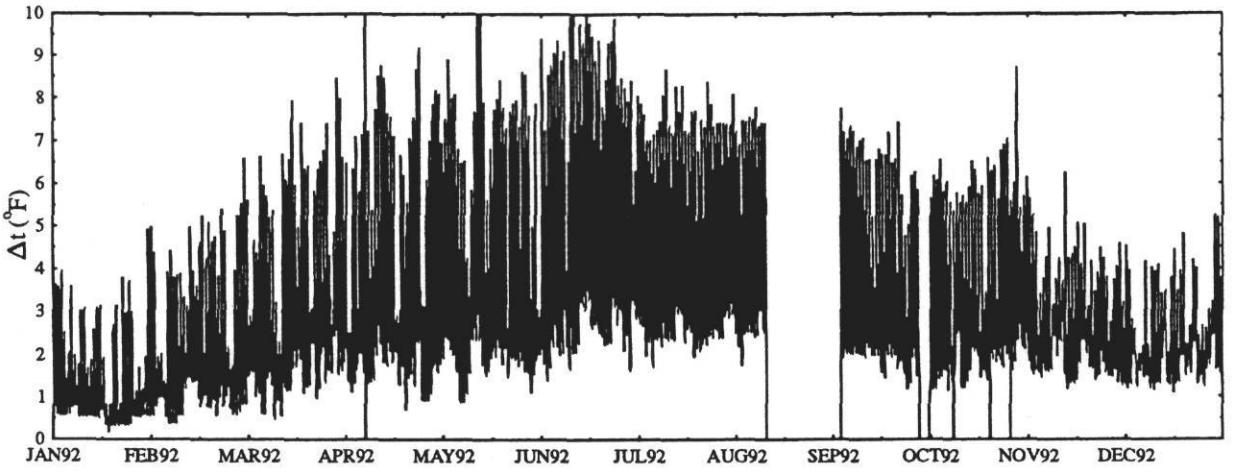
3. Buildup of scale does not dramatically affect meter performance.

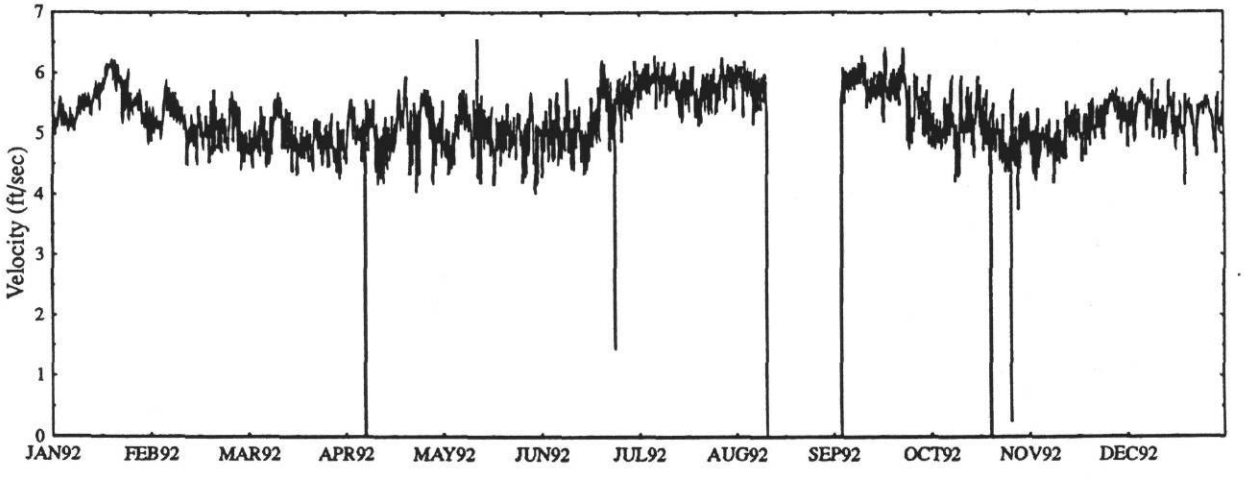
- The load cells were re-calibrated by the Department of Agriculture.
    - On average, the load cells were off by less than 0.5% of a given reading.
    - The actual error was a maximum of 15 pounds per 4000 pound increment or 0.375%.
- Final Corrections were made to the existing data based on flow calibration results from the lab. Sample curves are included which show the results of the corrections applied.

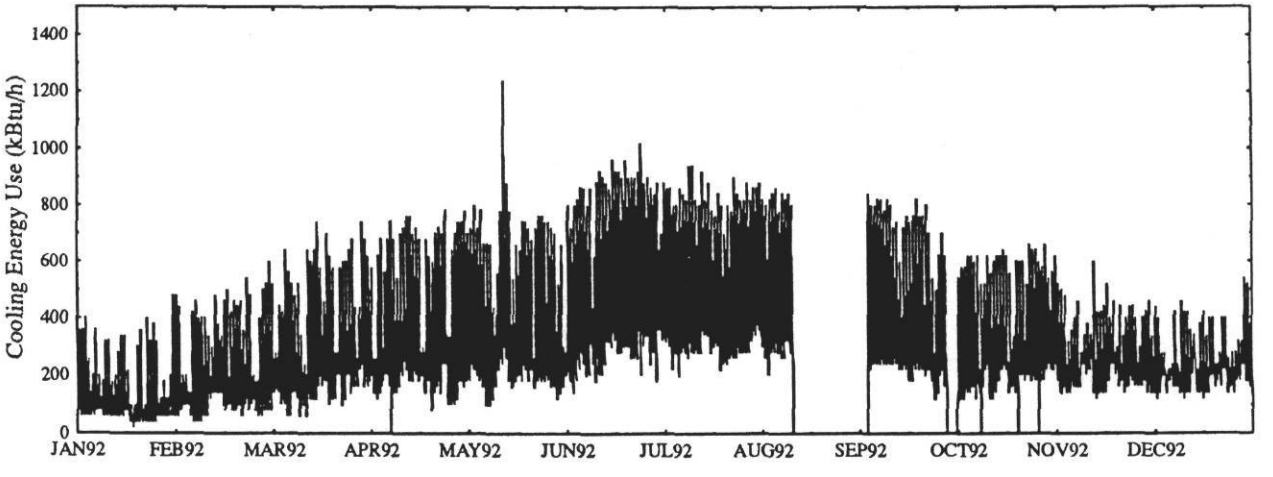

Δt (°F)
0
2
4
6
8
10
12
14
16
18
20
JAN92
FEB92
MAR92
APR92
MAY92
JUN92
JUL92
AUG92
SEP92
OCT92
NOV92
DEC92


Velocity (ft/sec)
0.0
0.5
1.0
1.5
2.0
2.5
Operation Change
Re-Calibration of
Controls
JAN92
FEB92
MAR92
APR92
MAY92
JUN92
JUL92
AUG92
SEP92
OCT92
NOV92
DEC92

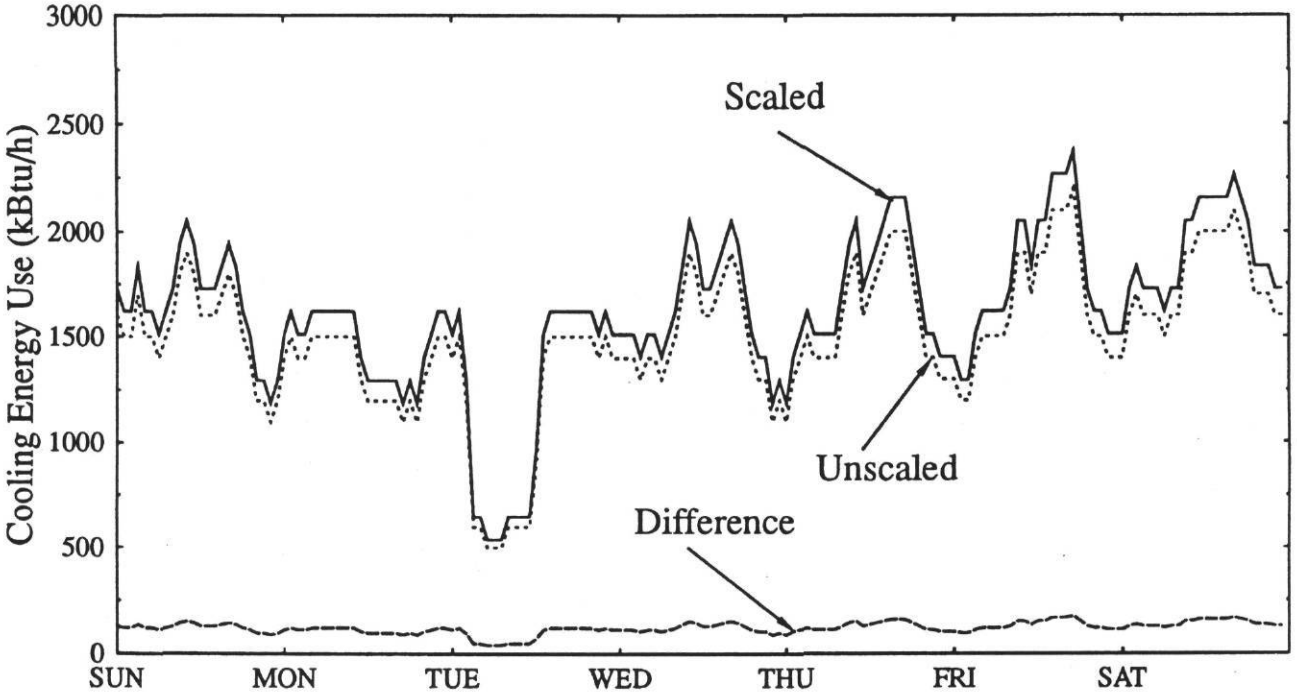

Cooling Energy Use (kBtu/h)
0
100
200
300
400
500
600
700
800
900
1000
JAN92
FEB92
MAR92
APR92
MAY92
JUN92
JUL92
AUG92
SEP92
OCT92
NOV92
DEC92


Δt (°F)
0
1
2
3
4
5
6
7
8
9
10
JAN92
FEB92
MAR92
APR92
MAY92
JUN92
JUL92
AUG92
SEP92
OCT92
NOV92
DEC92

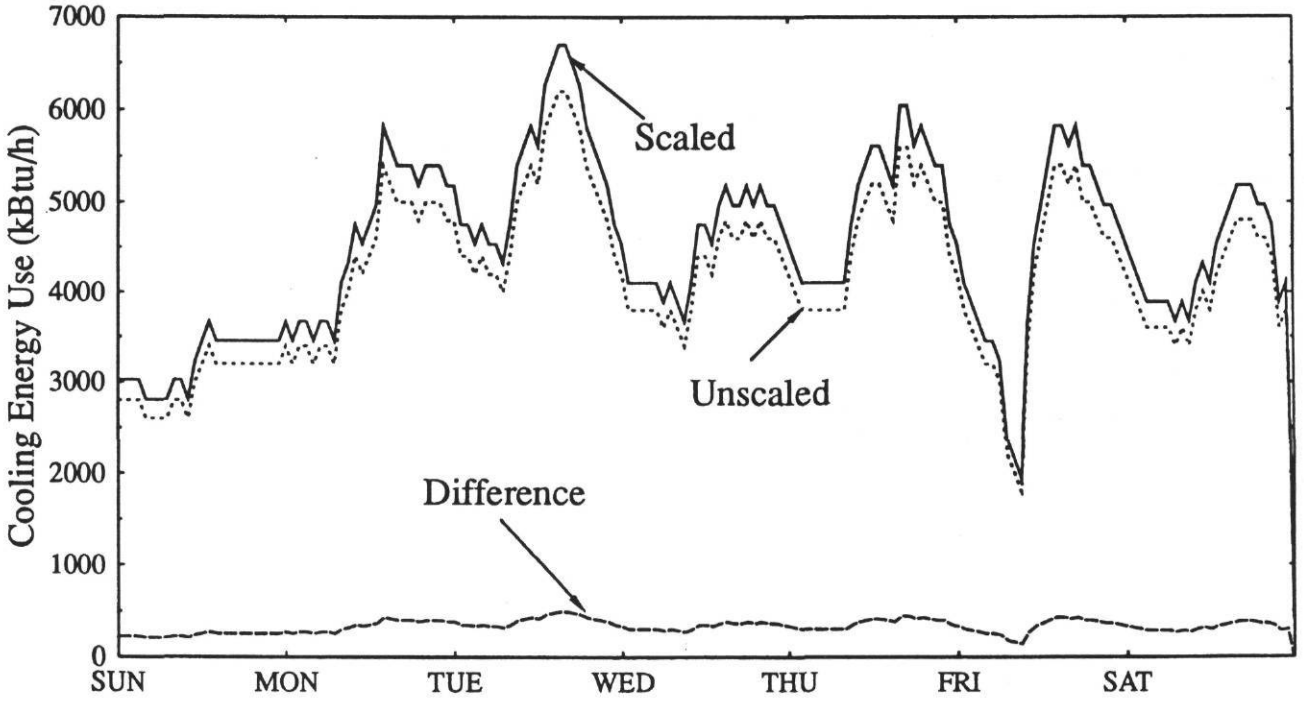

Velocity (ft/sec)
0
1
2
3
4
5
6
7
JAN92
FEB92
MAR92
APR92
MAY92
JUN92
JUL92
AUG92
SEP92
OCT92
NOV92
DEC92


Cooling Energy Use (kBtu/h)
0
200
400
600
800
1000
1200
1400
JAN92
FEB92
MAR92
APR92
MAY92
JUN92
JUL92
AUG92
SEP92
OCT92
NOV92
DEC92

8" Pipe Diameter



10" Pipe Diameter



TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK C DATA HANDLING AND RETRIEVAL

ACCOMPLISHMENTS

Jeff S. Haberl, P.I.
Robert Sparks
Dean Willis
Ron Chambers

June 1993

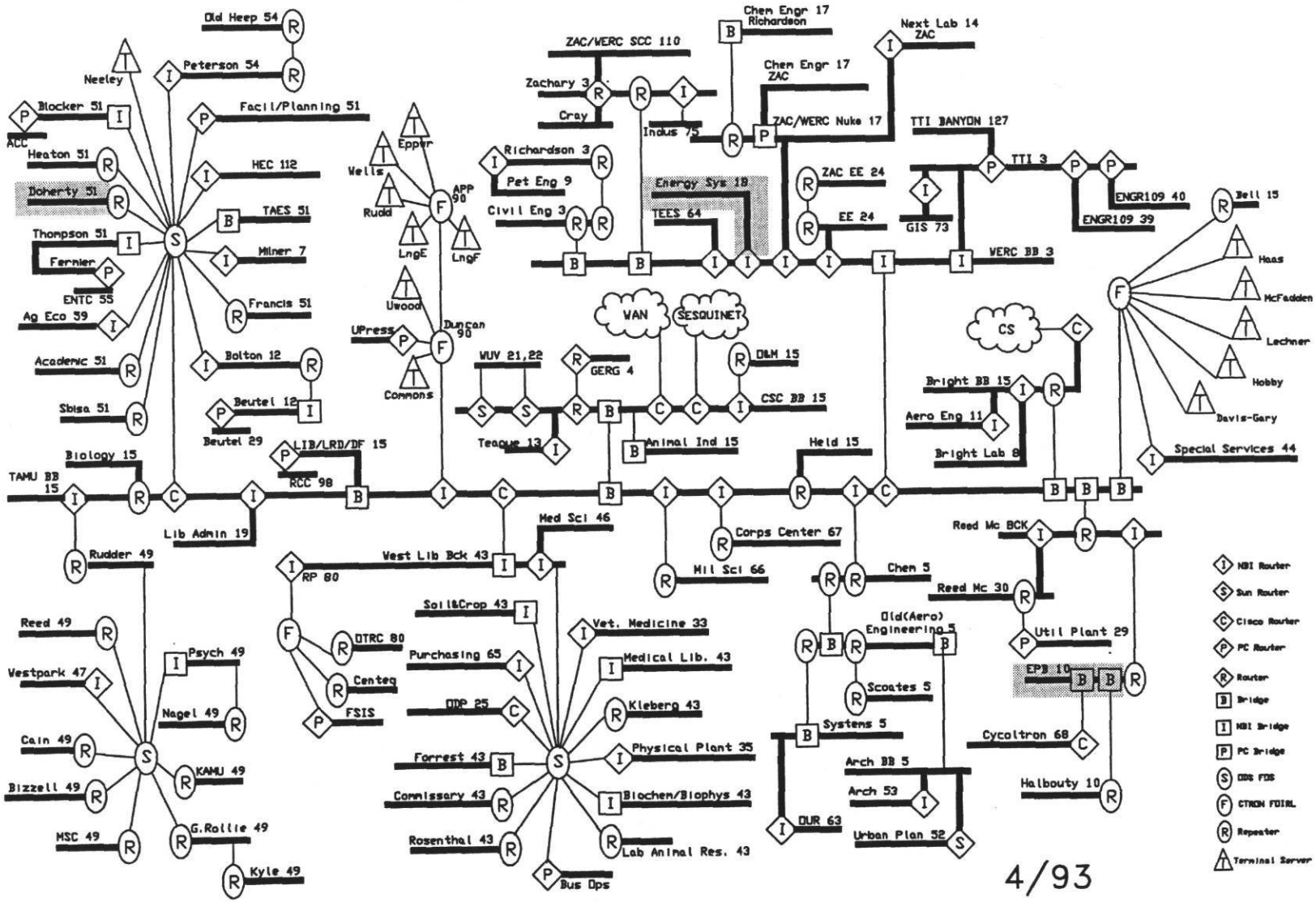
TASK C - RESPONSIBILITIES

- MAINTAIN AND EXPAND THE STATEWIDE NETWORK AND COMPUTER DATA BASE.

- RETRIEVE AND HANDLE OVER 3.0 MBYTES OF DATA PER WEEK AND INTERFACE BETWEEN DIFFERENT LOGGERS, AND COMPUTER SYSTEMS.

- STORE VERIFY AND EVALUATE DATA COLLECTED.

TAMU Logical Ethernet Backbone



Network Regions Used Heavily by LoanSTAR

Energy Systems Lab Computers

Servers:

UNIX Server

Data General Aviion AV-4020 RISC Multiprocessor
64 MB RAM
3.5 GB Disk

NetWare Server

ALR Business VEISA 386-33
16 MB RAM
1.5 GB Disk
EISA Bus-Master SCSI I/O controller

Floating License Server

Generic 80386SX-20
4 MB RAM
40 MB Disk

Other:

Location	PC-WS	UNIX-WS	X-TERMINAL	Printers
052 WERC	2			1
053 WERC	13	2	1	6
056 WERC	5		2	3
074 WERC	2			1
076 WERC	8	1		2
205 Doherty	8			1
EPB	7			7
Riverside	11			4
Portable	8			1
Total	64	3	3	26

TASK C - ACCOMPLISHMENTS

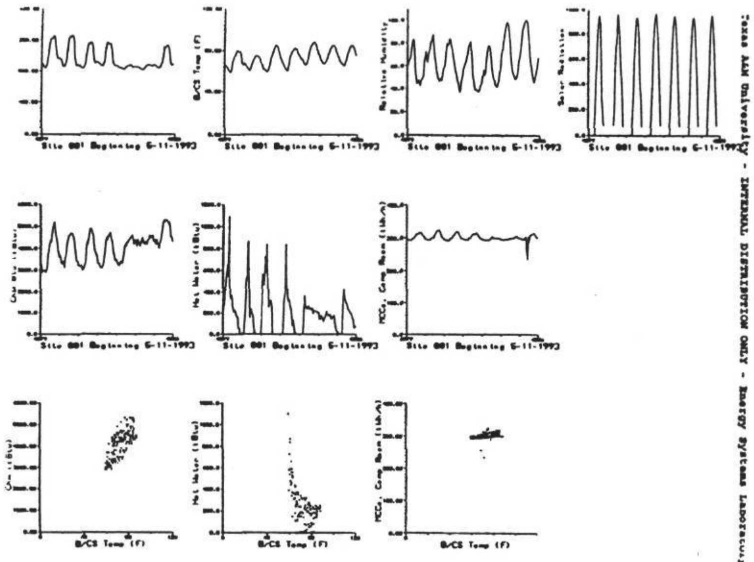
RETRIEVE AND ANALYZE OVER 3.0 MBYTES OF DATA PER WEEK.

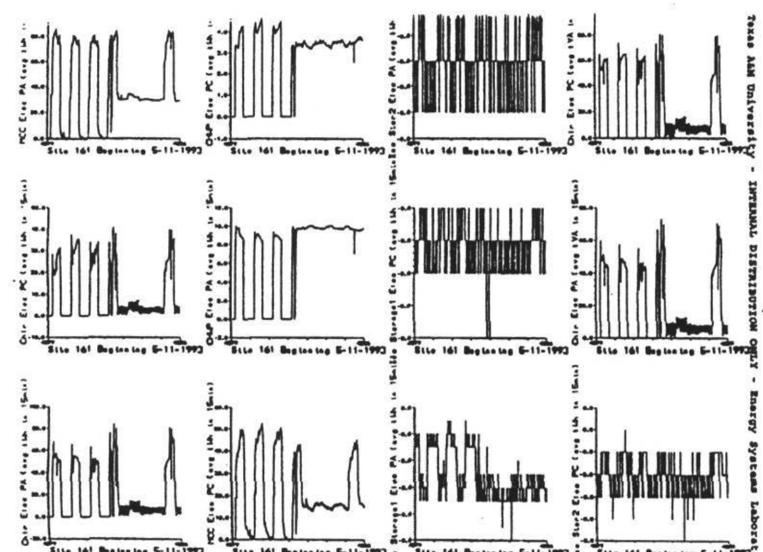
- Develop and use public domain POLLC180 software for polling Synergistics loggers.
- Collect and process 15-minute data from Synergistics loggers at GISD thermal storage sites.
- Enhance polling routines with additional Q.C. routines (power outage, check logger clock, analog calib check).
- Develop automated daylight savings reset and time shift routines.
- Expand EMCS feasibility study to include the Teletrol system at the State Capitol. Final report updated 3/93.
- Power factor software developed for calculating PF from KVA-KWH Synergistics data.

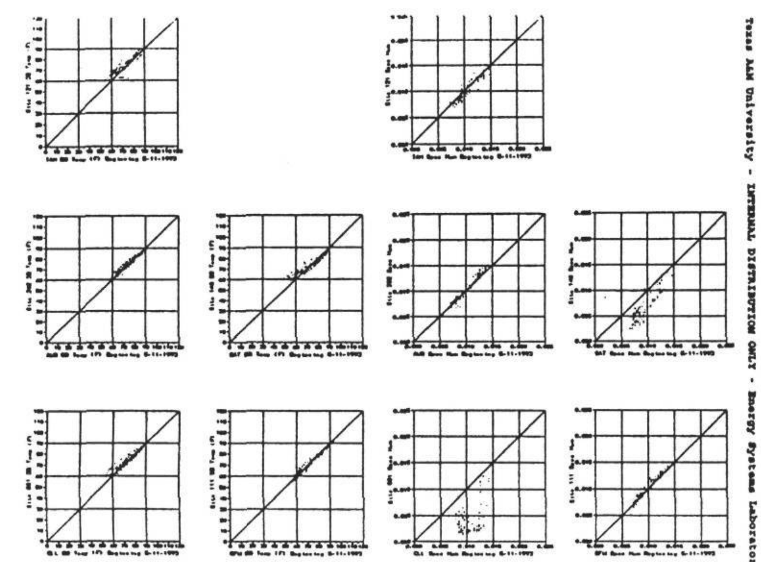
TASK C - ACCOMPLISHMENTS

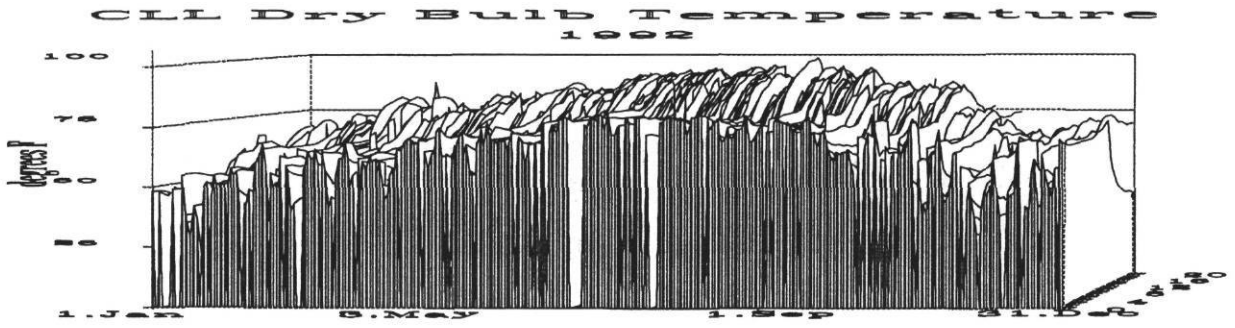
CURRENT Q.C. PROCEDURES:

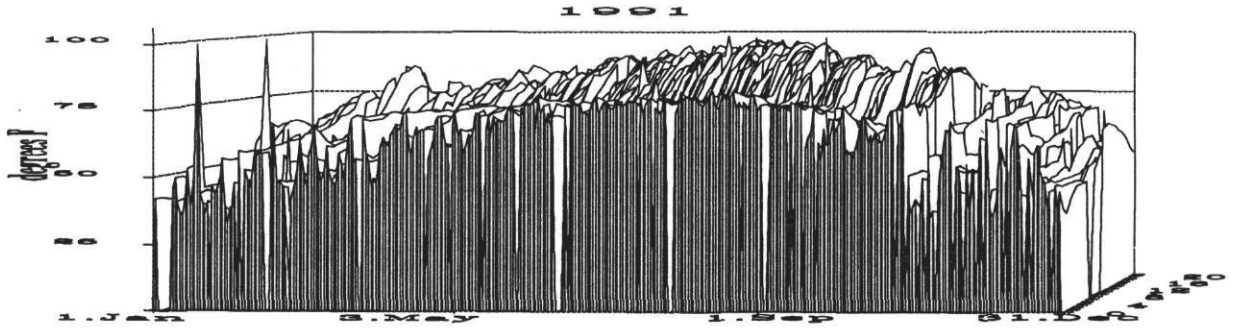
- Date, site and time stamp for each record retrieved.
- Analog calibration check and power outages checked using POLLC180.
- High/low limits checked using ARCHIVE.
- Missing data inserted with MISSING.
- Hardcopy IPNs reviewed by LoanSTAR staff.
- Weather channels cross checked with nearby N.W.S. Aviation Weather Observations.
- Database indices developed for checking long-term trends.
- Advanced data displays prototyped for improving Q.C.

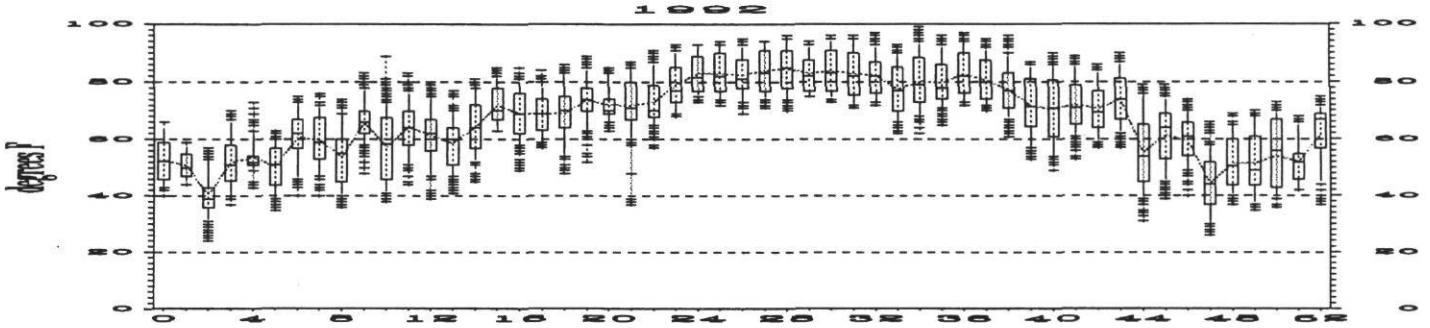

Texas A&M University - INTERNAL DISTRIBUTION ONLY - Energy Systems Laboratory
Site 001 Beginning 6-11-1993
B/CS Temp (F)

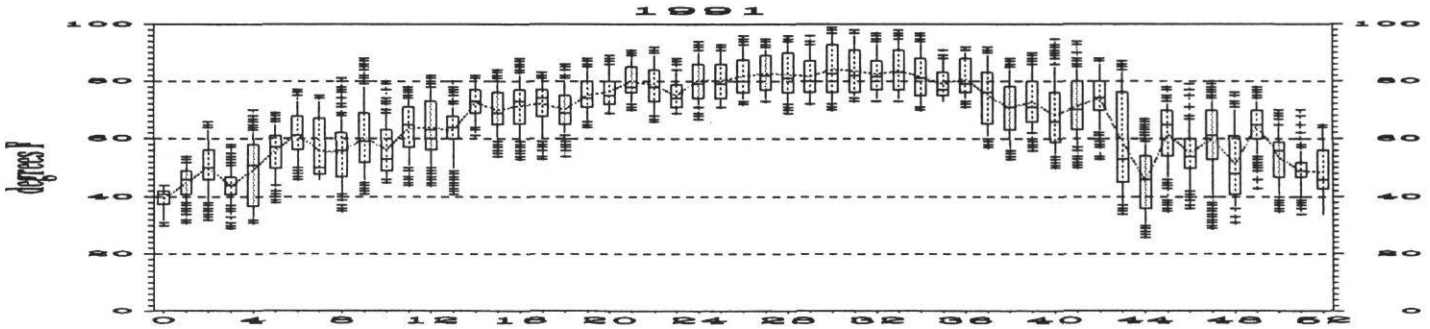

Texas A&M University - INTERNAL DISTRIBUTION ONLY - Energy Systems Laboratory
Site 161 Beginning 6-11-1993


Texas A&M University - INTERNAL DISTRIBUTION ONLY - Energy Systems Laboratory


CLL Dry Bulb Temperature
1992
degrees F
100
1.Jan
1.Sep

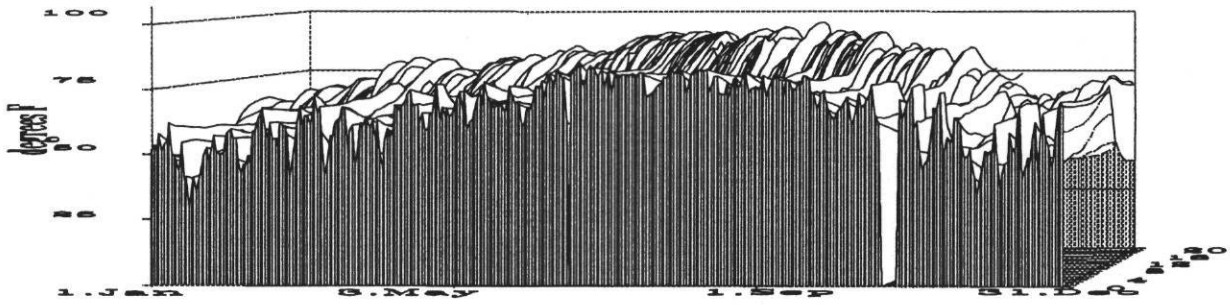

1991
degrees F
100
1.Jan
1.Sep


1992
degrees F
0
4
8
12
16
20
24
28
32
36
40
44
48
52

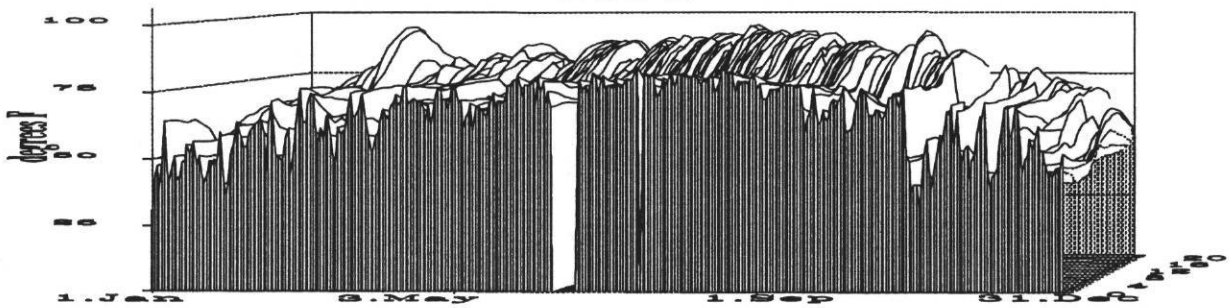

1991
degrees F
0
4
8
12
16
20
24
28
32
36
40
44
48
52

B/CS Dry Bulb Temperature

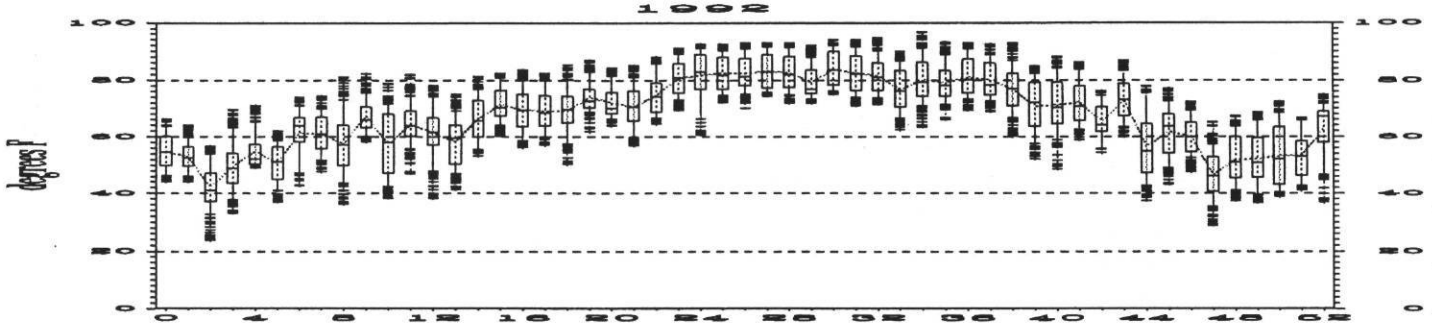
1992



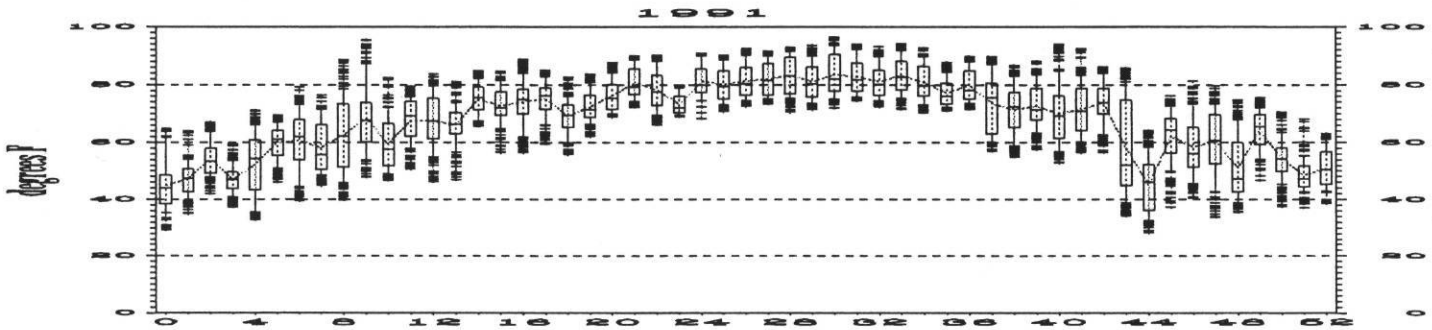
1991



1992



1991



TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK 6 IMPROVED ENERGY AUDIT PROCESS

ACCOMPLISHMENTS

Jeff S. Haberl, P.I.
John Houcek
Mingsheng Liu

June 1993

TASK 6 - RESPONSIBILITIES

- INVESTIGATE THE USE OF "DIPSTICK" AUDITS (DOE/BATTELLE).
- INCORPORATE DEMAND DATA AND OTHER SHORT TERM MONITORING INTO AUDITOR'S WORK.
- INVESTIGATE THE USE OF PRESCREENING INDICES INTO AUDIT.
- USE RESULTS FROM MEASURED SAVINGS TO IMPROVE THE AUDIT PROCESS.
- DEVELOP A WORKSHOP/WORKBOOK TO TRAIN OTHERS TO USE DATA ACQUISITION SYSTEMS AND LOANSTAR SOFTWARE.

TASK 6 - ACCOMPLISHMENTS

- LoanSTAR Monitoring Workshop developed and delivered.
  > Austin, TX, August 26, 1992.

- LoanSTAR Monitoring Seminar presented at Region VII ASHRAE CRC meeting.
  > San Antonio, TX, April 24, 1993.

- LoanSTAR Monitoring Workshop presented (USDOE Co-sponsor).
  > Minneapolis, Minn., May 5, 1993

- Graphical indices developed from LoanSTAR database.

- Initiated fieldwork for determining O&M prescreening indices.

You are invited to attend a

LoanSTAR Monitoring Workshop

COMPLETED

Presented by
The Energy Systems Laboratory
at Texas A&M University

9:00 a.m. to 5:00 p.m., August 26, 1992
Utilities Building, University of Texas at Austin

Sponsored by the
Texas Governor's Energy Office

You are invited to attend a building energy monitoring workshop that has been developed to familiarize building professionals with techniques that are used to gather and process hourly building energy and environmental data. This workshop will be presented by Texas A&M University using the procedures and software that have been developed for the Texas LoanSTAR program.

The workshop will emphasize a hands-on approach that covers the basics of measuring energy use and environmental conditions, including:

- connecting sensors to a logger,
- programming a logger,
- polling a logger, and
- preparing 2-D and 3-D graphs.

The workshop will also include a tour of a LoanSTAR site at the University of Texas at Austin.

Each workshop attendee will receive a 130+ page workbook that contains instructions and details about connecting a logger to a building, programming the logger, and quickly processing the data into useful plots on a PC with inexpensive graphics and spreadsheet programs.

A diskette is included in each workbook that contains public domain data processing routines and examples to guide the user in setting-up their first site and producing the plots.

WORKBOOK CONTENTS (W/SOFTWARE):

INTRODUCTION

- Designing an experiment.
- Types of programs.
- Identifying experimental parameters.
- Extent of monitoring.
- Basic monitoring in the program.

MEASUREMENT TECHNIQUES

- Basics of electricity monitoring.
- Measuring temperature.
- Measuring humidity.
- Measuring flow, Btus, etc.
- Installing and calibrating sensors.
- Analyzing errors.

USING A DATA LOGGER

- Connecting the sensors to the logger.
- Survival commands.
- Setting-up and polling a logger.

WHAT TO DO WITH THE DATA

- Processing and plotting raw data.
- Creating summary pages from raw data.
- Creating 3-D graphics with a spreadsheet.

There is no charge for the workshop. For more information call:
Dr. Jeff Haberl at Texas A&M University, College Station, TX, (409)845-6065.

3.2 SURVIVAL COMMANDS FOR PROGRAMMING THE LOGGER (cont.)

FIGURE 3-13: DIAGRAM OF AN EXAMPLE LOGGER SET-UP.

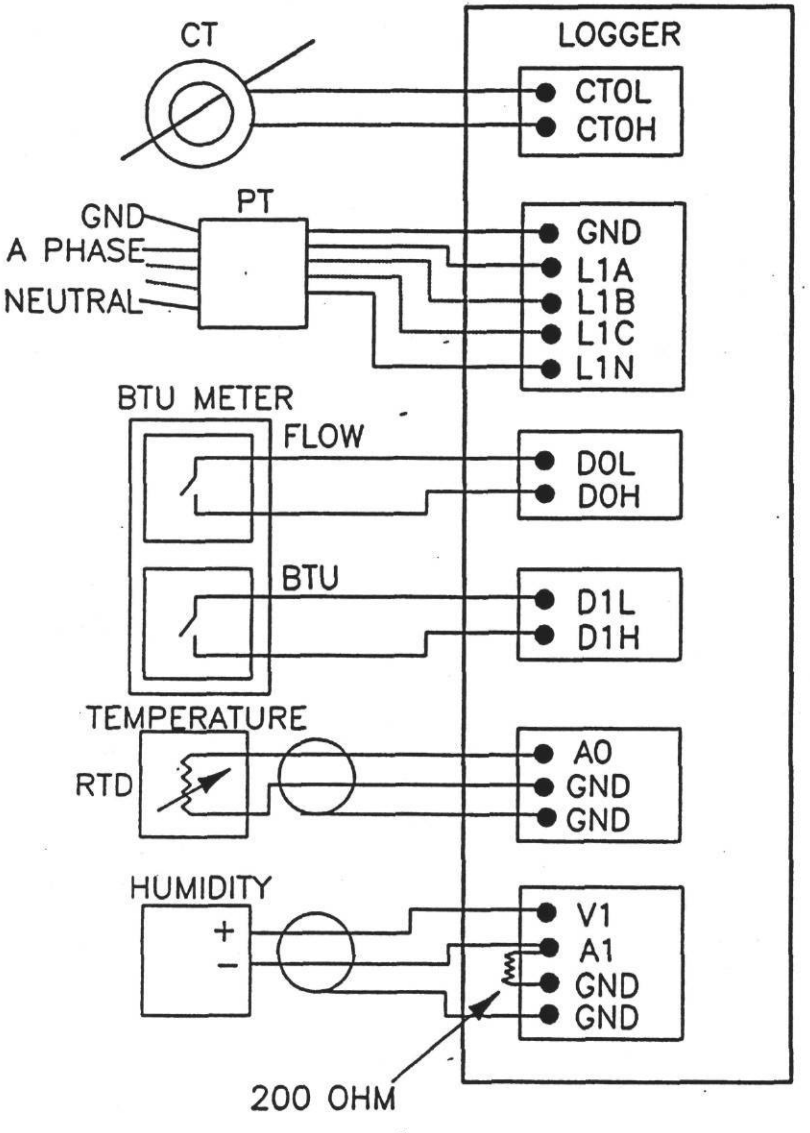


FIGURE 2-7 Functional Block Diagram for a Watt/Watt-hour Transducer (Reproduced with permission: Edison Electric Insitute's Handbook for Electricity Metering 1981).

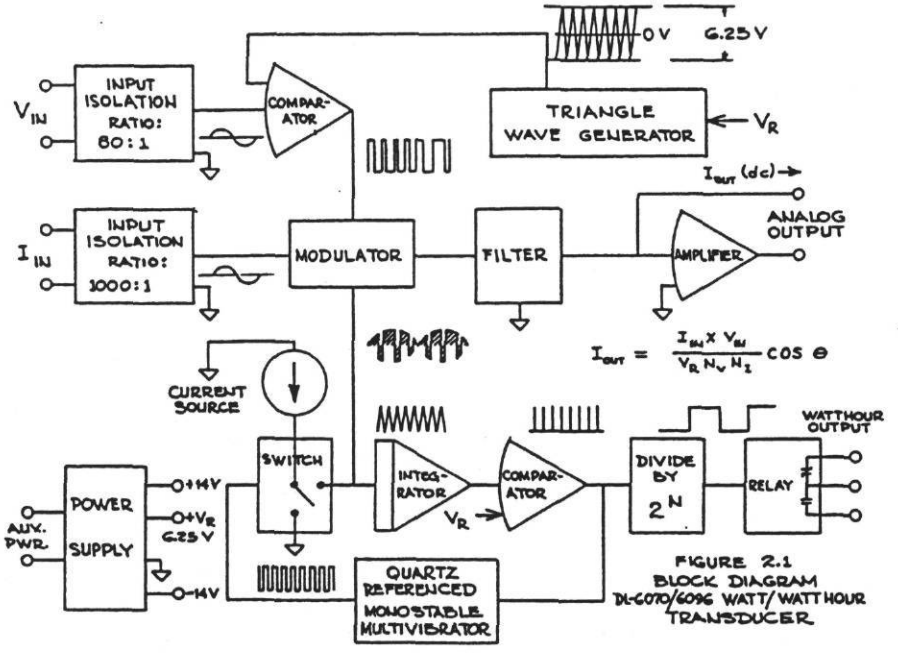
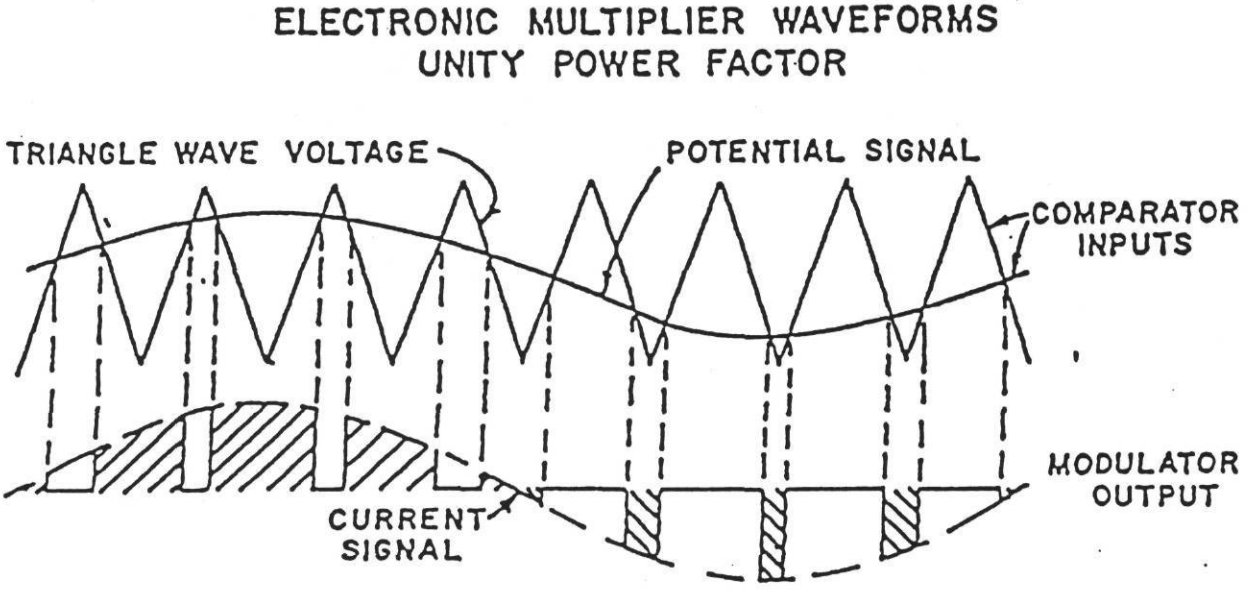


FIGURE 2-8 Electronic Multiplier Waveforms for a Watt/Watt-hour Transducer (Reproduced with permission: Edison Electric Insitute's Handbook for Electricity Metering 1981).



4.2 CREATION OF SUMMARY PAGES RAW DATA AND AREA WEATHER DATA (CONT).

FIGURE 4.6: FLOW CHART FOR SUMMARY PAGE UTSUMM.BAT.

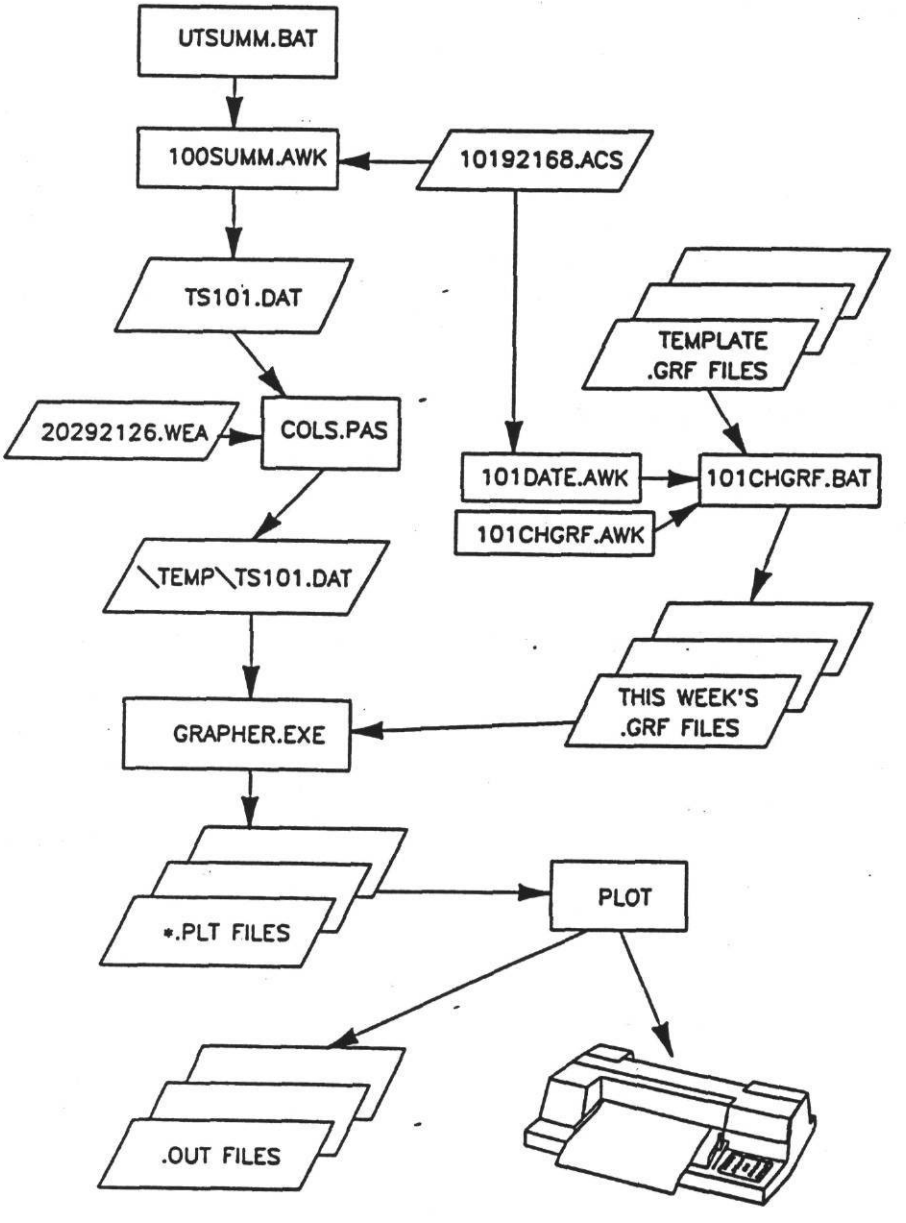


FIGURE 4.5 Example summary plot for site 101.

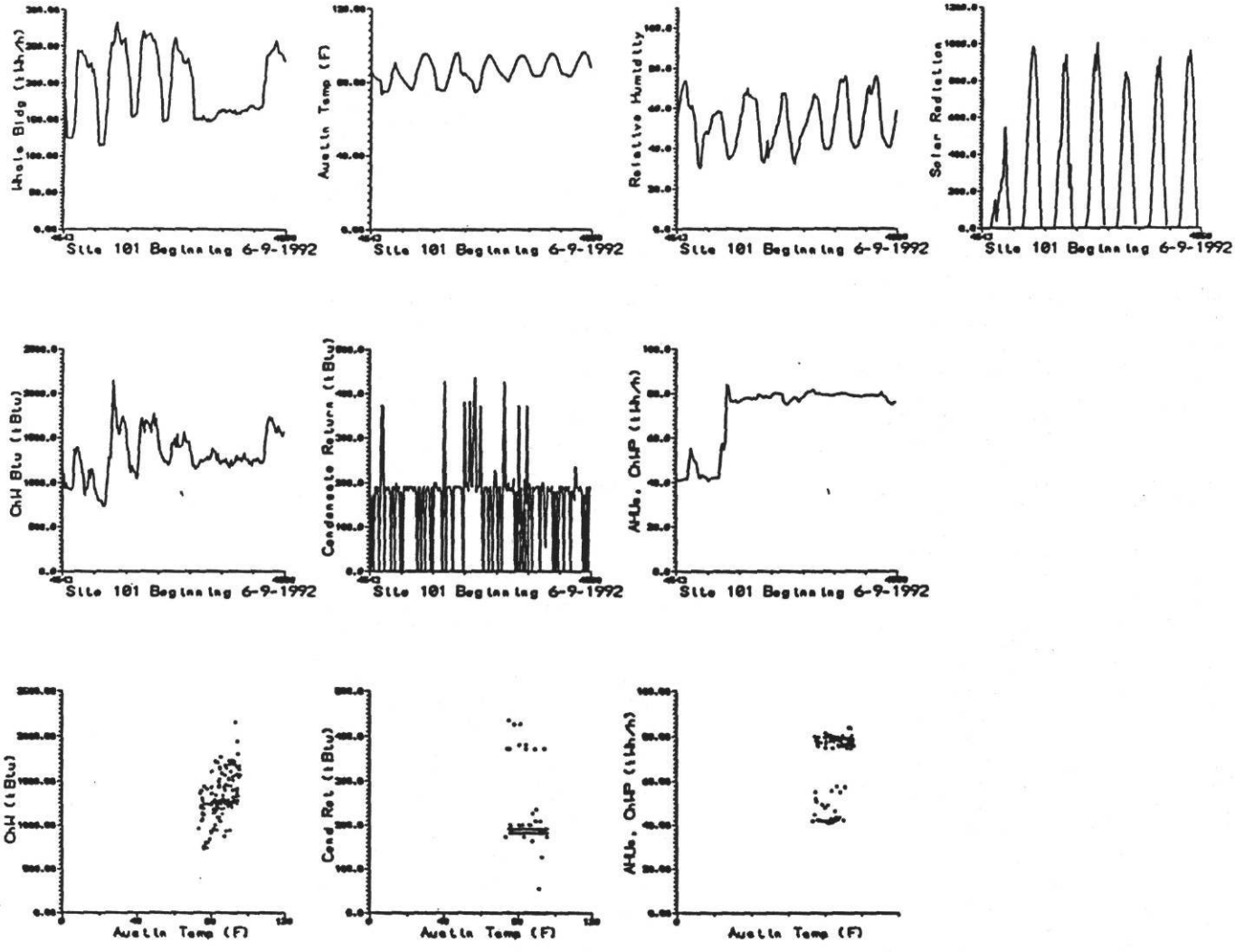


TABLE 4-12 Files included with the distribution diskette.

```
SAMPLEM0 3D      64961 09-24-91  10:50a
SAMPLEM1 3D      22481 09-24-91  10:50a
SAMPLEM1 3DP       512 07-11-92   1:29p
10192168 ACH     31920 06-24-92   9:32a
10192168 ACS     31920 06-24-92   9:32a
101CHGRF AWK       145 10-18-90  11:08p
101DATE  AWK       443 06-19-92  10:19a
101SUMM  AWK       639 05-06-92  12:22p
RAW2DAT  AWK      4142 06-27-91   2:38p
101CHGRF BAT       72 07-26-92   4:26p
101GRAPH BAT     1763 07-26-92   4:22p
R2A      BAT     2768 06-19-92  10:21a
UTSUMM   BAT     1614 06-19-92  10:38a
10190001 CHT     3053 05-06-92  11:54a
ARCHIVE  COM    40937 06-16-87   5:07p
COLS     COM    13551 06-16-87  10:55a
ABUT     COM    13381 06-16-87  10:58a
DAYDAT   COM    20210 08-31-87  12:17a
KDOW     COM    20058 08-31-87  12:19a
KEEP     COM    20321 08-31-87  12:13a
QSELECT  COM    20138 08-31-87  12:15a
REPL     COM    15377 06-16-87  10:56a
ROWS     COM    27259 06-16-87  10:55a
SELECT   COM    20011 08-31-87  12:17a
TAIL     COM    12656 06-16-87  10:58a
TIMERGE  COM    20661 08-31-87  12:16a
TOTAL    COM    24710 08-31-87  12:19a
WDOW     COM    20058 08-31-87  12:20a
WEED     COM    20351 08-31-87  12:18a
10192168 DAT    19891 06-24-92   9:32a
SAMPLE   DAT    57430 09-20-91   8:58a
T101     DAT    31920 06-24-92   9:32a
DIR      DIR        0 08-18-92  11:20a
ABUT     DOC     1976 04-24-87   1:09p
ARTTOOL  DOC     5376 08-31-87   2:01a
COLS     DOC     1921 04-22-87   9:36p
DAYDAT   DOC     1920 08-17-57   6:00p
KDOW     DOC     1280 08-17-57   6:01p
KEEP     DOC     1024 08-31-87  12:46a
QSELECT  DOC     1024 08-31-87  12:48a
REPL     DOC     4470 04-23-87   5:23p
ROWS     DOC    13420 06-17-87  11:46a
SELECT   DOC     1536 08-31-87  12:50a
TAIL     DOC     1517 04-24-87   1:18p
TIMERGE  DOC     2560 08-31-87   2:05a
TOOLBOX  DOC     2703 06-17-87  11:42a
TOTAL    DOC     1792 08-31-87   2:10a
WDOW     DOC      640 08-17-87   5:43p
WEED     DOC      768 08-31-87  12:52a
COLROW3D EXE    92787 09-19-91   8:54a
GAWK     EXE   134446 02-25-90   9:32p
MISSING  EXE    37471 11-13-91   4:27p
T1011    GRF      870 04-09-91   1:15p
T10110   GRF      865 04-09-91   1:15p
T10111   GRF      870 04-09-91   1:15p
T10112   GRF      870 05-06-92  12:17p
T10113   GRF      870 05-06-92  12:17p
T10114   GRF      870 05-06-92  12:17p
T10115   GRF      870 05-06-92  12:18p
T1012    GRF      867 04-09-91   1:15p
T1013    GRF      870 04-09-91   1:16p
T1014    GRF      864 04-09-91   1:16p
T1015    GRF      864 04-09-91   1:16p
T1016    GRF      867 04-09-91   1:16p
T1017    GRF      870 04-09-91   1:16p
T1018    GRF      874 04-09-91   1:16p
T1019    GRF      865 04-09-91   1:17p
TS1011   GRF      857 12-16-90   2:05a
TS10112  GRF      867 12-16-90  12:55a
TS1012   GRF      864 12-16-90  12:54a
TS1013   GRF      869 02-22-91   8:54a
TS1014   GRF      875 01-11-91  11:03a
TS1015   GRF      875 01-11-91  11:03a
TS1016   GRF      870 12-16-90  10:00p
TS1017   GRF      870 05-06-91   3:14p
TS1018   GRF      869 05-06-91   3:14p
TS1019   GRF      868 12-16-90  10:01p
10192168 LOG     1647 06-24-92   9:32a
MISSING  LOG       37 06-24-92   9:32a
SAMPLEM0 LOG      763 09-24-91  10:50a
101ONE   OUT    128275 06-24-92   9:35a
101SUMM  OUT    144613 06-24-92   9:43a
101TWO   OUT     31428 06-24-92   9:35a
ABUT     PAS     5601 06-16-87  10:58a
ARCHIVE  PAS    15869 06-16-87   5:09p
ARCPROC0 PAS    11410 06-10-87   3:19p
ARCPROC1 PAS    50829 06-15-87  11:40a
ARCPROC2 PAS    14038 06-09-87   5:10p
COLS     PAS     6064 06-16-87  10:55a
DATAUTIL PAS     8758 08-20-87   4:17p
DAYDAT   PAS     2165 07-30-87   5:24p
KDOW     PAS     2432 07-30-87   5:07p
KEEP     PAS     1690 08-31-87  12:11a
QSELECT  PAS     2304 07-30-87   5:08p
REPL     PAS     9668 06-16-87  10:56a
ROWS     PAS    34515 06-16-87  10:54a
SELECT   PAS     2048 07-30-87   5:06p
TAIL     PAS     3652 06-16-87  10:18a
TIMERGE  PAS     3200 07-30-87   5:09p
TOTAL    PAS     8770 07-30-87   5:45p
WDOW     PAS     2432 07-30-87   5:10p
WEED     PAS     1792 07-30-87   5:11p
WRAP     PAS    14536 08-20-87   4:16p
SAMPLEM0 PIC   118867 09-24-91  11:07a
SAMPLEM1 PIC    44239 09-24-91  11:05a
A        PLT       21 07-18-90   1:30p
B        PLT      512 11-16-89  10:24p
C        PLT      512 11-16-89  10:51p
T1017    PLT        0 07-26-92   4:16p
10192168 RAW    31248 06-16-92   3:03p
20292168 WEA    10224 06-17-92  12:24p
     113 file(s)  1629853 bytes
```

PEOPLE WHO HAVE ATTENDED LoanSTAR MONITORING WORKSHOPS

Austin, TX August 26, 1992

name	company	address
1. Yuk-Lun Lam	Governor's Energy Office	PO Box 12428, Austin, TX 78701
2. Gene Hackman	Waugh Engineering	PO Box 160582, Austin, TX 78716
3. Scott Clark	Carter & Burgess, Inc.	1100 Macon, Ft. Worth, TX 76102
4. W. Brown	Energy Systems	11901 Hamrich Court, Austin, TX 78759
5. Jaswir S. Judge	ECSD, City of Austin	City of Austin, 206 E. 9th St., Austin, TX 78701
6. Steve Jaeger	Texas Railroad Commission	Austin, TX
7. Donald Ayers	UT Utilities	PO Box 7580, Austin, TX 78713
8. Jay Johnston	Texas Energy Engineering Services, Inc.	B-127 Capitol View Center, 1301 Capitol of Texas Highway, Austin, TX 78713
9. Miles Abernathy	UT Utilities	PO Box 7580, Austin, TX 78713
10. Amado Ramirez, Jr.	UT Utilities	PO Box 7580, Austin, TX 78713
11. Chuck Ashe	Wisconsin Power & Light Co.	PO Box 192, Madison, WI 53701
12. Kim Zuhlke	Wisconsin Power & Light Co.	222 W. Washington Avenue, Madison, WI 53701-0192
13. Mike MacDonald	Oak Ridge National Laboratory	Building 3147, M.S. 6070, PO Box 2008, Oak Ridge, TN 37831-6070
14. Terry Sharp	Oak Ridge National Laboratory	Building 3147, M.S. 6070, PO Box 2008, Oak Ridge, TN 37831-6070
15. Max Harelik	Texas MHMR Maintenance & Construction	PO Box 12660, Austin, TX 78711-2668
16. Jim Rodriguez	Rodriguez Construction Engineers, Inc.	7073 A San Pedro, San Antonio, TX 78216
17. Hardy Romine	Romine, Romine, & Burgess	4216 Felkirk Dr. West, Ft. Worth, TX 76109
18. Scott Jarman	Energy Environment Inc.	311 Ranch Rd., 620 S. Suite 200, Austin, TX 78734
19. Jack Roberts	Fanning, Fanning, & Associates	6355 74th St., Lubbock, TX 79423
20. Joe Grimes	Grimes & Associates Consulting Engineers	PO Box 45, Wolforth, TX 79382
21. Everett Hall	UT-Austin	PO Box 7580, Austin, TX 78713
22. Denis Feary	SPGSC-Austin	PO Box 1307, 1711 San Jacinto, Austin, TX 78711-3047
23. John Houcek	Energy Systems Laboratory	Texas A&M University, Mechanical Engineering Dept., Energy Systems Laboratory, College Station, TX 77840

San Antonio, TX April 24, 1993

name	company	address
24. Hamid Habibi	Cromwell Truemper Levy Thompson Woodsmall, Inc.	101 South Spring Street, Little Rock, AR 72201
25. Henry W. Wade	Wade Company	PO Box 3506, Little Rock, AR 72203
26. Raymond Taylor, Jr.	United States Air Force	10825 Edgecrest, San Antonio, TX 78217
27. Howard Godfrey	G&G Controls, Inc.	11002 East 51st Street South, Tulsa, OK 74146
28. Don Angle	H.G. Angle Co., Inc.	456 West 61st St., Shreveport, LA 71106
29. Donald C. Carter	The University of Oklahoma	160 Felgar St. Room 101K, Norman, OK 73019-0460
30. Ed Garcia	Vista Chemical	PO Box 120024, Austin, TX 78720
31. Larry Eckert	United States Air Force	47 SPTG/EDMC, 250 4th St., Laughlin AFB, TX 78840-5121
32. Richard E. Rhodes	JWP Brandt Engineering Co.	321 W. Ben White, Suite #104, Austin, TX 78704 or 12755 Cogburn Ave., San Antonio, TX 78249
33. Mike Welborn	Powers of Arkansas	1601 Westpark Dr., Suite 7, Little Rock,. AR 72204
34. Jarrell D. Pruitt	Southwest Research Institute	6220 Culebra Road, PO Drawer 28510, San Antonio, TX 78228-0510
35. Robert J. Sullivent	Mechanical/Electrical/Energy Consultants, Inc.	1412 South Boston, Suite 710, Tulsa, OK 74119
36. Jerry A. Baldwin	Air Distribution Products, Inc.	707 Loyola Drive, Little Rock, AR 72211-5530
37. Davis	Brown & Root, Inc.	10200 Bellaire Boulevard (77072-5299), P.O. Box 4574, Houston, TX 77210-4574
38. Kessner	Carrier Corporation	4307 Vineland Road, Suite H-9, Orlando, FL 32811
39. Jim Hall	Trinity Contractors, Inc.	2425 Dillard, Grand Prairie, TX 75051; P.O. Box 6278, Arlington, TX 76005
40. Harry Romine	Tarrant County Hospital District John Peter Smith Hospital	1500 South Main St.. Ft. Worth, TX 76104

Minneapolis, MN May 5, 1993

name	company	address
41. Mohan N. Amberker	Amberker Associates Inc.	9211 Plymouth Ave N, Minneapolis, MN 55427
42. Brian L. Benson	Ellerbe Becket	800 Lasalle Ave, Minneapolis, MN 55402
43. David O. Bergstrom	Macalester College	1600 Grand Avenue, St. Paul, MN 55105
44. Paul M. Bothwell	Moose Lake Reg. Treatment Center	1000 Lakeshore Drive, Moose Lake, MN 55767
45. Ray Boyer	North Dakota State University	SU Station, PO Box 5383, Fargo, ND 58105-
46. Lou Boyon	Rochester Institute of Technology	P.O. Box 9887, Physical Plant, Rochester, NY 14623
47. Michael H. Brewer	Muhlenberg College	2400 Chew Street, Allentown, PA 18104
48. Susan C. Dahlin	Northern States Power Company	414 Nicollet Mall, Minneapolis, MN 55401
49. John R. Gustafson	Minnesota Power	30 West Superior St., Duluth, MN 55802
50. Neil A. Howell	University of WI-System Administration	1930 Monroe St., Room 203, Madison, WI 53711
51. Bill Lemcke	Central Michigan University	216 Combined Services Bldg, Mount Pleasant, MI 48859
52. Frank L. Marsili	St. Mienrad Archabbey	Physical Facilities Office, St. Meinrad, IN 47577
53. Blake C. McGibbon	McGill University	840 Dr. Penfield, Montreal, Quebec H3A 1A4, CANADA
54. Roberto Meinrath	Yale University	PO Box 2964, 20 Ashmun St., New Haven, CT 06520-2964
55. Vergil Moneo	University of Regina	Physical Plant/Mtce. Bldg., Regina, SK S4S OA2, CANADA
56. John P. Morris	Colorado State University	Facilities Services Center, Fort Collins, CO 80523
57. William F. Mueller	University of Minnesota	100 Union Street SE, Sheperd Labs, Minneapolis, MN 55455
58. Robert M. Pumroy	University of Minnesota	1936 Commonwealth Ave., St. Paul, MN 55108
59. Dan G. Puzak	Honeywell	12001 State Highway 55, Plymouth, MN 55441
60. Mike W. Sachi	Center for Energy & Urban Env.	510 1st Ave N, suite 400, Minneapolis, MN 55403
61. Michael A. Sheils	University of Minnesota	Facilities Management Shops Bldg. 200, Minneapolis, MN 55455
62. Elmer Smolnisky	Augustana College	29th & Summit, Sioux Falls, SD 57197
63. Daniel P . Wichman	Hennepin County	A2208 Government Center, Minneapolis, MN 55487
64. Charlie E. Zwisler	University of Minnesota	Facilities Management, 200 Shops Building, Minneapolis, MN 55455
65. Jim Borer	MnBRC	Room 220,1425 University Avenue SE, Minneapolis, MN 55455
66. Charlie Huizenga	University of California-Berkeley	390 Wurster Hall, University of California-Berkeley, Berkeley, CA 94720
67. Barry Bridges	MnBRC	UBEEP Room 220,1425 University Avenue Se, Minneapolis, MN 55455
68. Jim Douglas	MnBRC	Room 220, 1425 University Avenue, Minneapolis, MN 55455
69. Jeffrey J. Gale	2510 Consultants	10512 Quebec Road, Bloomington, MN 55438
70. Martin Gerads	MnBRC	UBEEP, Room 220, 1425 University Avenue SE, Minneapolis, MN 55455

71. David Grimsrud	MnBRC	UBEEP, Room 220, 1425 University Avenue SE, Minneapolis, MN 55455
72. Scott Harris	MnBRC	5257 Beard Avenue South, Minneapolis, MN 55410
73. Daniel Hatlich	MnBRC	Room 220, 1425 University Avenue, Minneapolis, MN 55455
74. Jack Ikoal	State of Minnesota	Admin/Plant Management, 625 North Robert Street, St. Paul, MN 55101
75. Farong Li	MnBRC	Room 220, 1425 University Avenue SE, Minneapolis, MN 55455
76. Doug Maddox	MnBRC	5800 Baker Road, Suite 100, Minnesota, MN 55455
77. Mike Platteter	MnBRC	Room 220, 1425 University Avenue, Minneapolis, MN 55455
78. Lester S. Shen	Underground Space Center	University of Minnesota, 790 Civil and Mineral Engineering Bldg., Minneapolis, MN 55455
79. Rajan Thomas	State of Minnesota	Plant Management 625 North Robert Street, St. Paul, MN 55101
80. Charles Walin	MnBRC	Room 220, 1425 University Avenue SE, Minneapolis, MN 55455
81. Steve Winkelman	MnBRC	2108 24th Avenue South, Minneapolis, MN 55406

TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE DEVELOPMENT

ACCOMPLISHMENTS

David E. Claridge, P.I.
Jeff S. Haberl, P.I.

June 1993

TASK D - RESPONSIBILITIES

- VERIFY 3.0 MBYTES PER WEEK OF INCOMING INFORMATION

- DEVELOP PROCEDURES/ANALYZE COLLECTED ENERGY DATA.

- MECR, AECR, AND DSN PRODUCTION SOFTWARE.

- DESIGN AND DEVELOP SOFTWARE FOR HANDLING LOANSTAR DATA.

TASK D ACCOMPLISHMENTS ANALYSIS & SOFTWARE DEVELOPMENT PRESENTATIONS:

Database Summary Notebook & Advanced Visualization - Jeff Haberl

Software Development - Robert Sparks

Analysis Development - David Claridge

Savings Measurement - David Claridge & Kelly Kissock

TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE DEVELOPMENT

DATABASE SUMMARY NOTEBOOK

Jeff S. Haberl, P.I.
Ron Chambers, Database Administrator

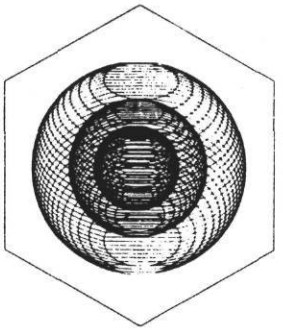
June 1993

LoanSTAR Monitoring and Analysis Program

Database Summary Notebook

1989 through 1992

Submitted to the
Texas Governor's Energy Office
by the
Monitoring and Analysis Task
David E. Claridge, Principal Investigator

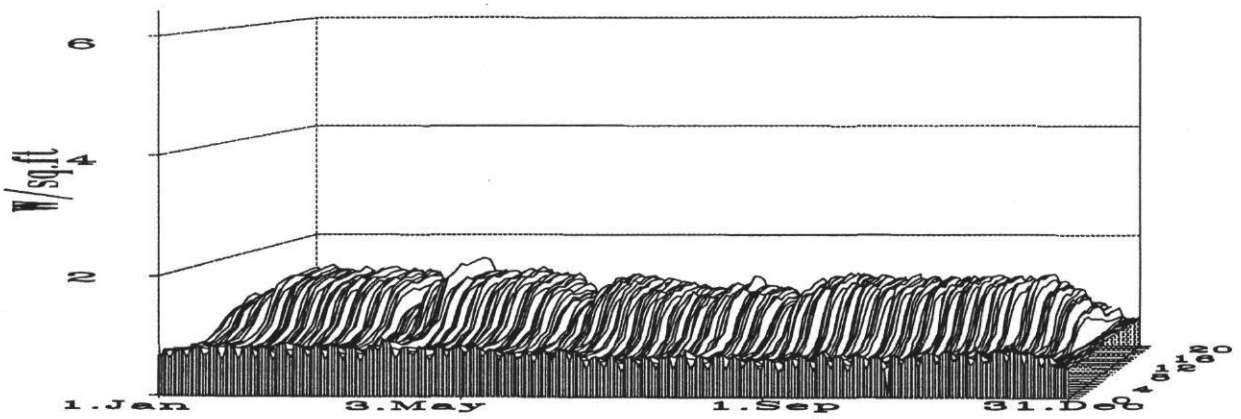


ENERGY SYSTEMS LABORATORY
Department of Mechanical Engineering
Texas Engineering Experiment Station
Texas A&M University System

Education Bldg(EDB)

W.B Electric as W/sq.ft

1992



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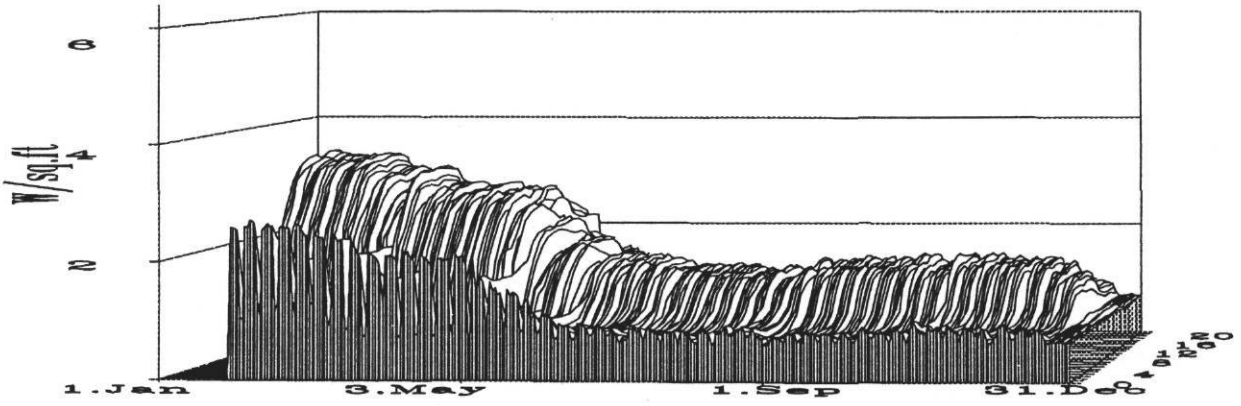

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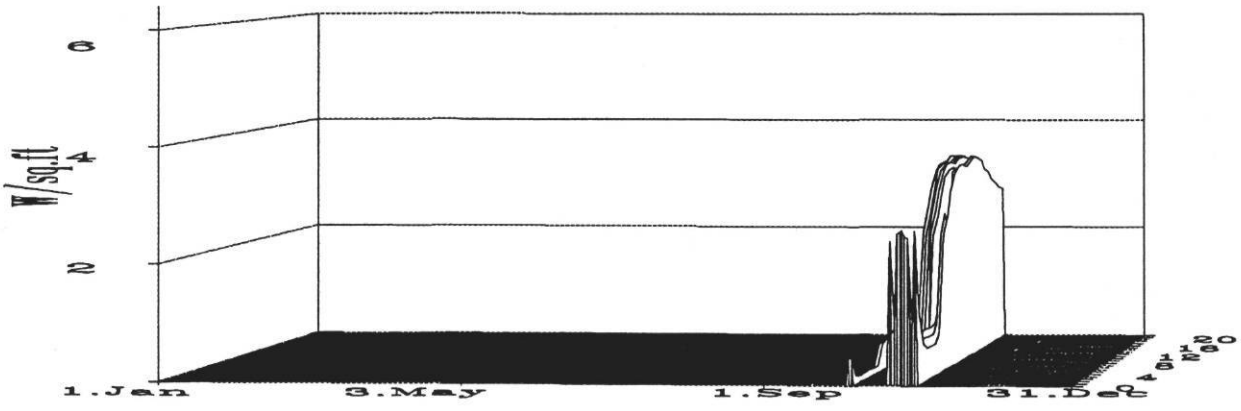
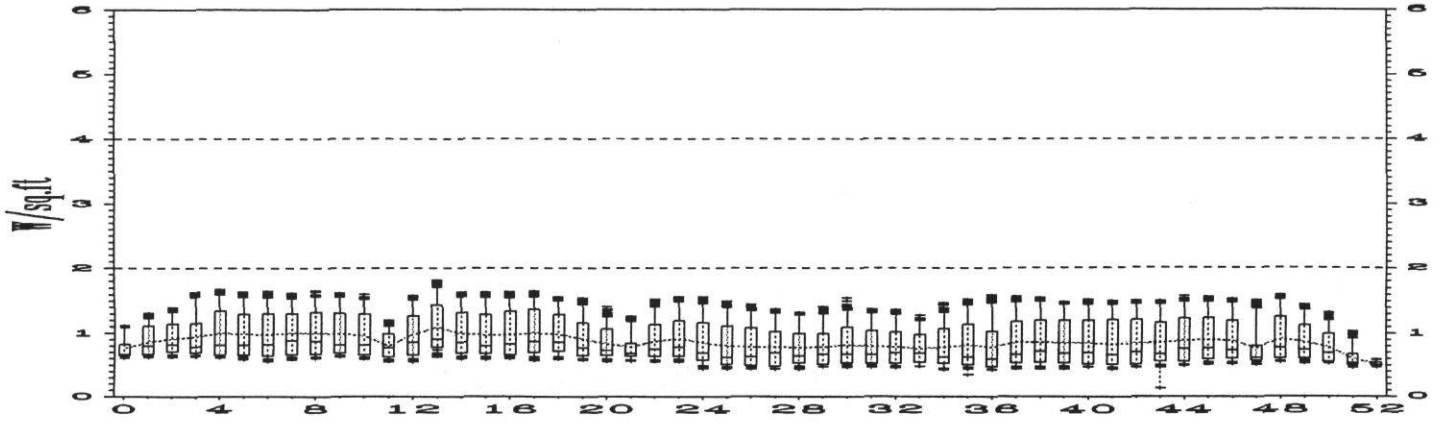


Education Bldg(EDB)

W.B Electric as W/sq.ft

1992



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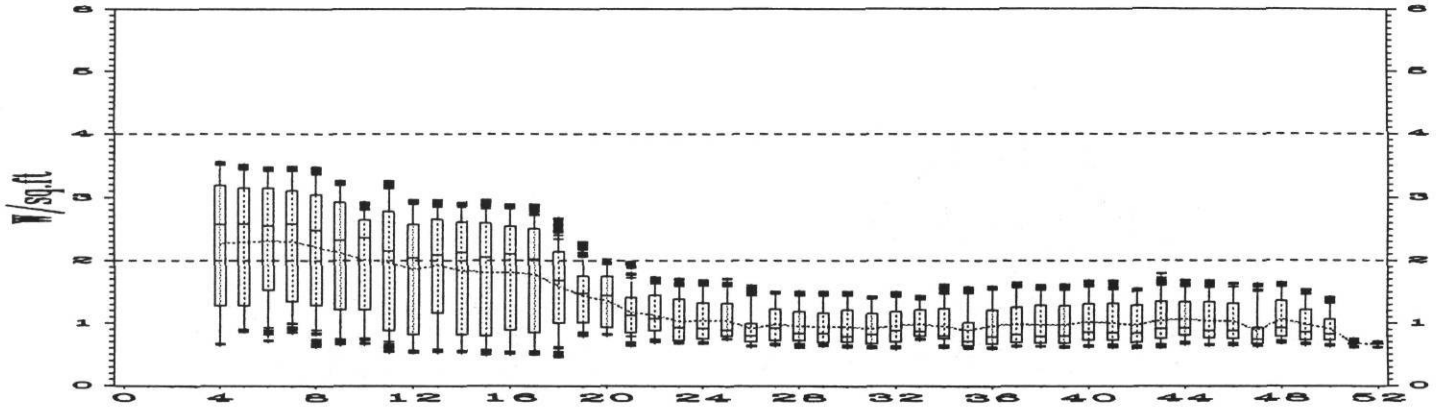

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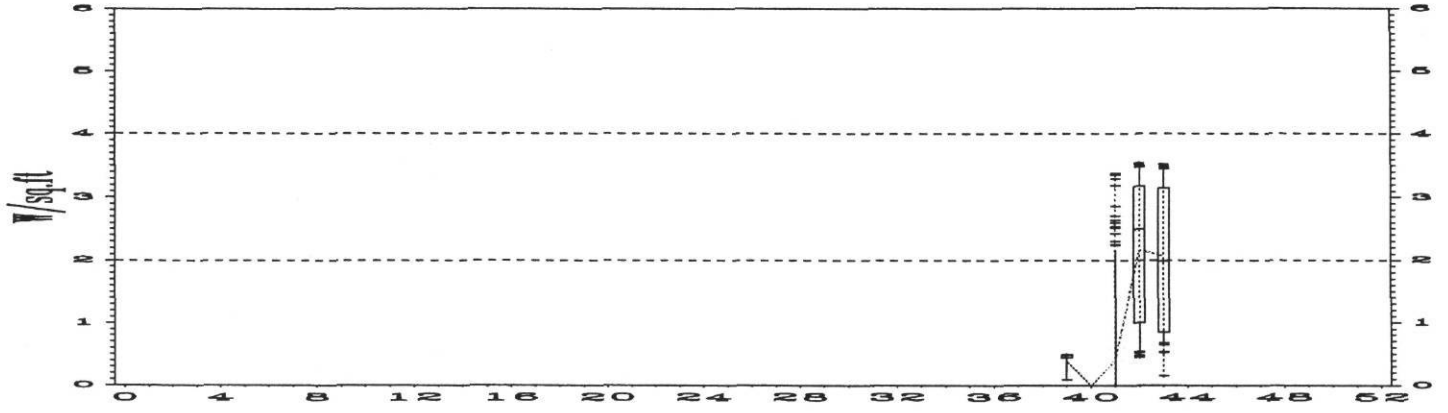
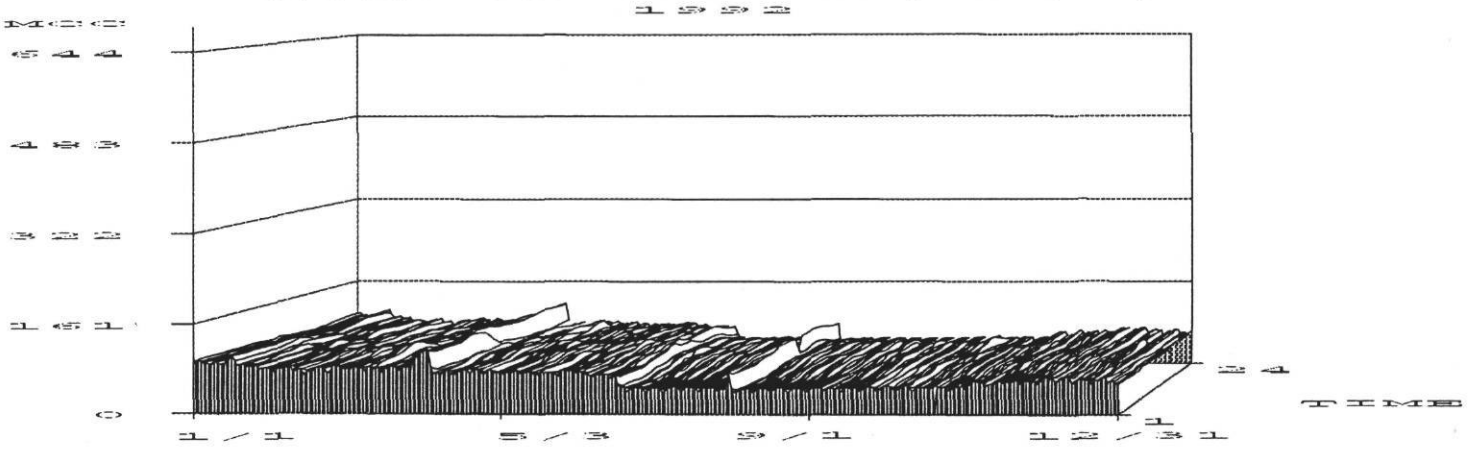
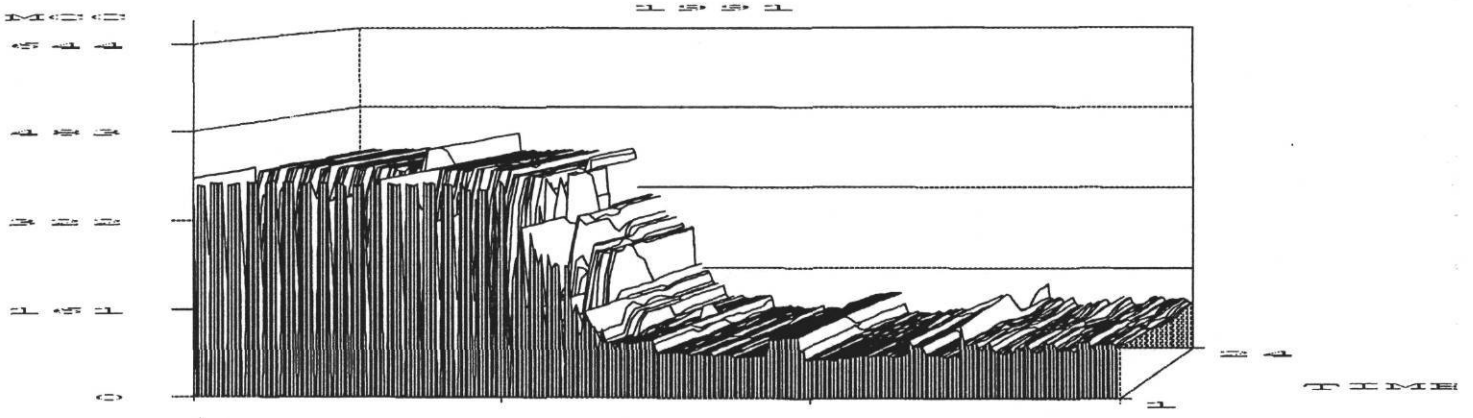
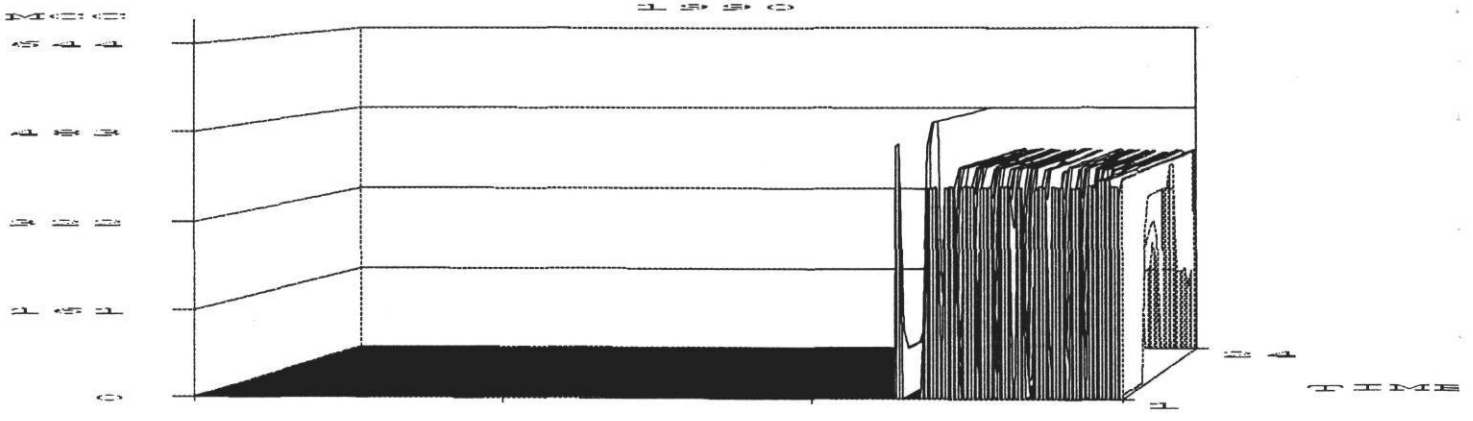


Weeks are Sundays thru Saturdays

Motor Control Cen. (kWh/h)

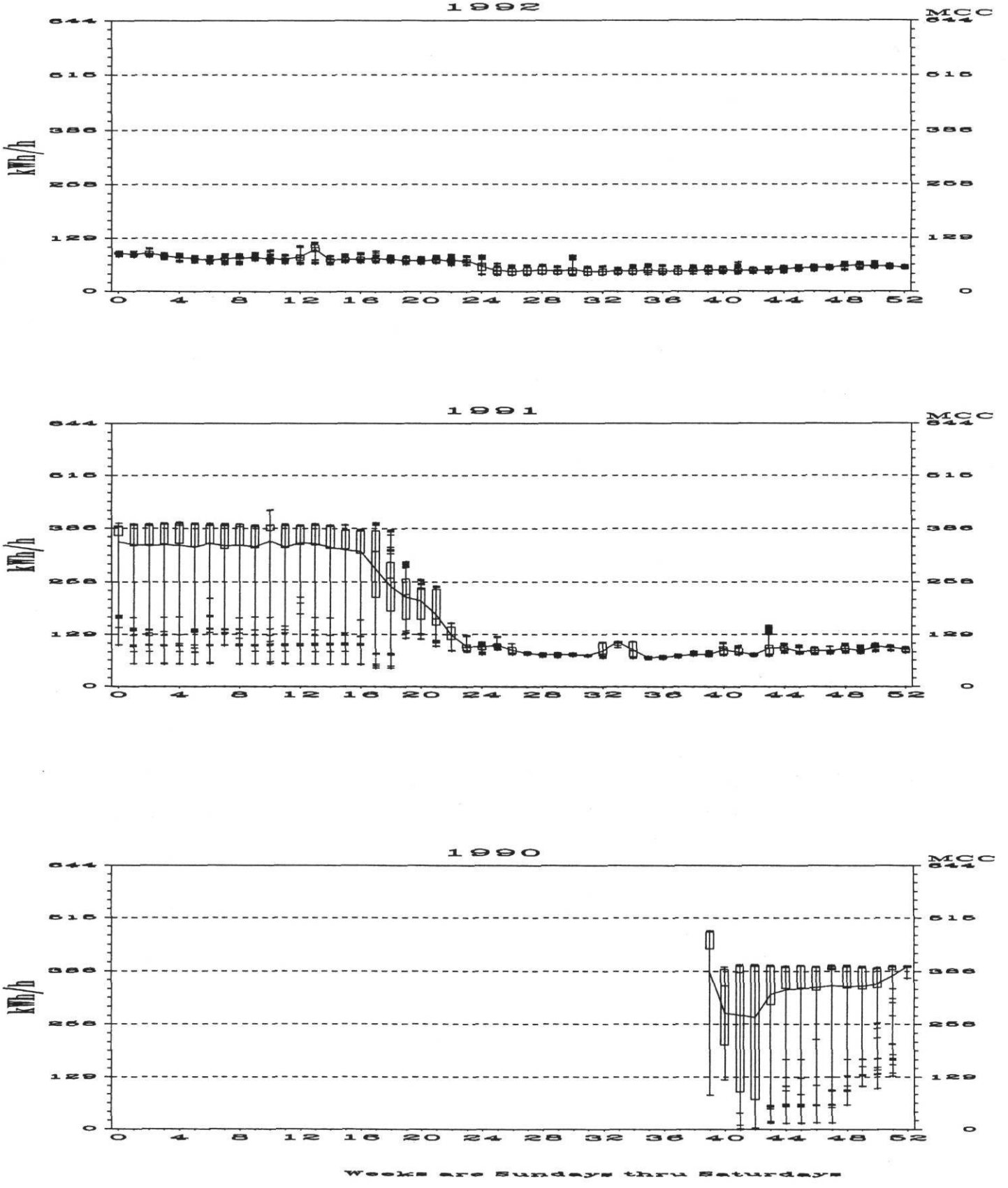






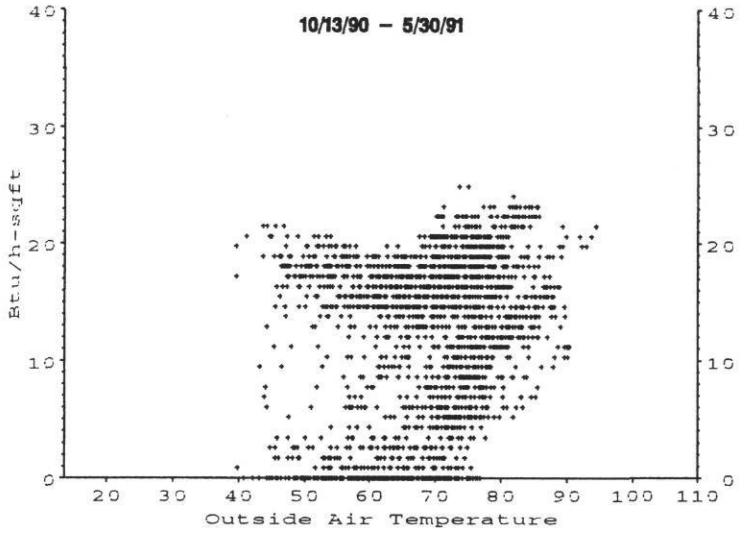
Education Bldg(EDB)

Motor Cont. Cen. (kWh/h)

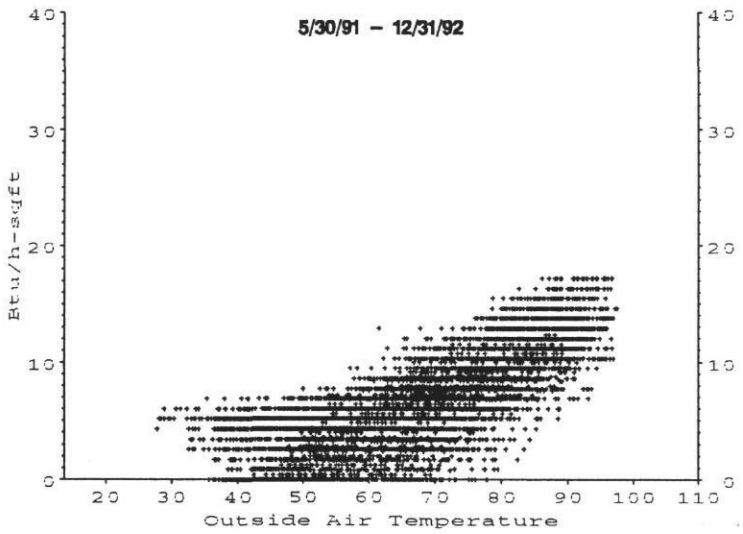


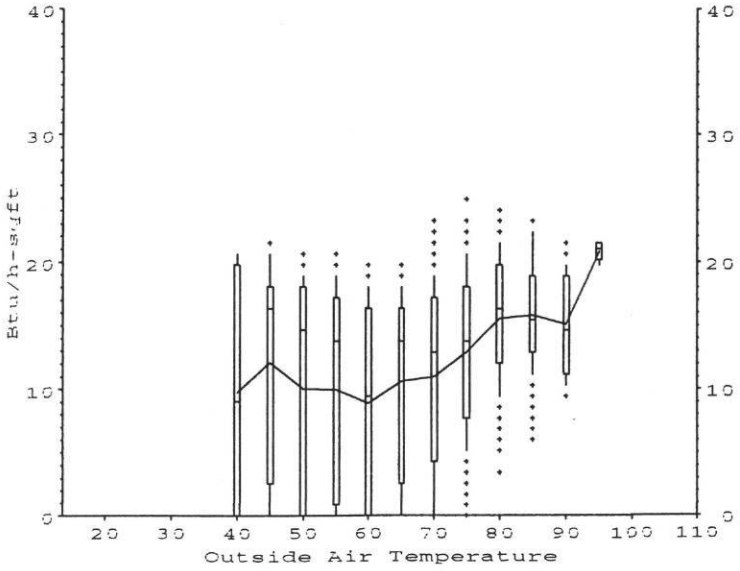
Education Bldg(EDB)

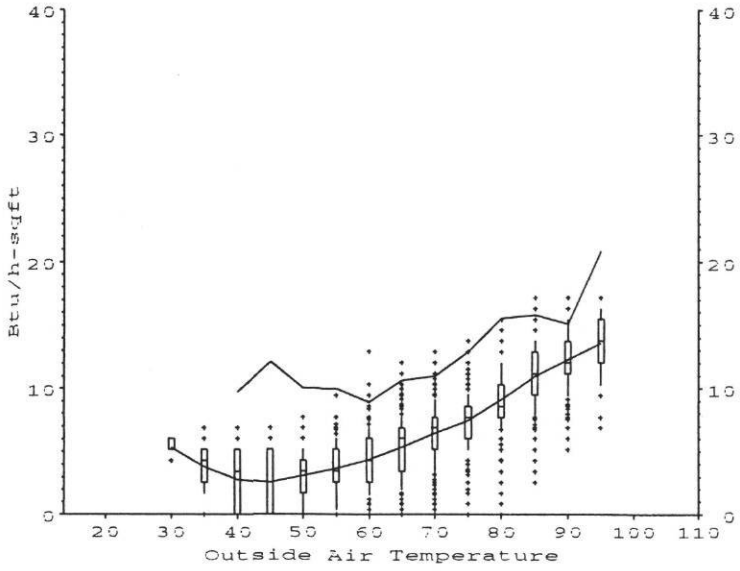
Hourly Pre-Retrofit CHW Consumption



Hourly Post/Const.-Retrofit CHW Consumption

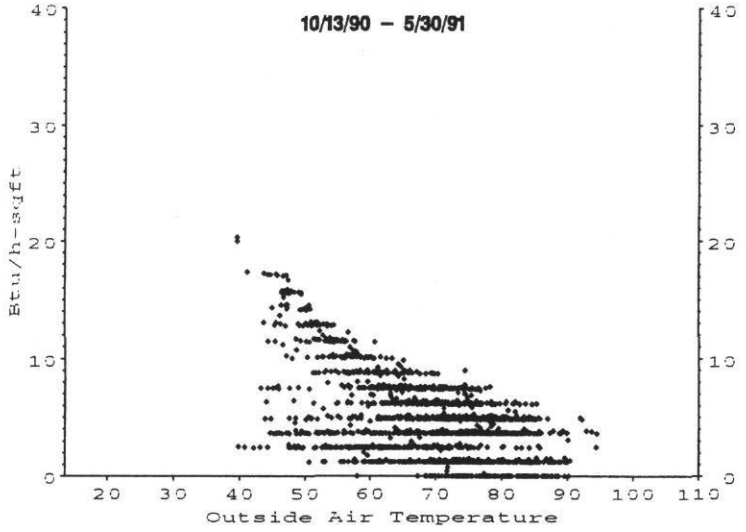




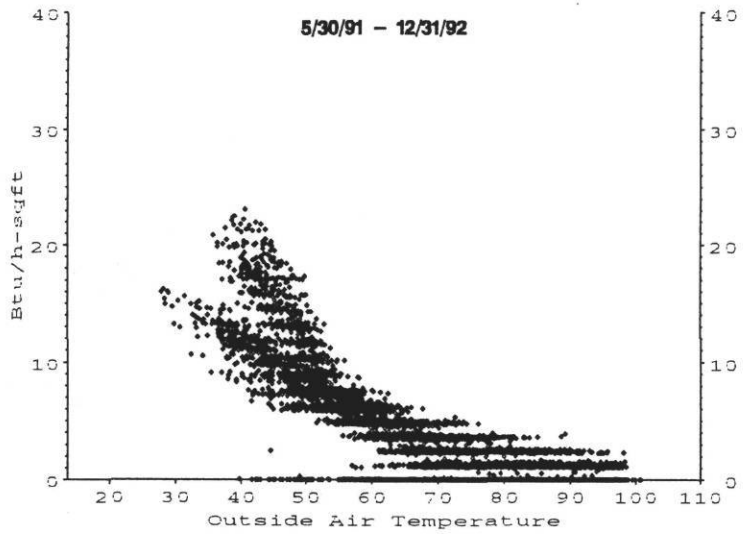


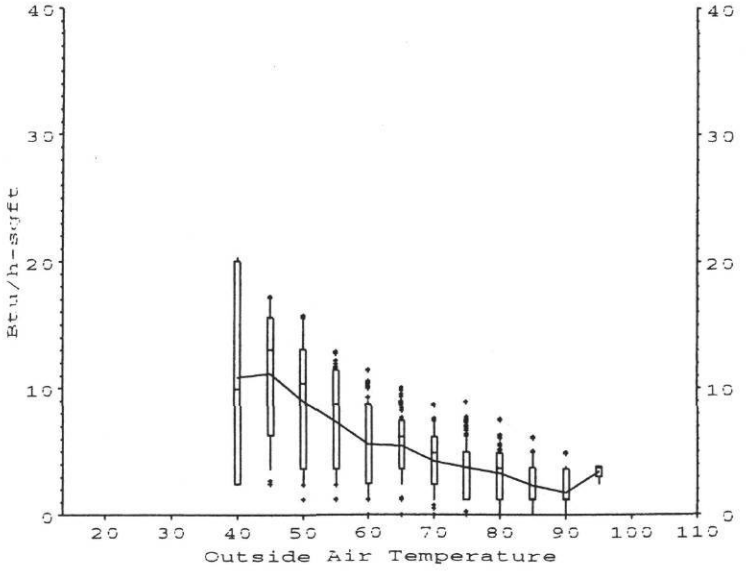
Education Bldg(EDB)

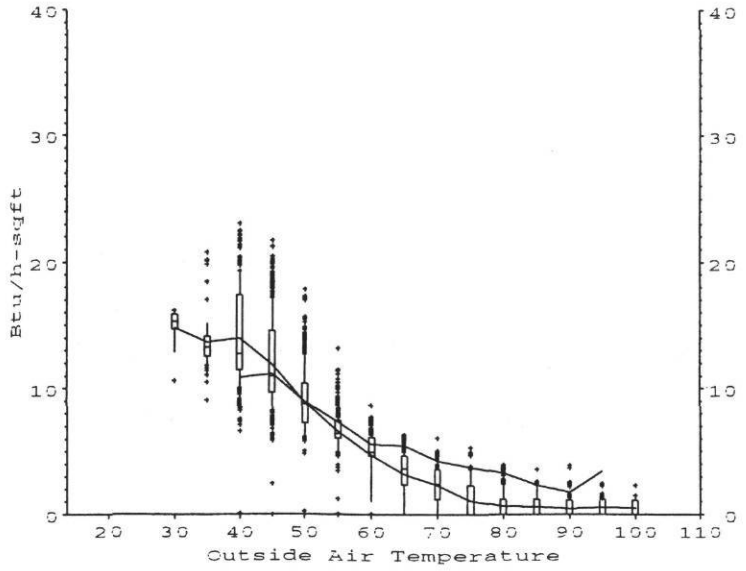
Hourly Pre-Retrofit HW Consumption



Hourly Post/Const.-Retrofit HW Consumption

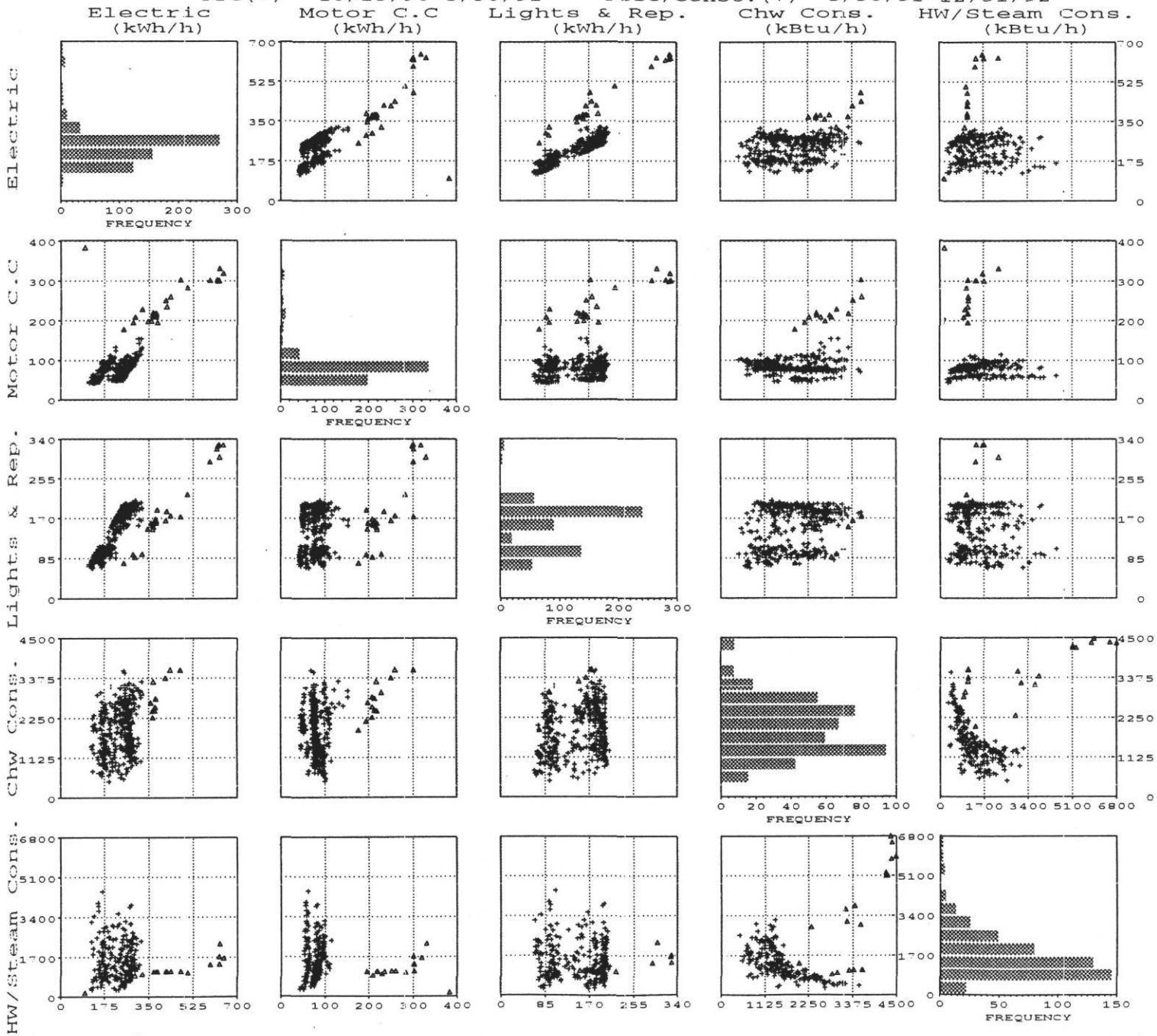






Education Bldg(EDB)
Daily Averaged Values

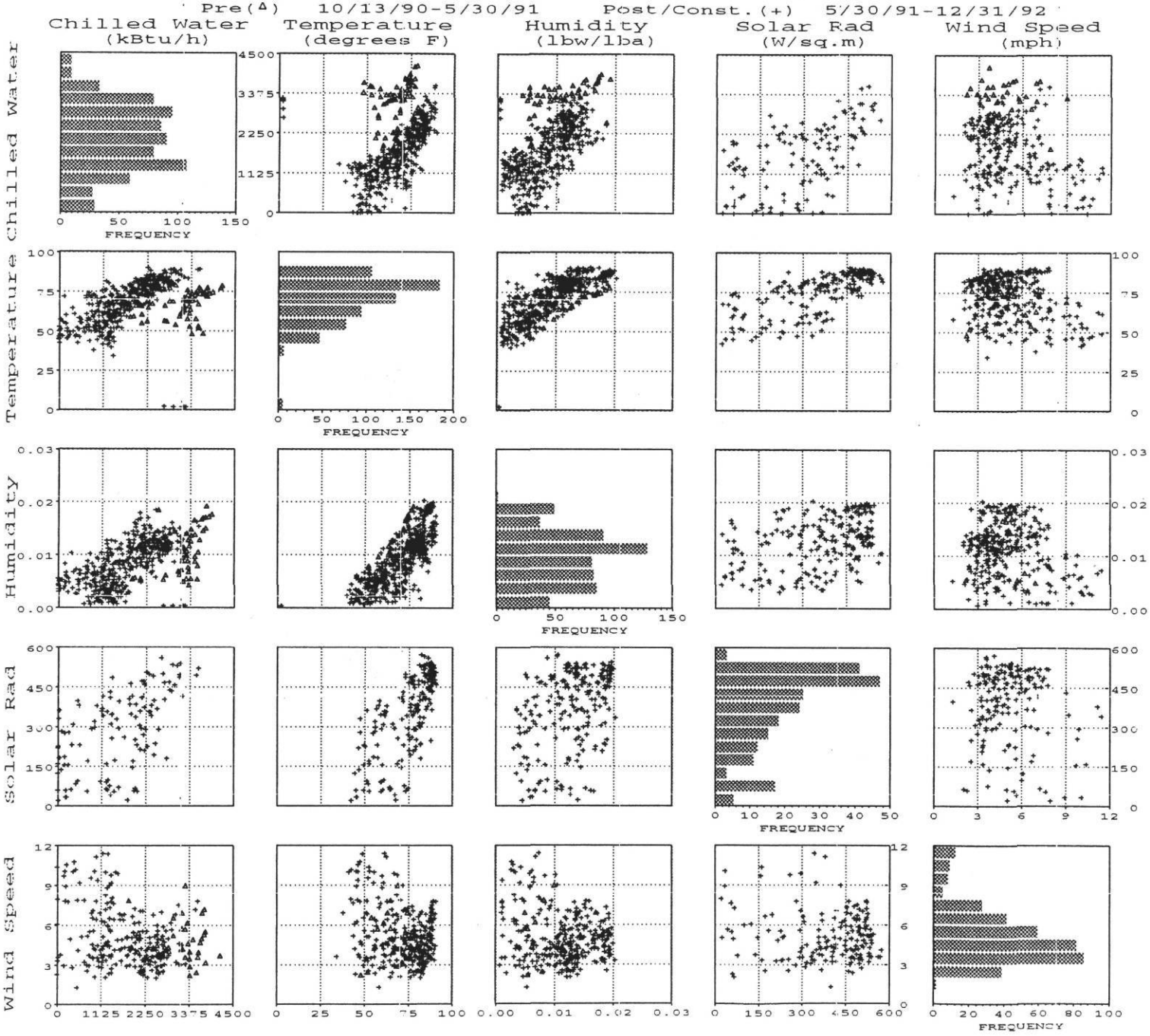
Pre(Δ) 10/13/90-5/30/91 Post/Const.(+) 5/30/91-12/31/92



Education Bldg(EDB)

Daily Averaged Values

Pre(Δ) 10/13/90-5/30/91 Post/Const.(+) 5/30/91-12/31/92



Education Bldg(EDB)

Daily Averaged Values

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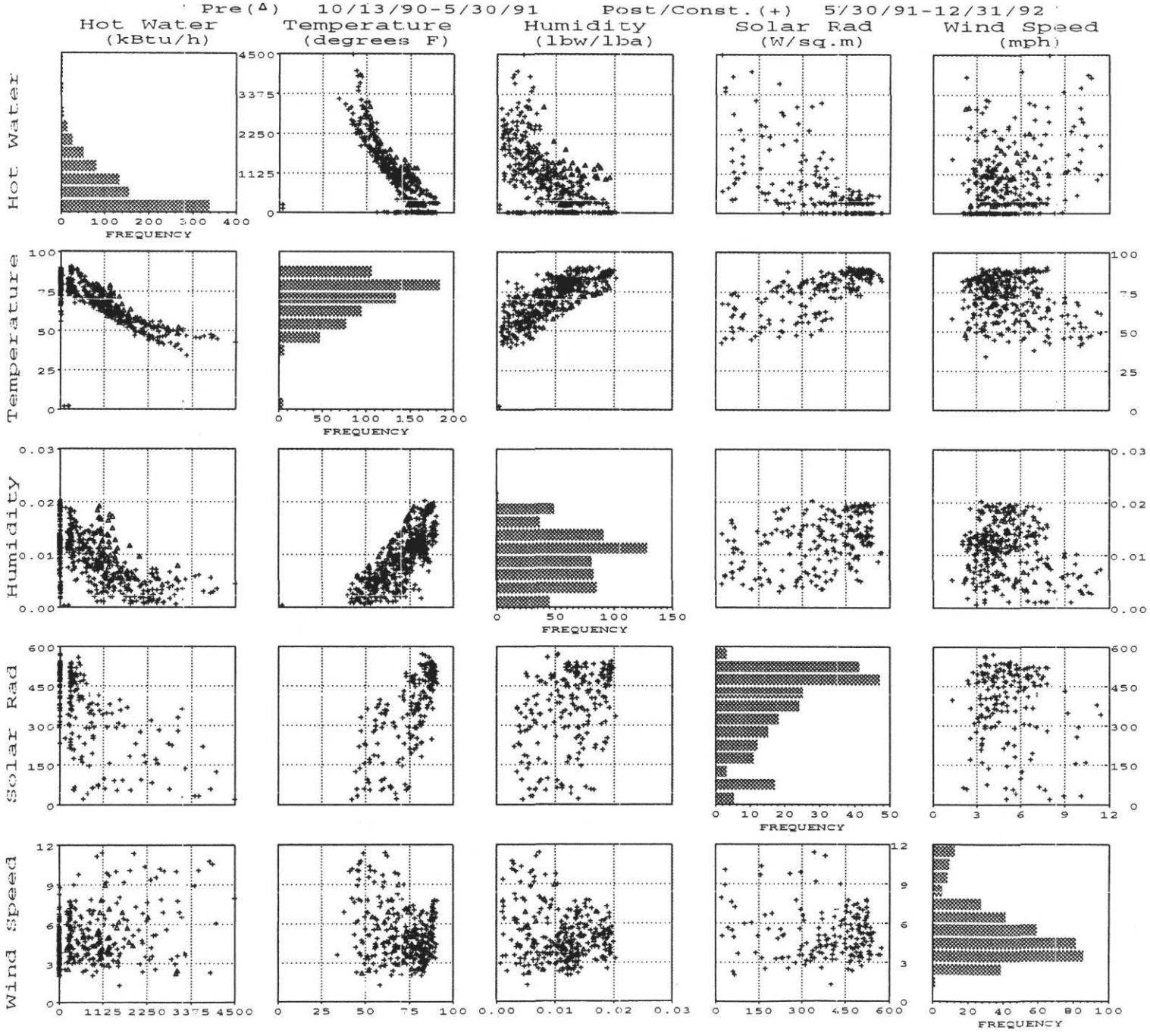
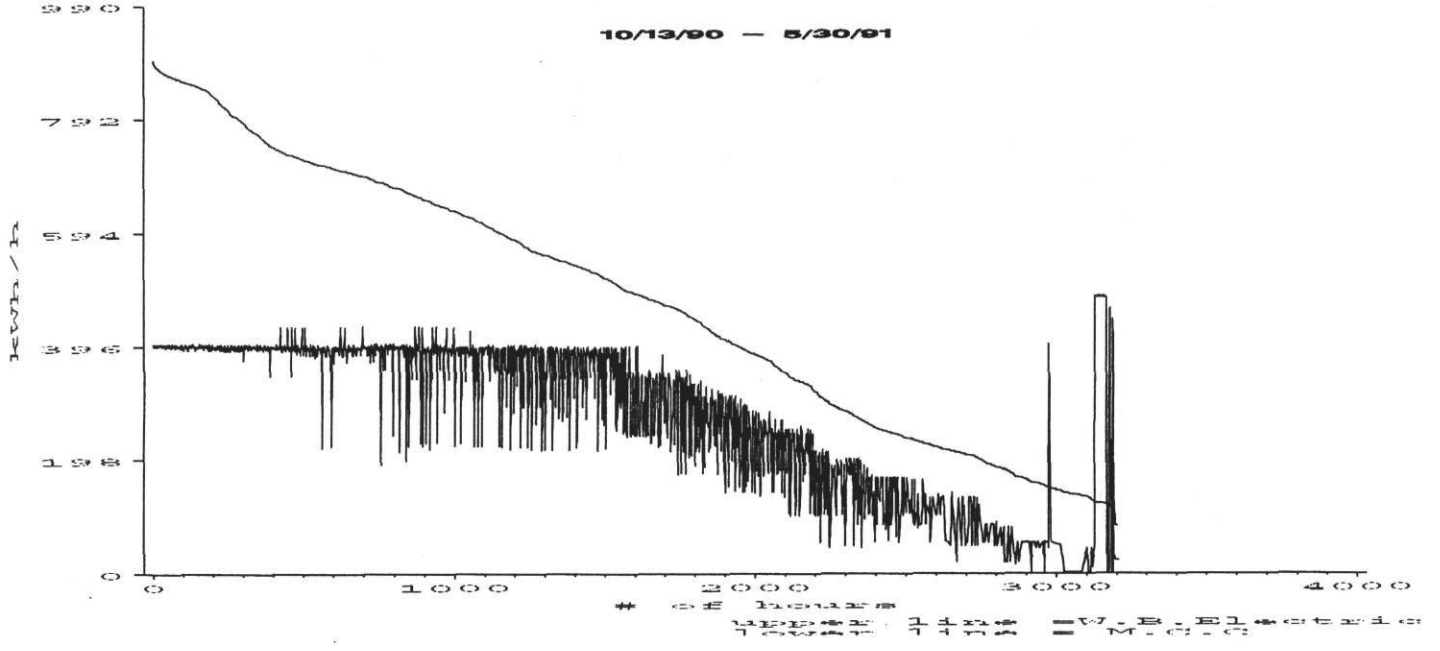


Education Bldg (EDB)

W.B.Electric & M.C.C as kWh/h

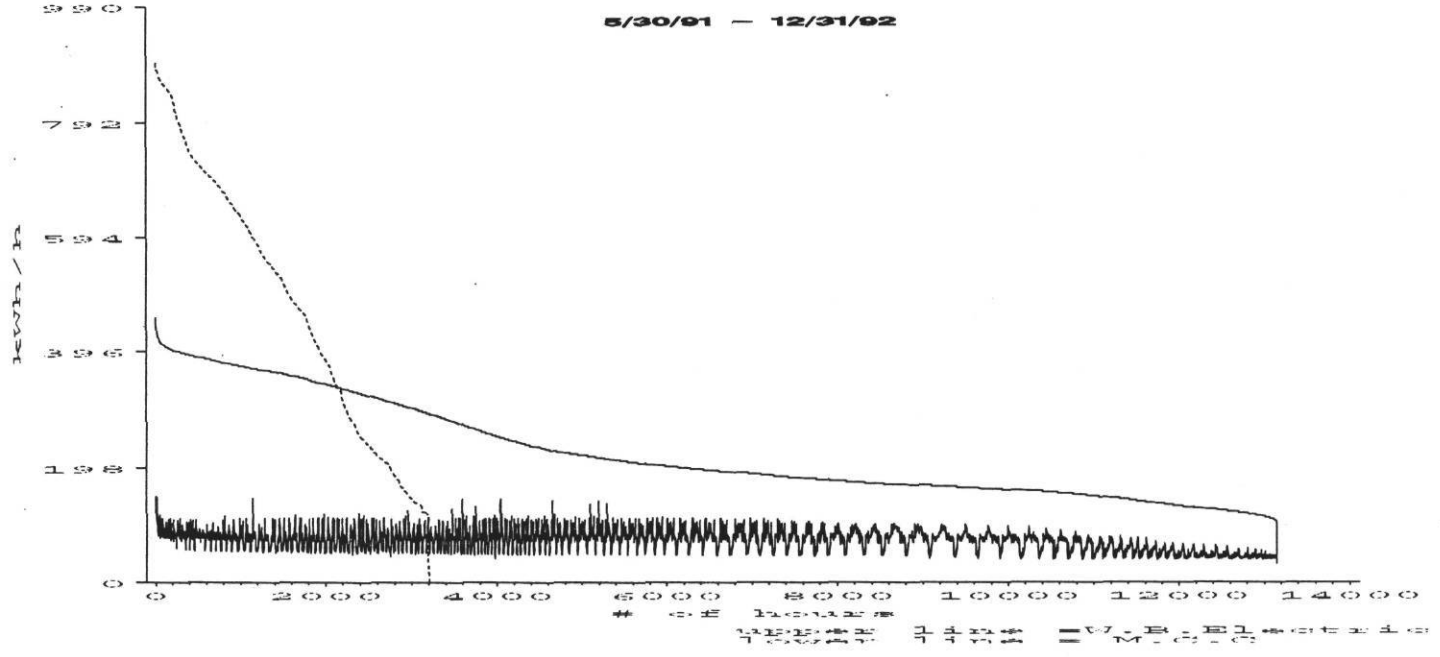
Pre-Retrofit Period

10/13/90 — 5/30/91



Post-Retrofit Period

5/30/91 — 12/31/92



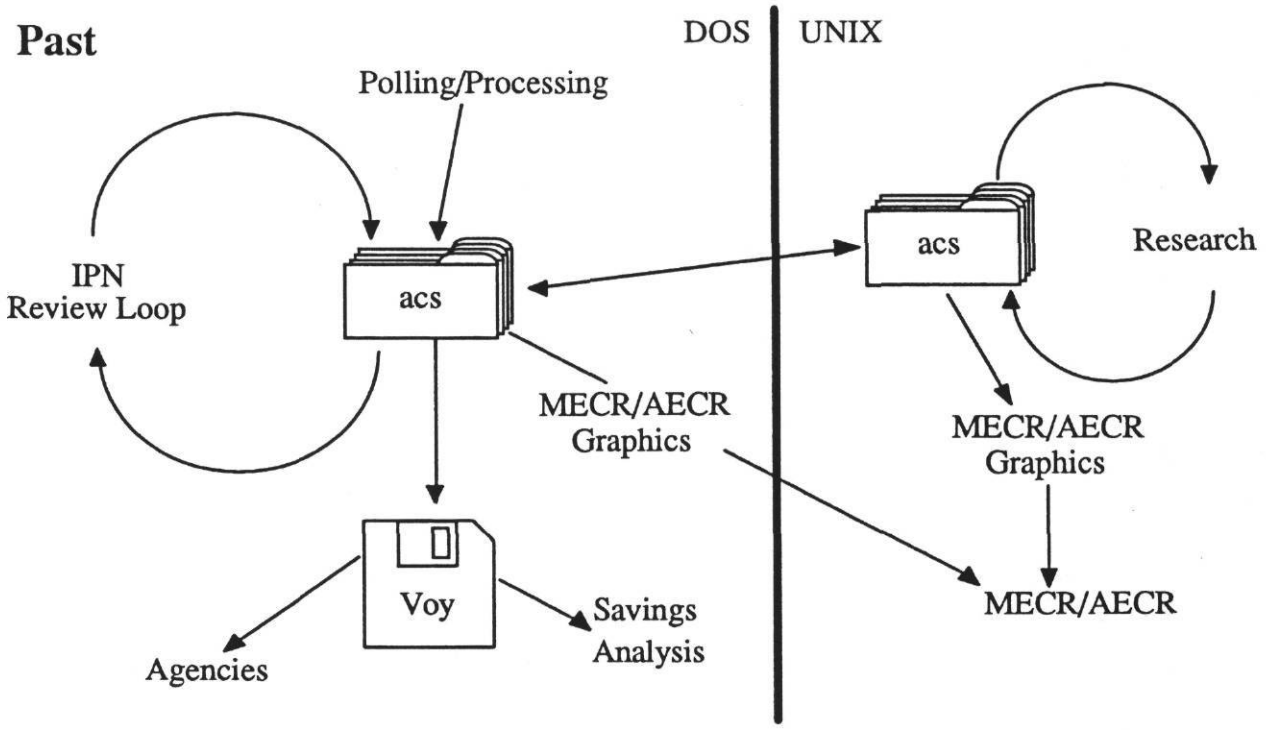
TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE DEVELOPMENT

SOFTWARE DEVELOPMENT

Robert Sparks, Programming Manager
Ron Chambers, Database Administrator
Jeff S. Haberl, P.I.

June 1993


Past
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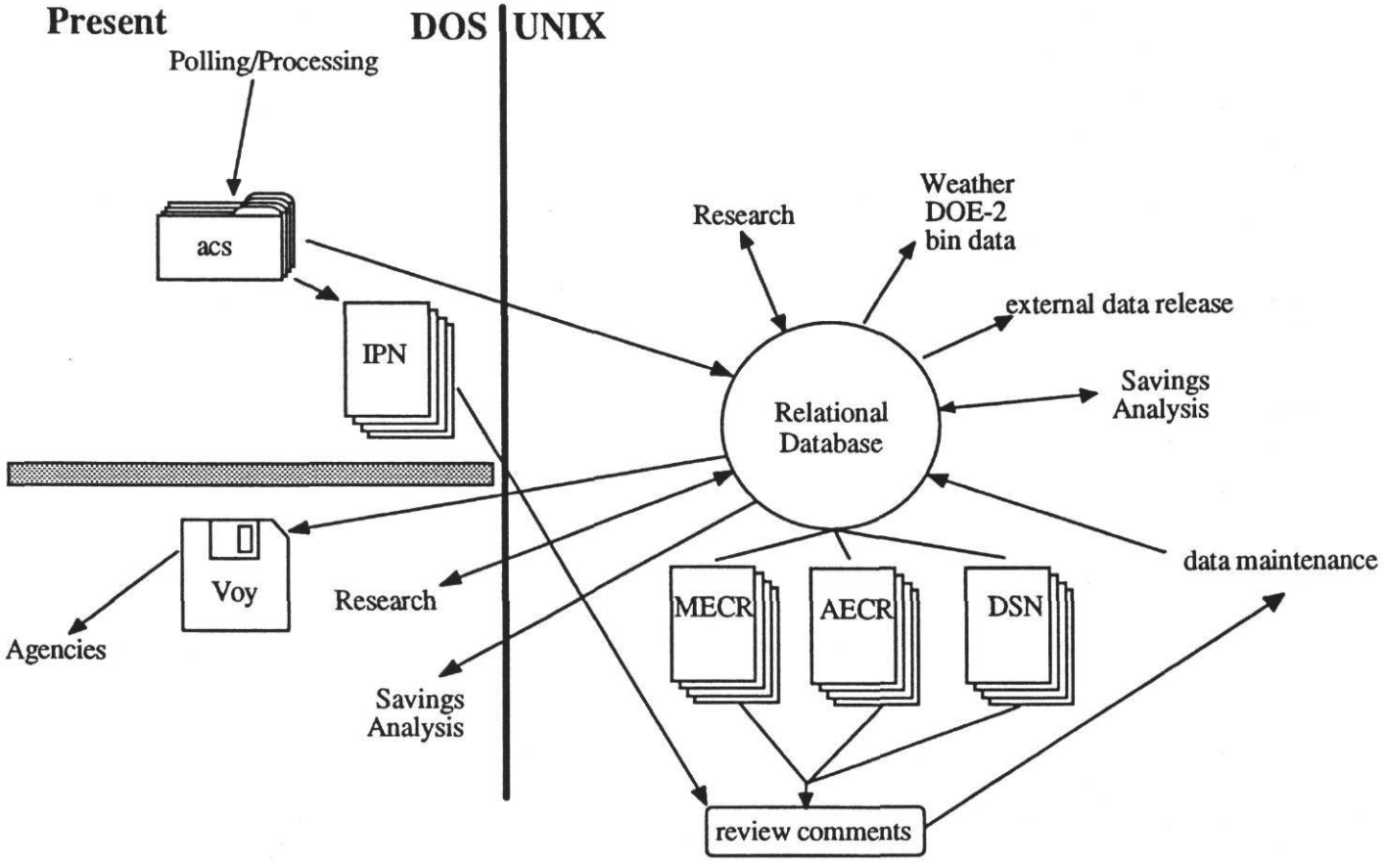
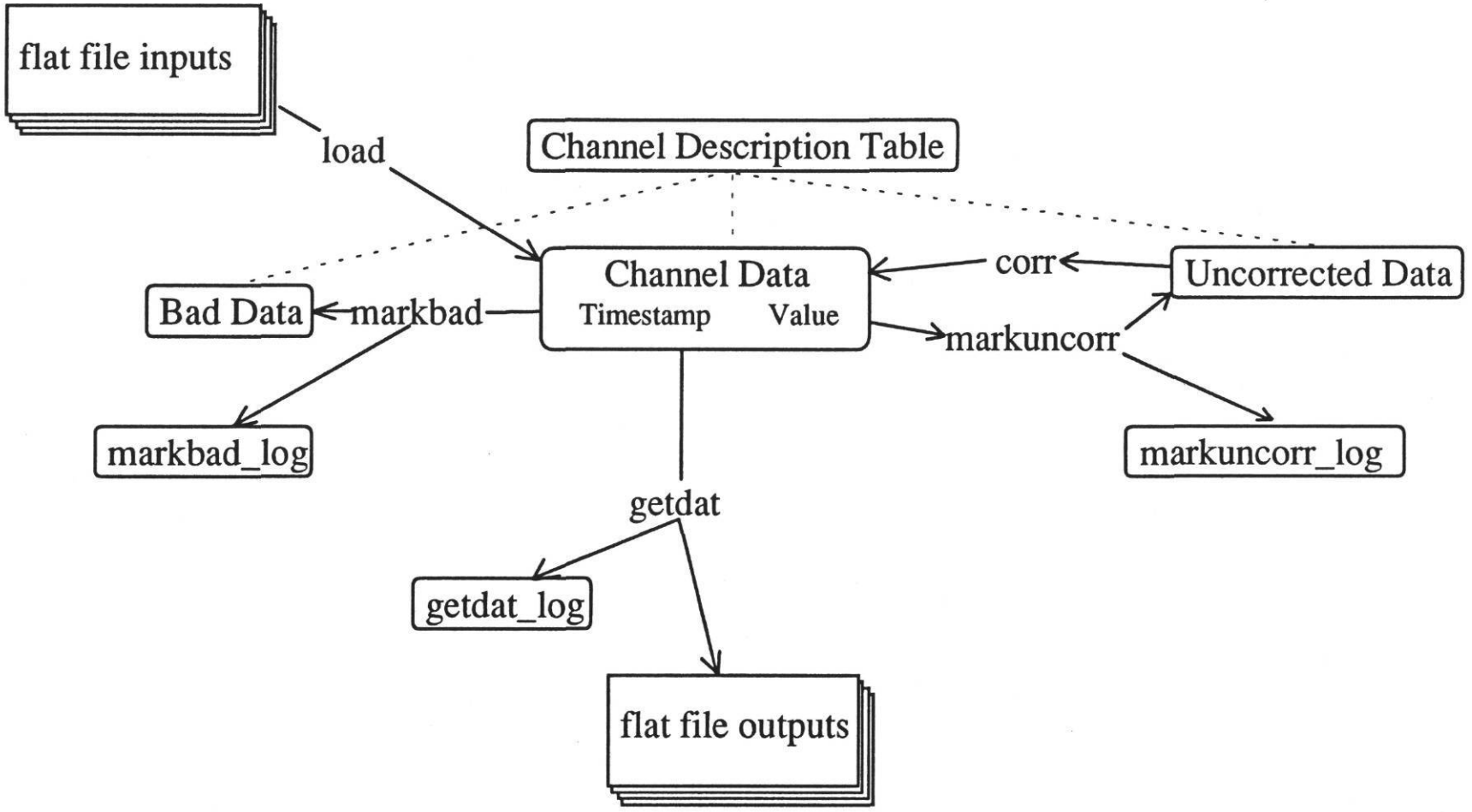
MECR/AECR
Agencies


Present
DOS
UNIX
Polling/Processing
acs
IPN
Research
Weather
DOE-2
bin data
external data release
Savings
Analysis
Relational
Database
data maintenance
Voy
Agencies
Research
Savings
Analysis
MECR
AECR
DSN
review comments

LoanSTAR Database Structure and Status



- 1020 channels of information (over 12 million individual readings to date)
- Growth rate greater than 162000 records per week (2.5 Mb / week)
- < 2% data marked bad
- ~ 6% data requiring correction after collection

MECR Production

Original Production Methods

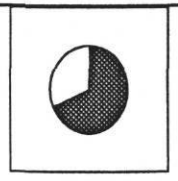
- 3 production machines (2 PCs, 1 UNIX)
- Local databases on production machines requiring distribution time and painstaking propagation of changes
- Each section produced independently requiring frequent operator interaction
- Multiple graphing tools used making maintenance (particularly adding new sites) difficult.

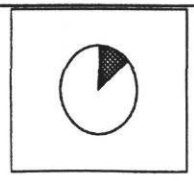
Current Production Methods

- All work done on one machine (UNIX)
- All data accessed directly from relational database
- Entire report for a site initiated with a single command. No further operator attention required.
- All graphics produced in a similar fashion using a single graphing tool (SAS).

Graph/Table Production Times

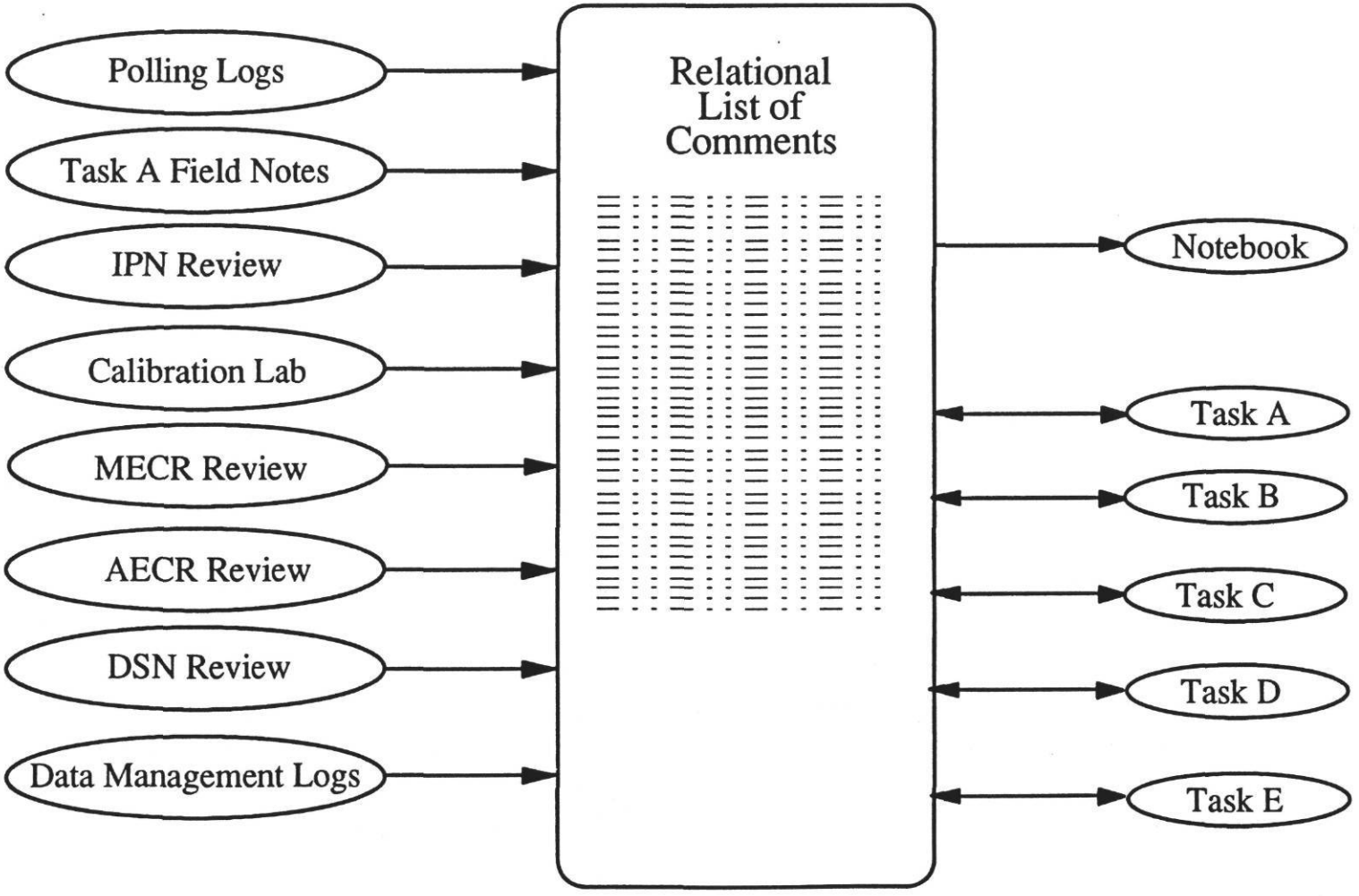
	Original Methods min:sec	Current Methods min:sec
Page 1	1:30	< 1 sec
Page 2	5:00	1:30
Page 3	2:00	0:30
Page 4	4:00	0:45
Page 5	2:00	1:00
Page 6	< 1 sec	< 1 sec
Totals	19 min 30 sec	3 min 45.5 sec
Computing time for 51 sites	16 hours 34 min	3 hours 12 min





iComment

Centralized Commenting and Logging



TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE DEVELOPMENT

ADVANCED DATA VISUALIZATION

Jeff S. Haberl, P.I.
Robert Sparks, Programming Manager

June 1993

ADVANCED DATA VISUALIZATION: HOW CAN IT HELP LOANSTAR?

- Need to quickly identify problematic sensors and report to field crew.

- Difficult to detect bad data from normal data across 70 sites.

- Typical graphical problems:
  - > severe data overlap,
  - > detection,
  - > distance judgments,
  - > limited to weekly plots.

- Consulted the literature on exploratory data analysis (Tukey, Tufte, Cleveland).

ADVANCED DATA VISUALIZATION: HOW TO PROCEED?

EFFECTIVENESS OF ELEMENTARY GRAPHICAL TASKS (1.MOST > 7. LEAST EFFECTIVE)

1. Position along a common scale.
2. Position along an identical non-aligned scale.
3. Length.
4. Angle and slope.
5. Area.
6. Volume.
7. Color hue, color saturation, density.

ADVANCED DATA VISUALIZATION: HOW TO IMPROVE THE LOANSTAR INSPECTION PROCESS.

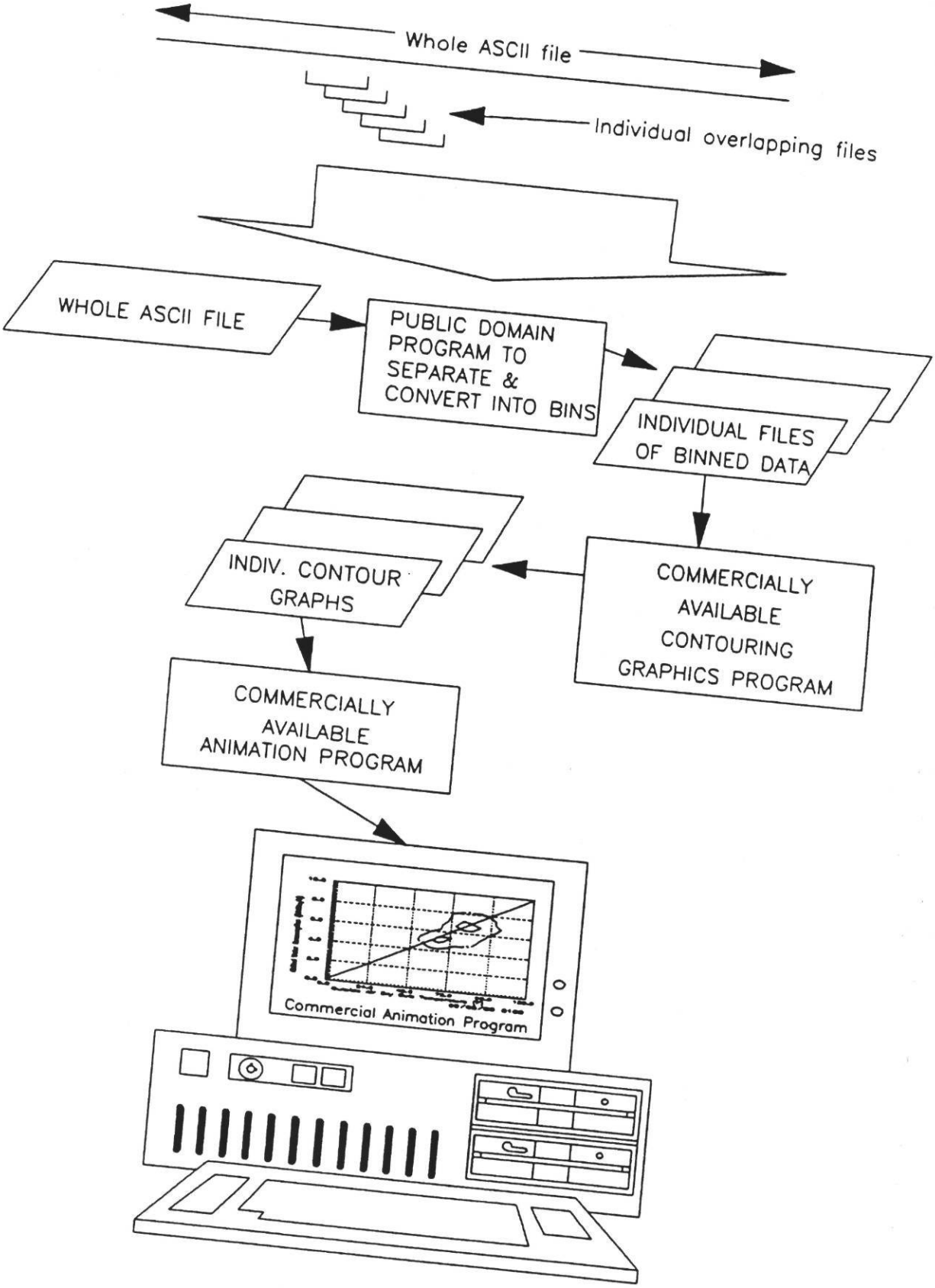
1. *Contour* hourly data points to improve the detection of the central tendency of a group of points.

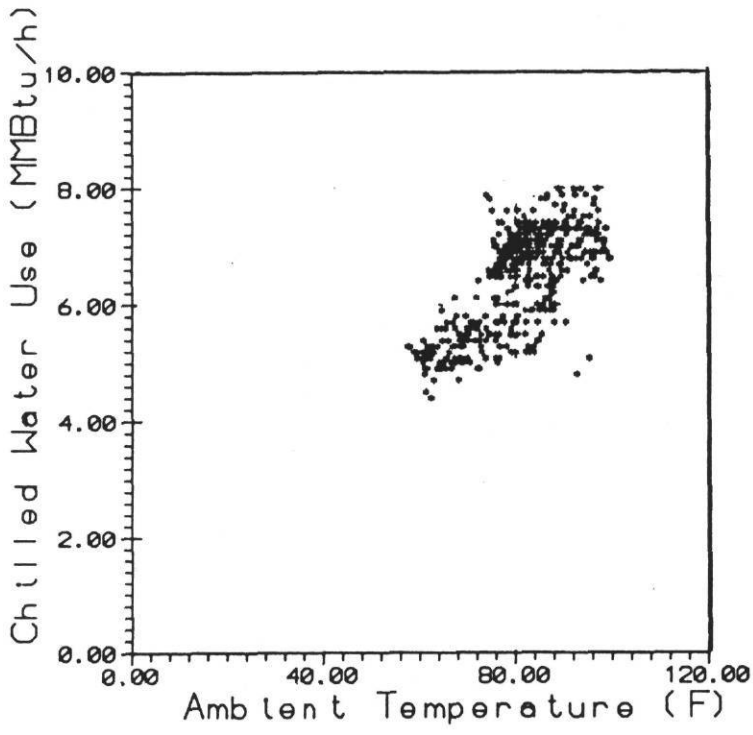
2. Use *dashed horizontal and vertical lines* to assist with the distance judgments (dashed = minor feature).

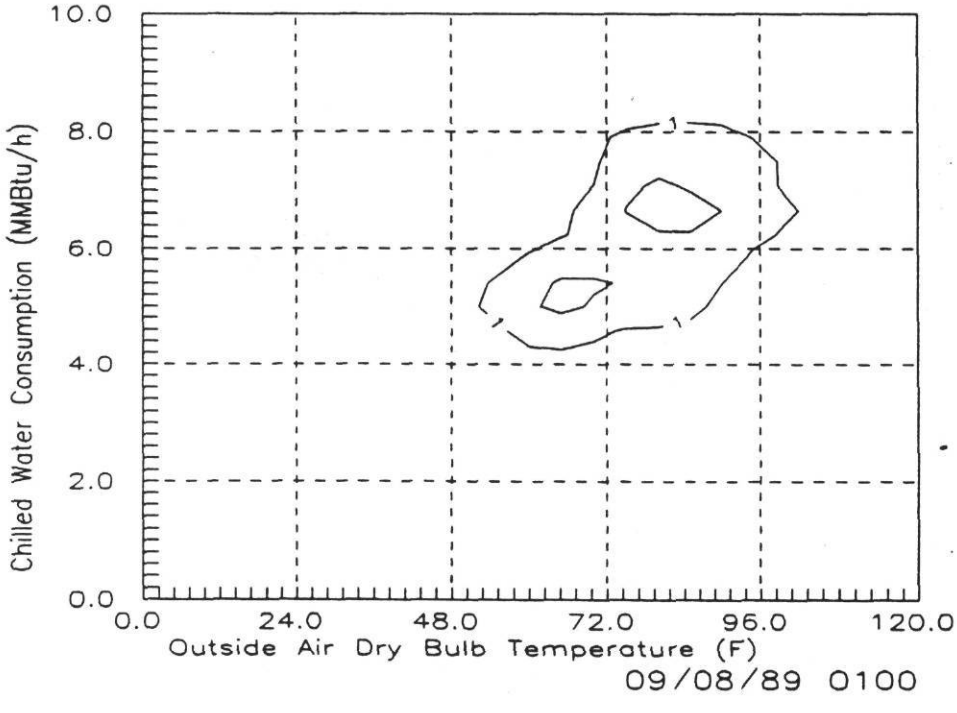
3. *Add a line* to represent the statistical model (if needed) to aid in superposition.

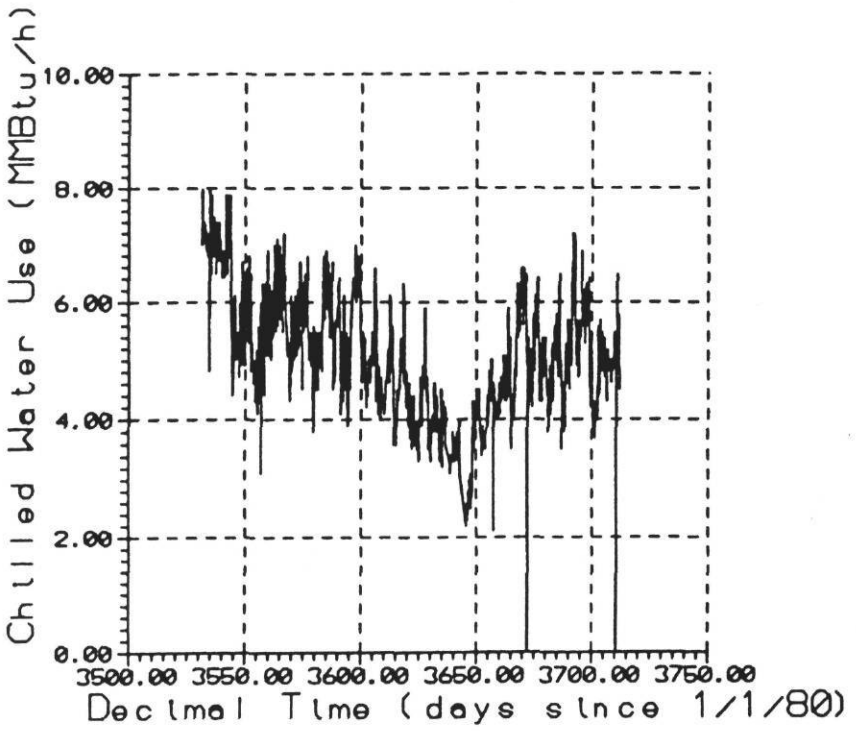
4. Add *time-sequencing* (or animation) to enhance super-positioning.

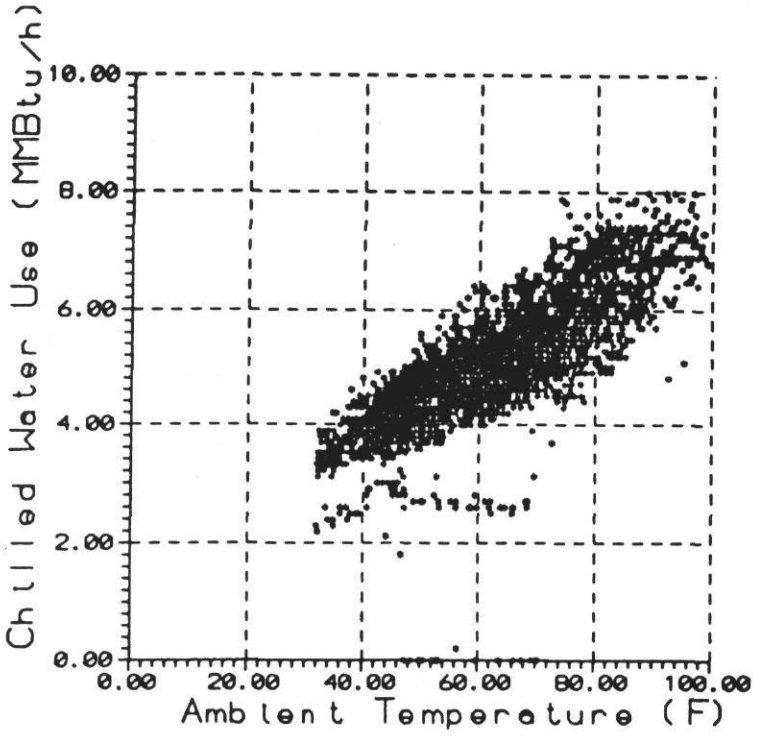
5. Add *date stamp* to assist with frame by frame tracking.

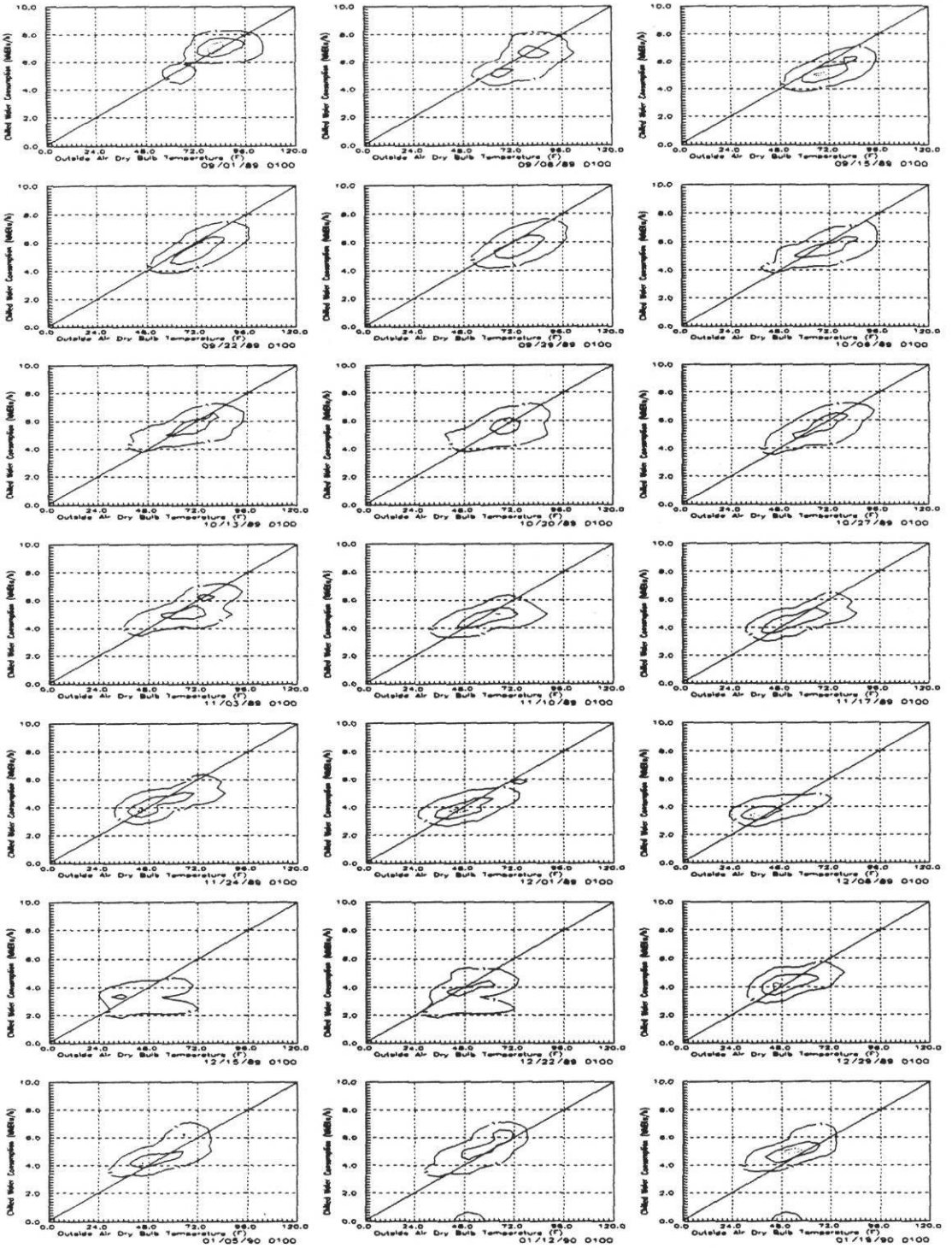

Whole ASCII file
Individual overlapping files
WHOLE ASCII FILE
PUBLIC DOMAIN PROGRAM TO SEPARATE & CONVERT INTO BINS
INDIVIDUAL FILES OF BINNED DATA
INDIV. CONTOUR GRAPHS
COMMERCIALLY AVAILABLE CONTOURING GRAPHICS PROGRAM
COMMERCIALLY AVAILABLE ANIMATION PROGRAM
Commercial Animation Program


Chilled Water Use (MMBtu/h)
10.00
8.00
6.00
4.00
2.00
0.00
0.00
40.00
80.00
120.00
Ambient Temperature (F)


Chilled Water Consumption (MMBtu/h)
10.0
8.0
6.0
4.0
2.0
0.0
0.0
24.0
48.0
72.0
96.0
120.0
Outside Air Dry Bulb Temperature (F)
09/08/89 0100


Chilled Water Use (MMBtu/h)
10.00
8.00
6.00
4.00
2.00
0.00
3500.00 3550.00 3600.00 3650.00 3700.00 3750.00
Decimal Time (days since 1/1/80)


Chilled Water Use (MMBtu/h)
10.00
8.00
6.00
4.00
2.00
0.00
0.00 20.00 40.00 60.00 80.00 100.00
Ambient Temperature (F)


Chilled Water Consumption (MBtu/h)
Outside Air Dry Bulb Temperature (F)
09/01/89 0100
09/08/89 0100
09/15/89 0100
09/22/89 0100
09/29/89 0100
10/06/89 0100
10/13/89 0100
10/20/89 0100
10/27/89 0100
11/03/89 0100
11/10/89 0100
11/17/89 0100
11/24/89 0100
12/01/89 0100
12/08/89 0100
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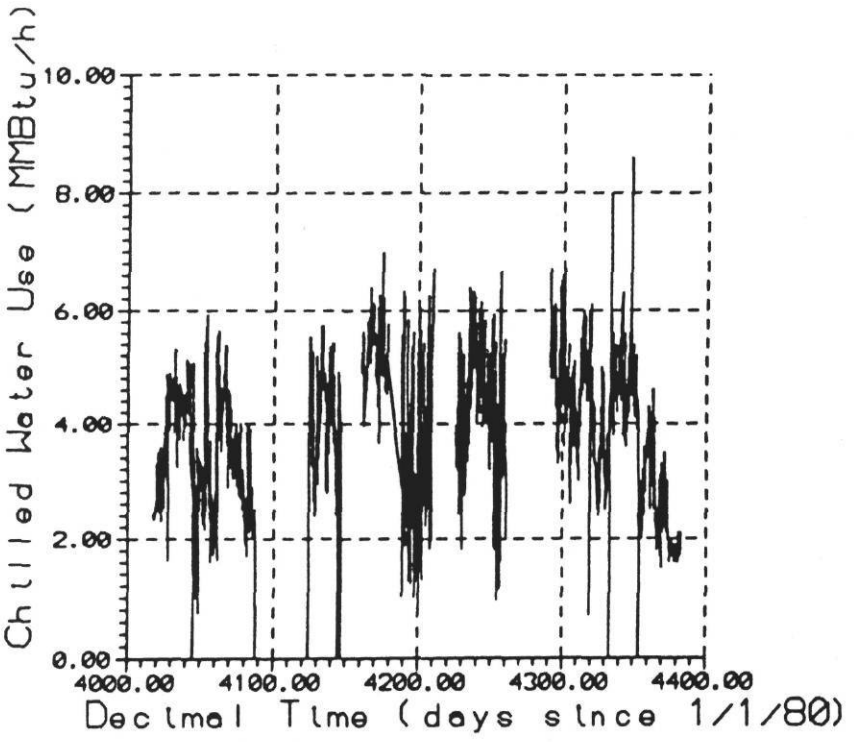
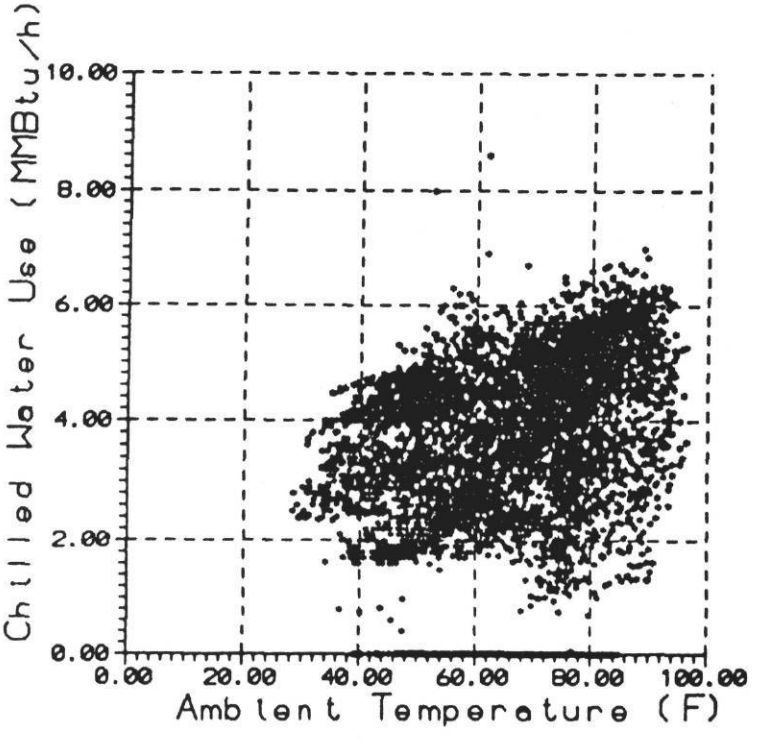
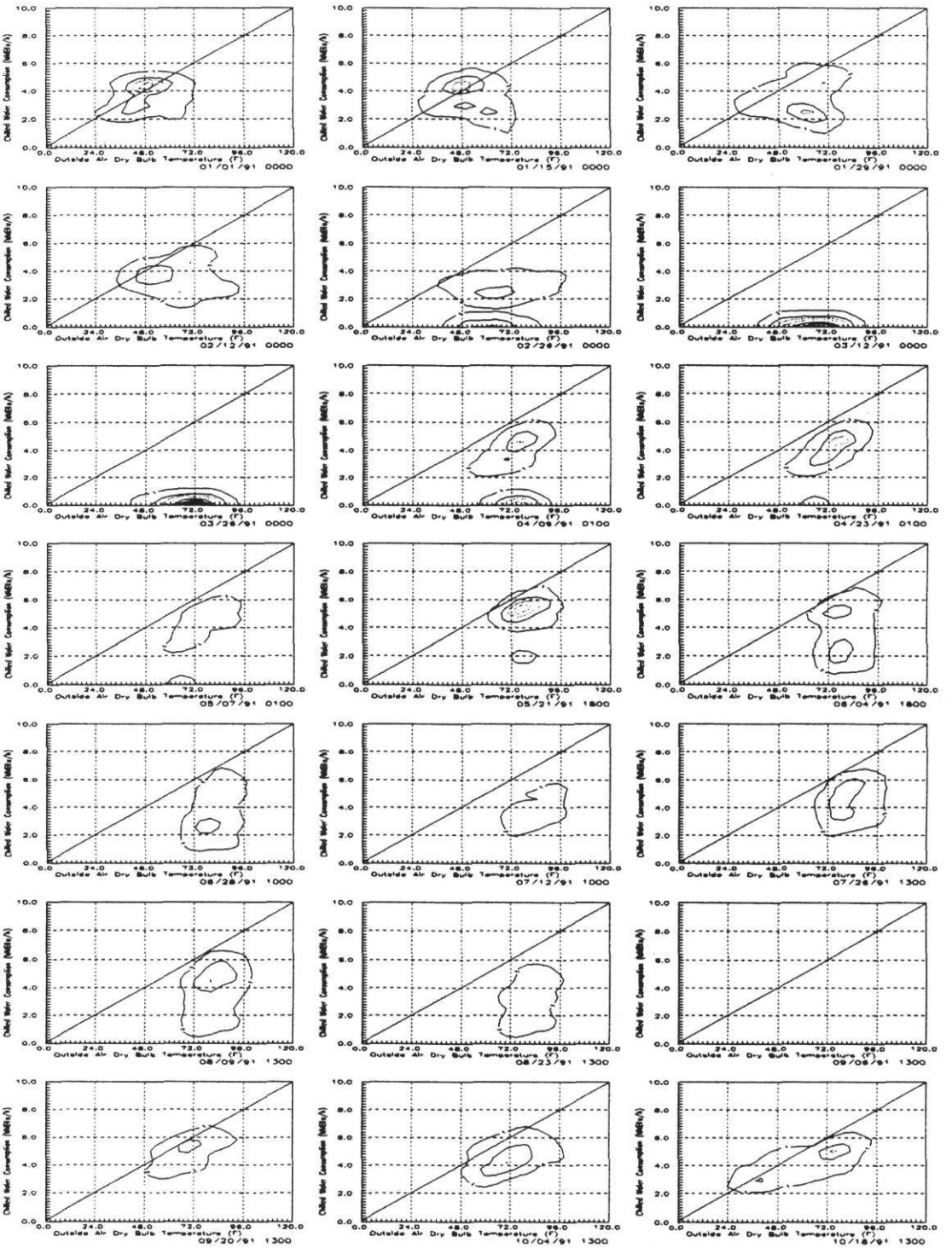
01/05/90 0100
01/12/90 0100
01/19/90 0100


Chilled Water Use (MMBtu/h)
10.00
8.00
6.00
4.00
2.00
0.00
4000.00
4100.00
4200.00
4300.00
4400.00
Decimal Time (days since 1/1/80)


Chilled Water Use (MMBtu/h)
10.00
8.00
6.00
4.00
2.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
Ambient Temperature (F)


Chilled Water Consumption (MBTu/h)
Outside Air Dry Bulb Temperature (F)
01/01/91 0000
01/15/91 0000
01/29/91 0000
02/12/91 0000
02/26/91 0000
03/12/91 0000
03/26/91 0000
04/09/91 0100
04/23/91 0100
05/07/91 0100
05/21/91 1800
06/04/91 1800
06/28/91 1000
07/12/91 1000
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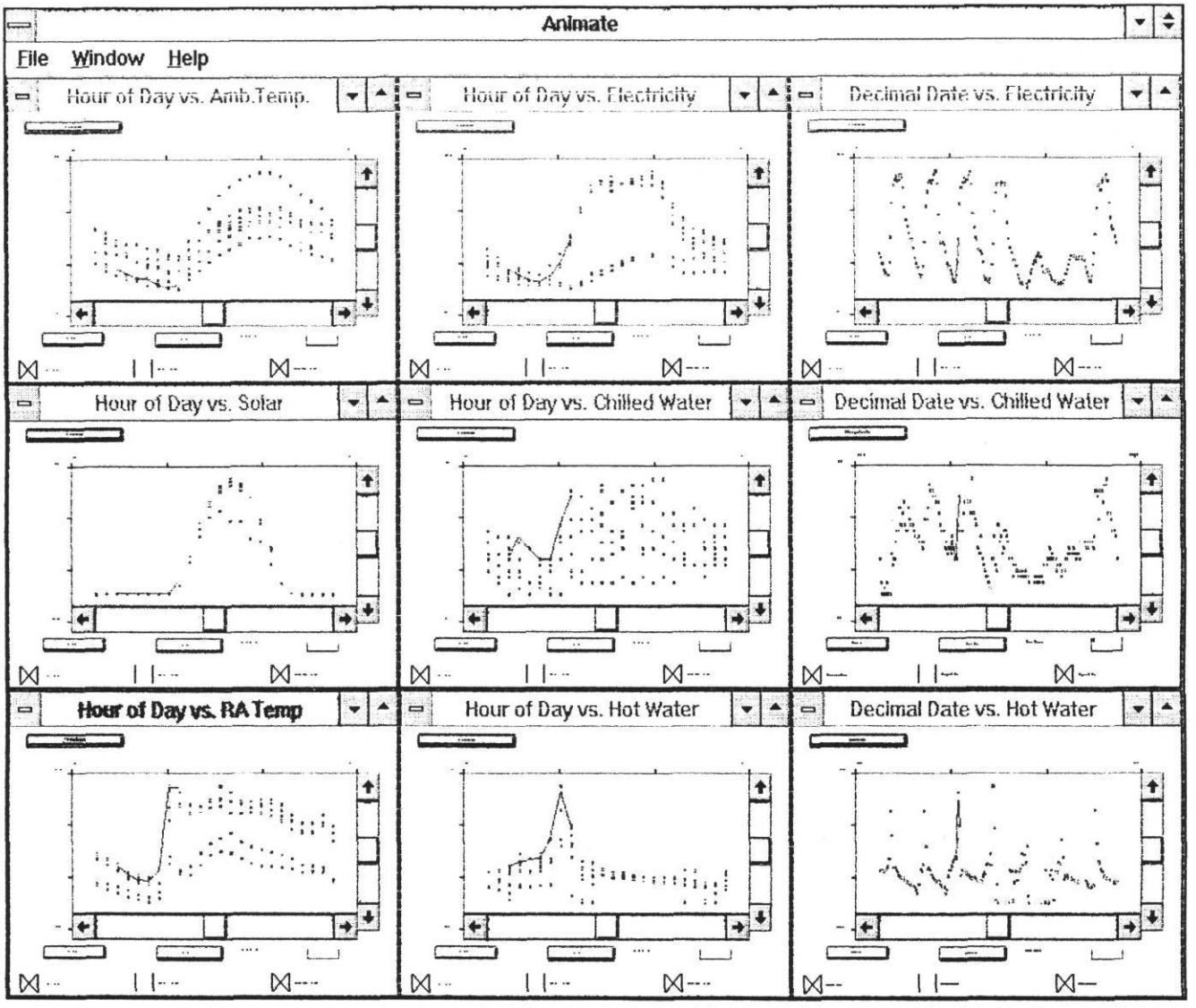
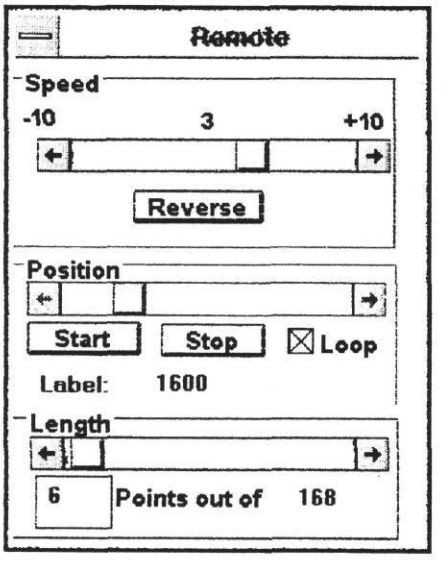
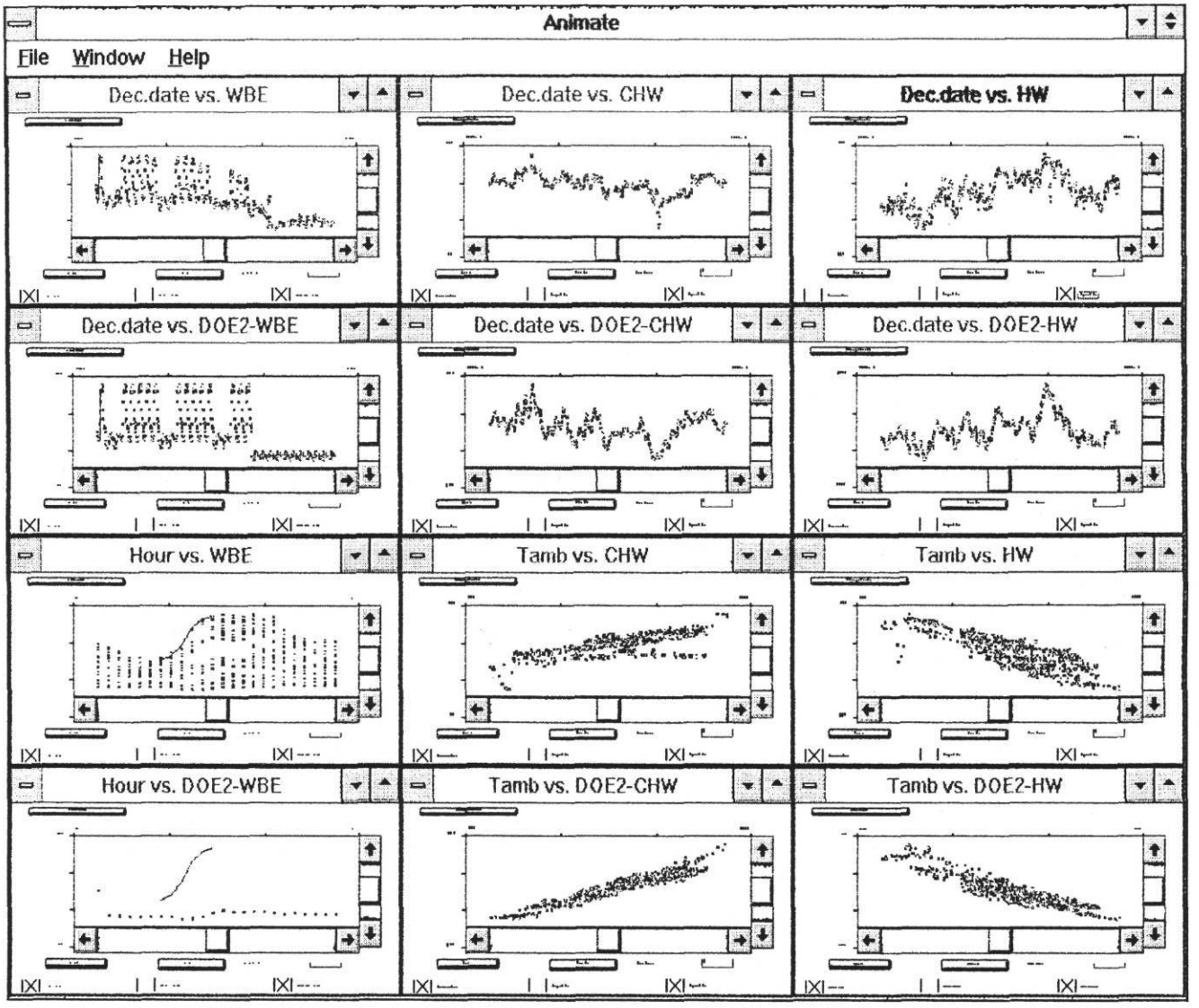
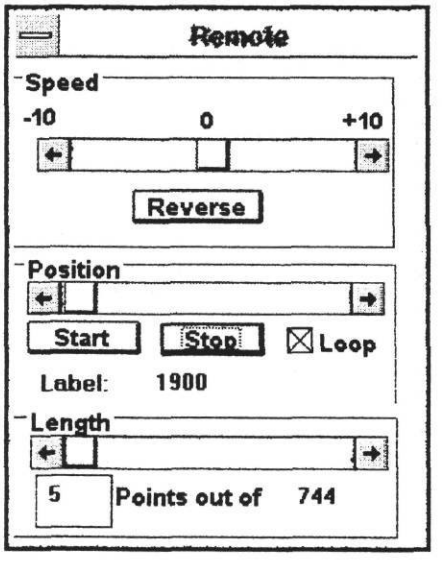
09/06/91 1300
09/20/91 1300
10/04/91 1300
10/18/91 1300


Animate
File Window Help
Hour of Day vs. Amb.Temp.
Hour of Day vs. Electricity
Decimal Date vs. Electricity
Hour of Day vs. Solar
Hour of Day vs. Chilled Water
Decimal Date vs. Chilled Water
Hour of Day vs. RA Temp
Hour of Day vs. Hot Water
Decimal Date vs. Hot Water


Remote
Speed
-10
3
+10
Reverse
Position
Start
Stop
Loop
Label: 1600
Length
6
Points out of 168


Animate
File Window Help
Dec.date vs. WBE
Dec.date vs. CHW
Dec.date vs. HW
Dec.date vs. DOE2-WBE
Dec.date vs. DOE2-CHW
Dec.date vs. DOE2-HW
Hour vs. WBE
Tamb vs. CHW
Tamb vs. HW
Hour vs. DOE2-WBE
Tamb vs. DOE2-CHW
Tamb vs. DOE2-HW


Remote
Speed
-10
0
+10
Reverse
Position
Start
Stop
Loop
Label:
1900
Length
5
Points out of
744

ENERGY SYSTEMS LABORATORY
Dept. of Mechanical Engineering/Texas A&M University
College Station, TX 77843-3123

AVAILABLE SOFTWARE

These packages are available for distribution now. Others will be added as they are ready.
Send inquiries to the attention of Mr. Robert Sparks, ph. 409-847-8779.

1. **023-124** Adjusts time stamps in columnar data to convert from the 0-23 representation of hours to 1-24 representation. $15.00	14. **MK3DSurf** Creates a 3D surface animation from time series data using Golden Software's SURFER and Lantern Corporation's MOVIE. $15.00
2. **3DMac** A Lotus 1-2-3 macro that facilitates graphing 3D surfaces using Intex Solutions' 3D-Graphics. $15.00	15. **MKVoy-DOS** Prepares time series data for compilation into Lantern Corporation's Voyager. $15.00
3. **3DMacXL** A Microsoft Excel v4.0 macro for producing 3D surface plots. $15.00	16. **Min_Conv** Converts an n-minute data stream to an m-minute data stream where n divides m. (e.g. 15 min. to hourly or hourly to daily)r $15.00
4. **Air** Performs psychrometric calculations on columnar data. $15.00	17. **Min_Shift** Moves timestamps in a file by an arbitrary number of minutes (useful for correcting for DST) $15.00
5. **Animate** A flexible MS Windows compatible program for producing X-Y animation of columnar data. $15.00	18. **Missing** Replaces missing records (rows) in columnar data. $15.00
6. **Archive A&M** Princeton Archive with A&M patches. $15.00	19. **PollC180** Unattended polling of Synergistics C180. $15.00
7. **ColRow3D** Converts columnar data to a matrix suitable for input to Intex Solution's 3D-Graphics add-in for Lotus 123. $15.00	20. **PowerFactor** Calculates power factors from kW & kVA on an arbitrary number of phases. $15.00
8. **Datcon** Converts dates and times between Gregorian, Julian and decimal formats. $15.00	21. **PRMWatch** Graphs the output of the Esterline Angus Power Reporter Module in real time. $15.00
9. **EModel** An MS-Windows program for browsing, manipulating, and modeling columnar data (with special features for time series data). It is copyrighted by TEES and Kelly Kissock for distribution in the public domain. $100.00	22. **Psychrometric plotting with Grapher** A .plt template of a psychometric chart for use with Golden Software's Grapher. $15.00
10. **KWC** A PC-based interface to the Acurex Autocalc which includes program editing and real time graphics. $15.00	23. **Raw2Dat** Cleans Synergistics data for use with Archive (see the LoanSTAR Monitoring Workbook). $15.00
11. **LoanSTAR Monitoring Workbook** This workbook is intended to be a stand-alone survival guide to acquiring energy use and environmental data in buildings. It includes monitoring procedures and data analysis routines developed for the Texas LoanSTAR program and is copyrighted for distribution in the public domain. *$35.00 - Write for availability.*	24. **TimeMerge** Combines two timestamped data streams, merging on the timestamp fields. $15.00
12. **MKMov** Produces contour animation from time series data using Golden Software 's SURFER and Lantern Corporation's MOVIE. $15.00	25. **Xair** X windows utility psychometric calculator. $15.00
13. **MkMov3D** Creates a 3D animation from time series data using Lotus 123, Intex Solution's 3D Graphics and Lantern Corporation's MOVIE. $15.00	26. **Solrpath** A graphical preprocessing program that plots Olgyay's sunpath diagram and shading protractor for any location. Requires Grapher. $15.00

TEXAS LoanSTAR
MONITORING & ANALYSIS PROGRAM

TASK D

ANALYSIS & SOFTWARE DEVELOPMENT: ANALYSIS DEVELOPMENT ACCOMPLISHMENTS

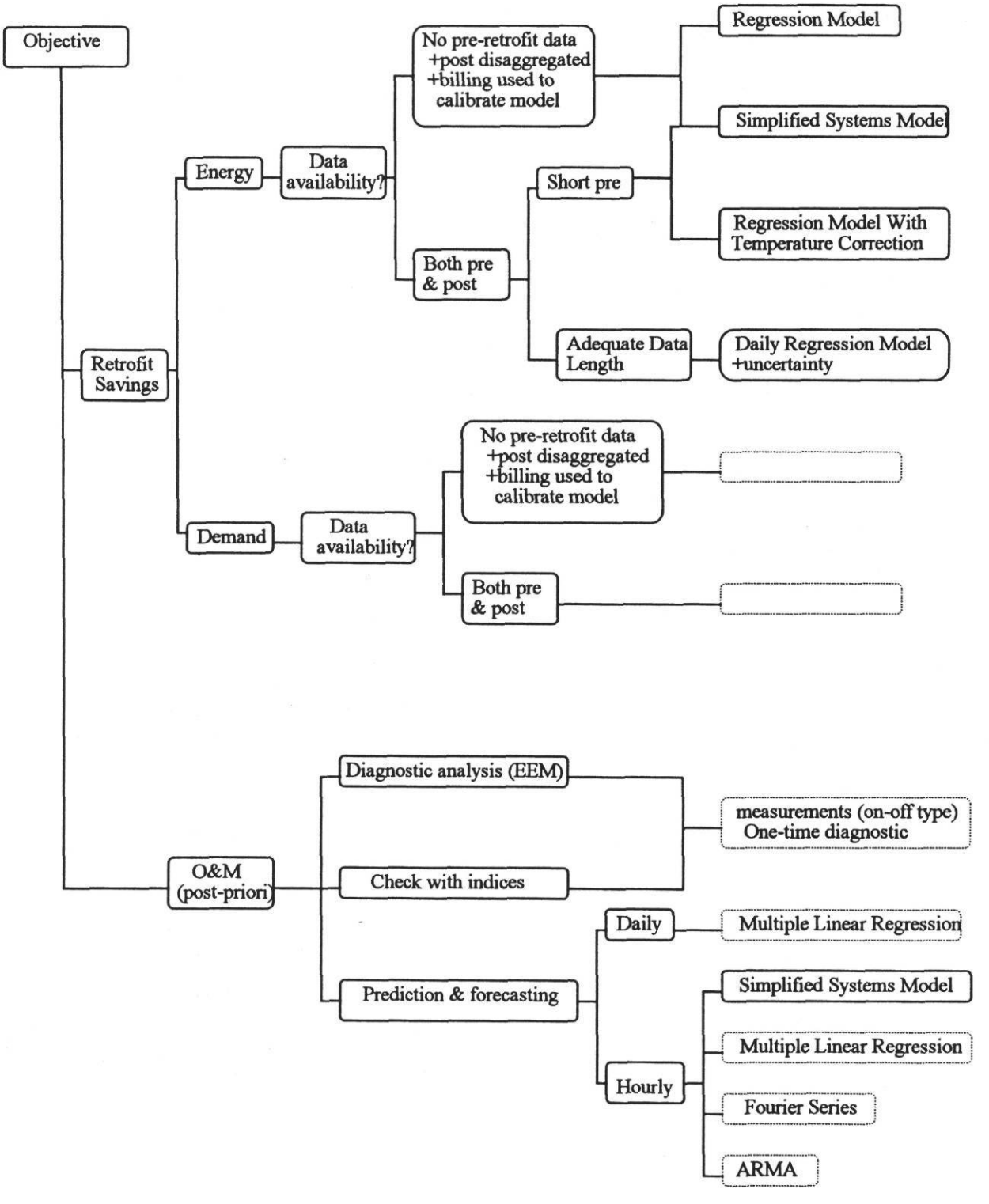
David E. Claridge, Ph.D., P.E.
Jeff S. Haberl, Ph.D., P.E.
T. Agami Reddy, Ph.D.
Srinivas Katipamula, Ph.D.
Kelly Kissock

Presentation to the MARC Meeting

by

David E. Claridge
June 3, 1993

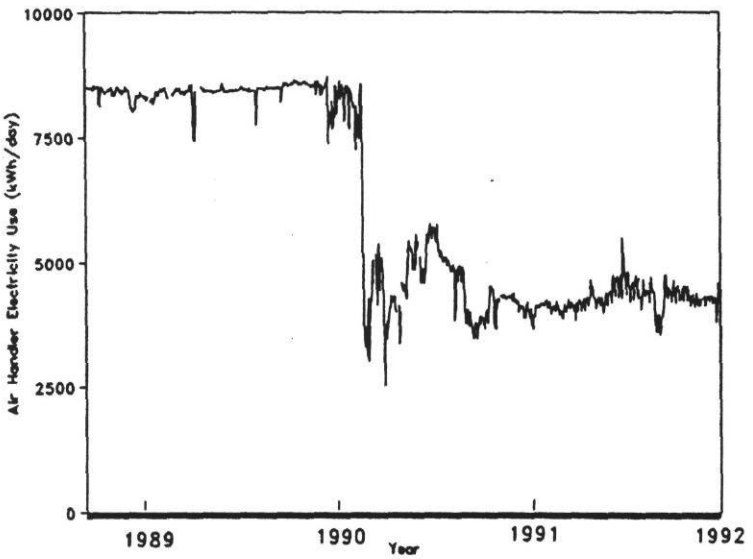
LOANSTAR ANALYSIS PROCEDURES



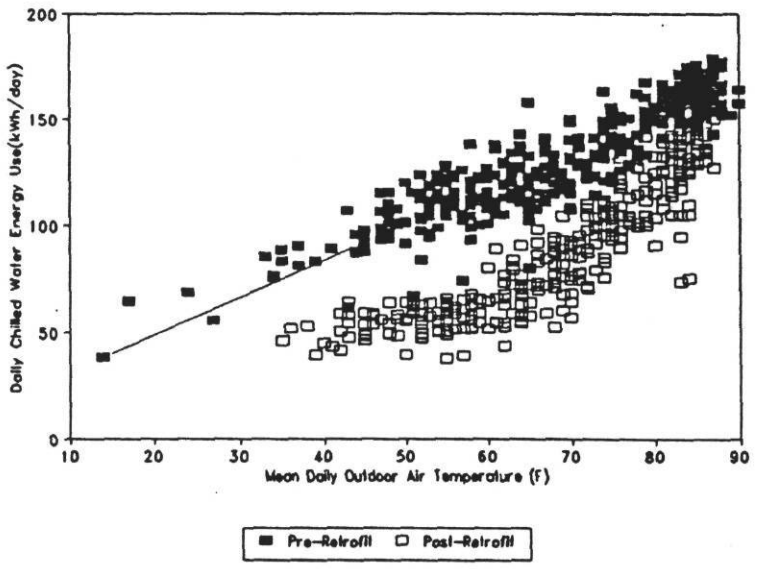
SAVINGS MEASUREMENT

For the case with adequate pre-retrofit data savings are measured as the difference between a pre-retrofit baseline and measured post-retrofit consumption as illustrated.

Typical Pre and Post-Retrofit Air Handler Electricity Use



Typical Pre and Post-Retrofit Chilled Water Energy Use



INVESTIGATION OF THE ANNUAL PREDICTIVE ABILITY OF MODELS FROM SHORT PRE-RETROFIT PERIODS

Motivation

- The majority of our pre-retrofit data sets are less than a year long.
- Models from these "short" data sets may not accurately predict annual energy use.
- This may influence our determination of energy savings.

Objectives of Study

- Determine if and by how much models from short data periods mispredict annual energy use.
- Determine the characteristics of short data periods which influence their annual predictive ability.
- Outline methods to adjust models from short data periods to more accurately predict annual energy use.

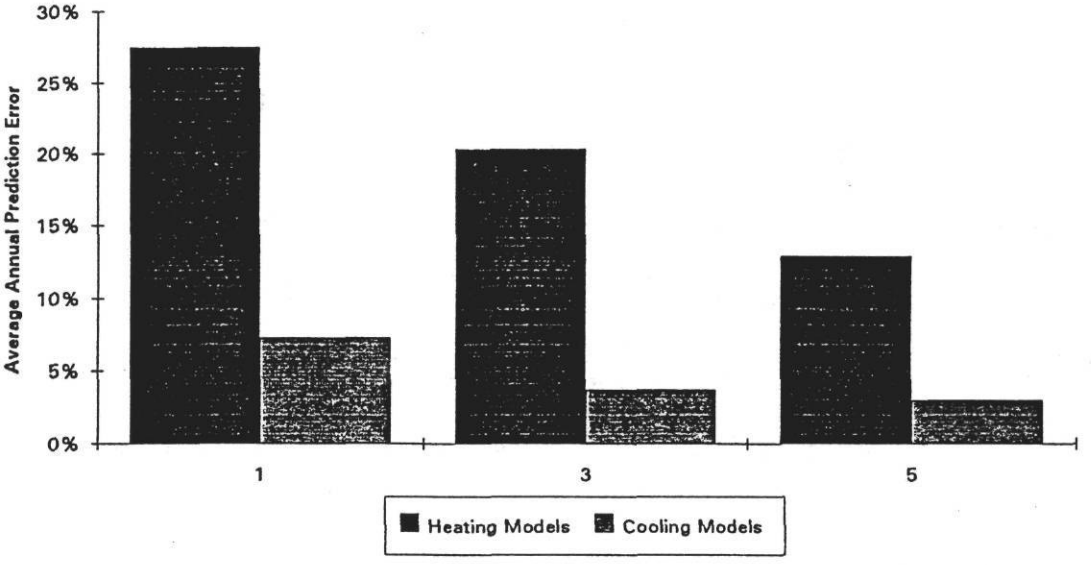
Methodology

- Limit study to simple linear regression models.
- Divide 5 year-long data sets into groups of short data sets that range from one to five minutes in length.
- Compare the annual predictive ability of models from the short data sets to the actual annual energy use using:

$$\text{Normalized Annual Energy Use} = E_{short}/E_{annual}$$

Average Annual Prediction Error of Models Based on One, Three and Five Month Sliding Windows

$$\text{Average Annual Prediction Error} = \frac{\sum_{i=1}^{12} \left| \text{NAEU}_i - 1 \right|}{12}$$



CONCLUSIONS

- Models based on short data periods may seriously misrepresent annual energy use.
- Models from longer data periods are more accurate than models from shorter data periods.
- The best predictors of both cooling and heating annual energy use are models from data-sets with mean temperatures close to the annual mean temperature.
- Cooling models from warm months tend to over-predict annual energy use and models from cool months tend to under-predict annual energy use.
- Heating models from warm months tend to under-predict annual energy use and models from cool months tend to over-predict annual energy use.

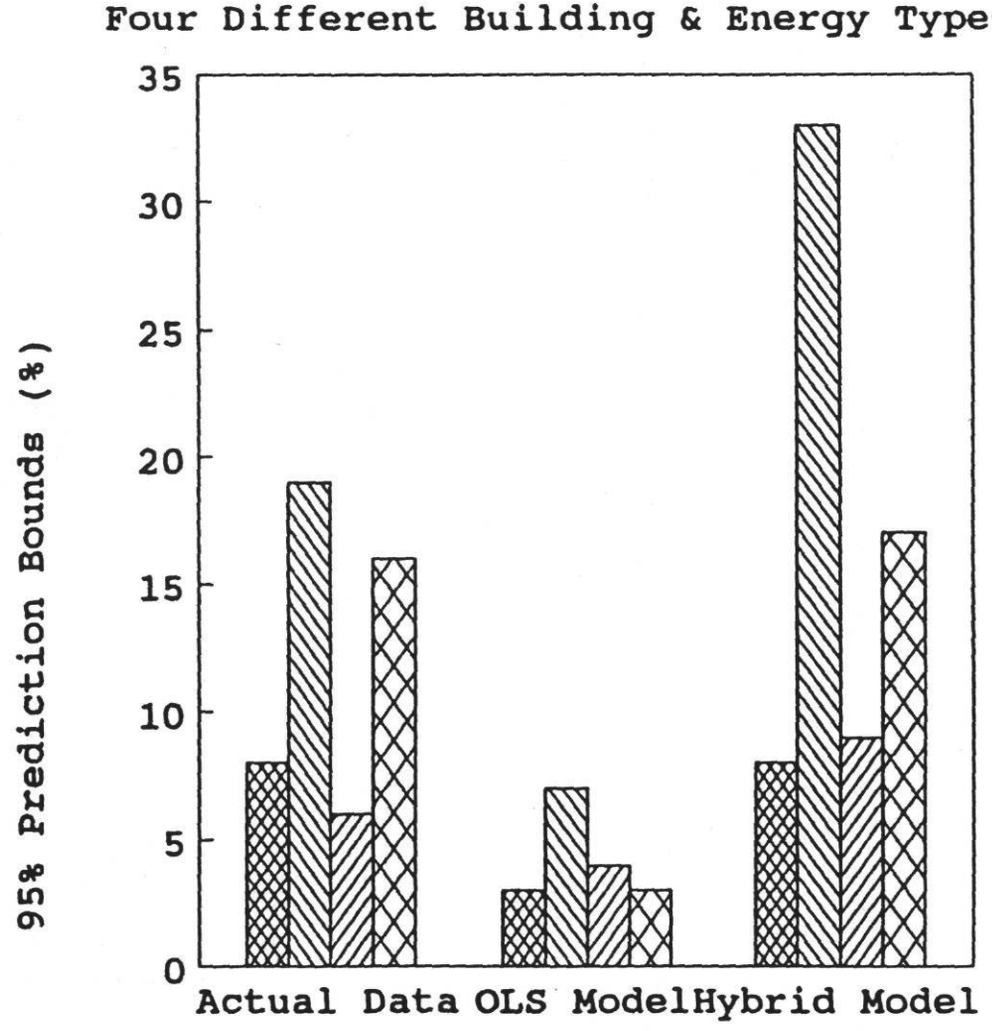
Estimating Uncertainty in Measured Retrofit Savings

- Statistical models are not "perfect". Energy use models have strong residual patterns which invalidate use of standard equations for estimating uncertainty.

- "Hybrid" model approach has been developed which is akin to Ordinary Least Squares in terms of model prediction but which is far more realistic in terms of estimating uncertainty bounds.

- Currently in the process of coding the equations for uncertainty in the LoanSTAR retrofit savings routines.

Comparison of Uncertainty Bounds

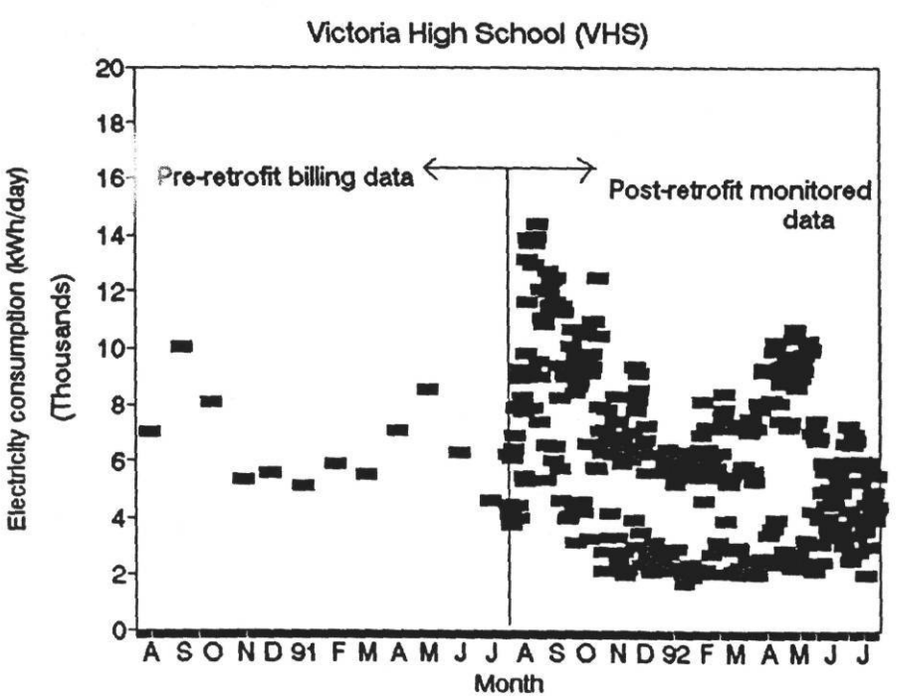


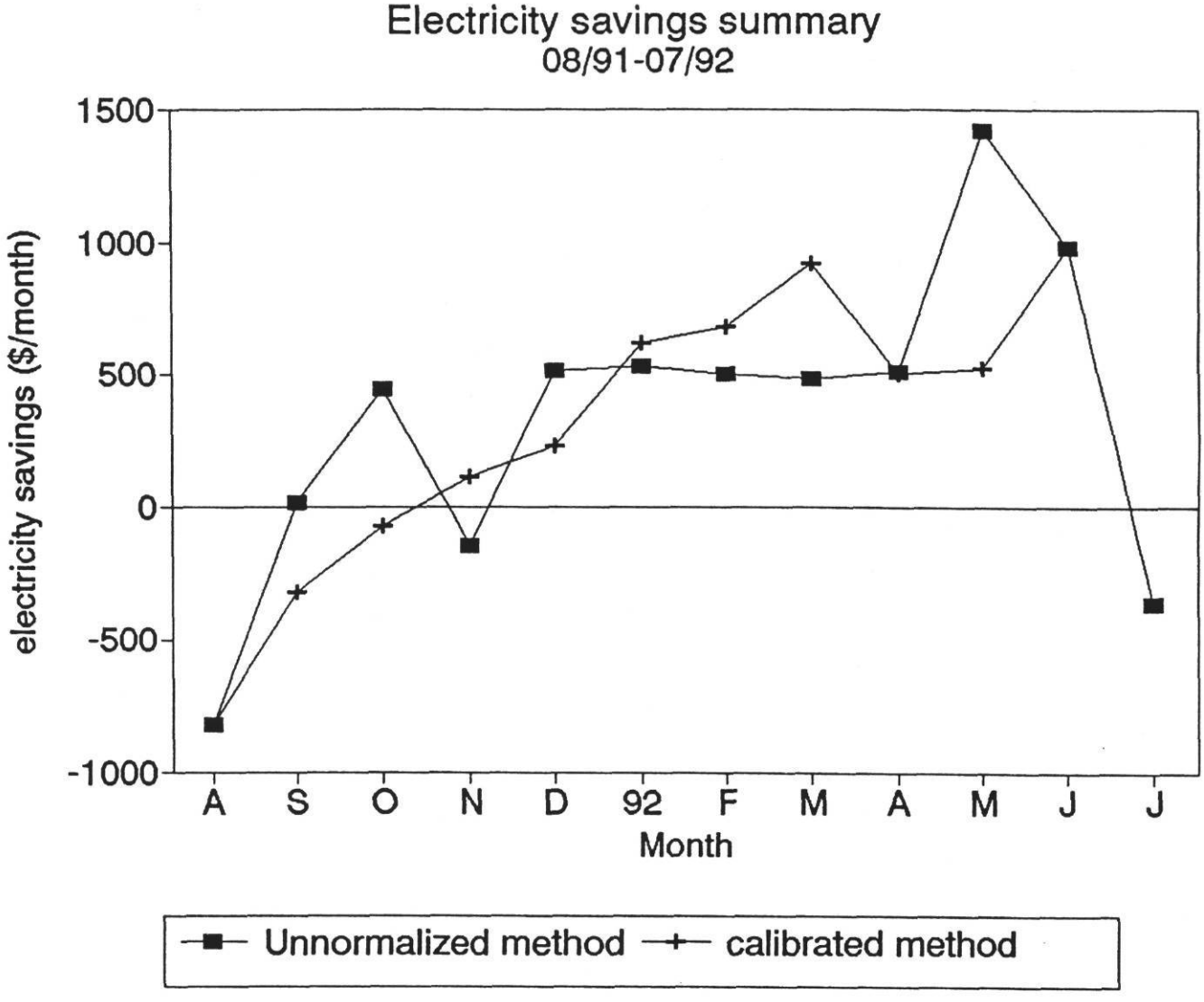
Retrofit Savings In Buildings With "Mixed" Data

- "Mixed" data - Pre-retrofit utility bills
  Post-retrofit monitored data

- Unnormalized utility bill comparison.

- Calibrated method - monitored data used to develop a statistical model which is calibrated to pre-retrofit utility bills.

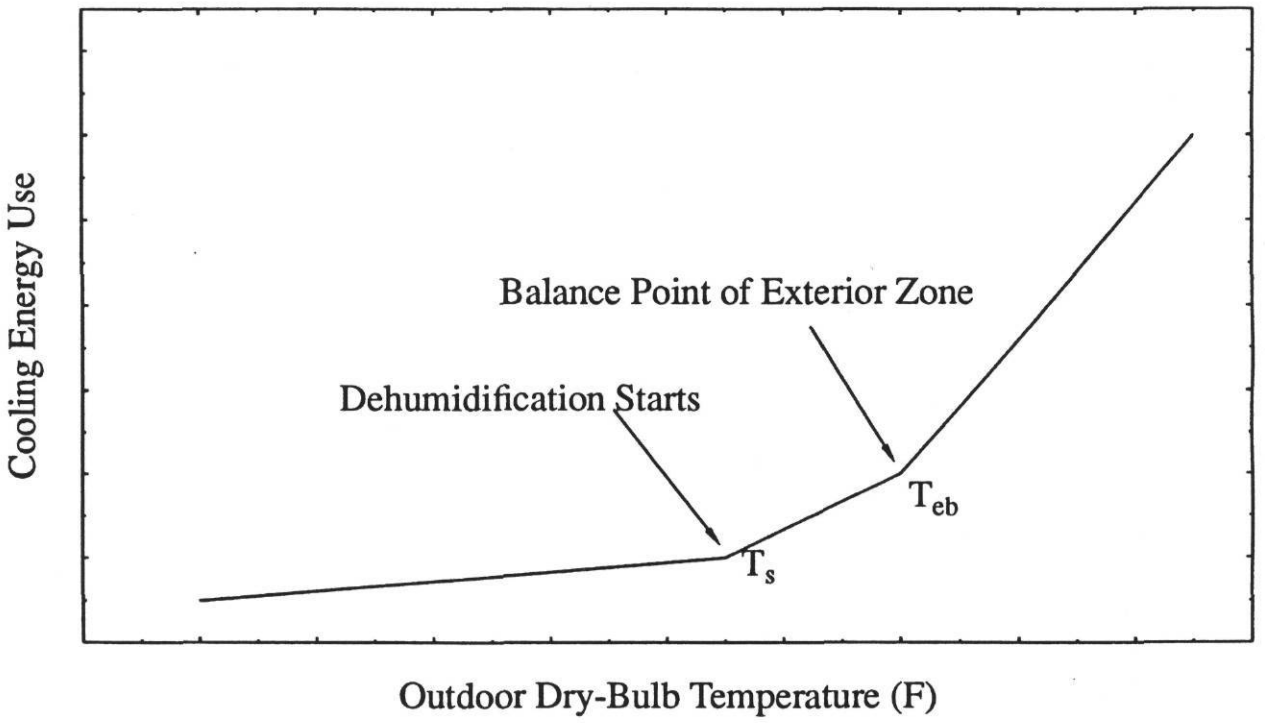




VHS COST SAVINGS SUMMARY

	ELEC. ENERGY	ELEC. DEMAND	ELEC. TOTAL	GAS	TOTAL
	($/MON)	($/MON)	($/MON)	($/MON)	($/MON)
TOTAL	3333.796	-6907	-3573.2	18924.62	15351.42

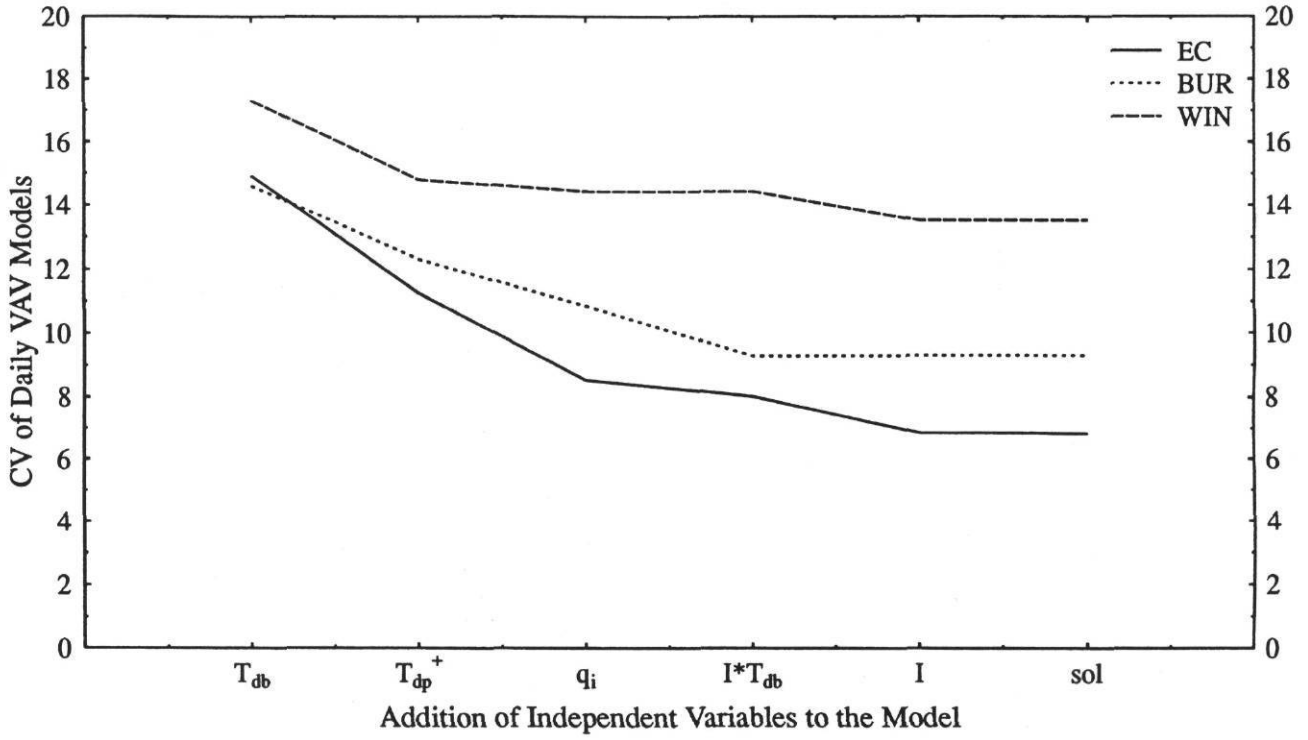
Regression Model Based on Engineering Principles



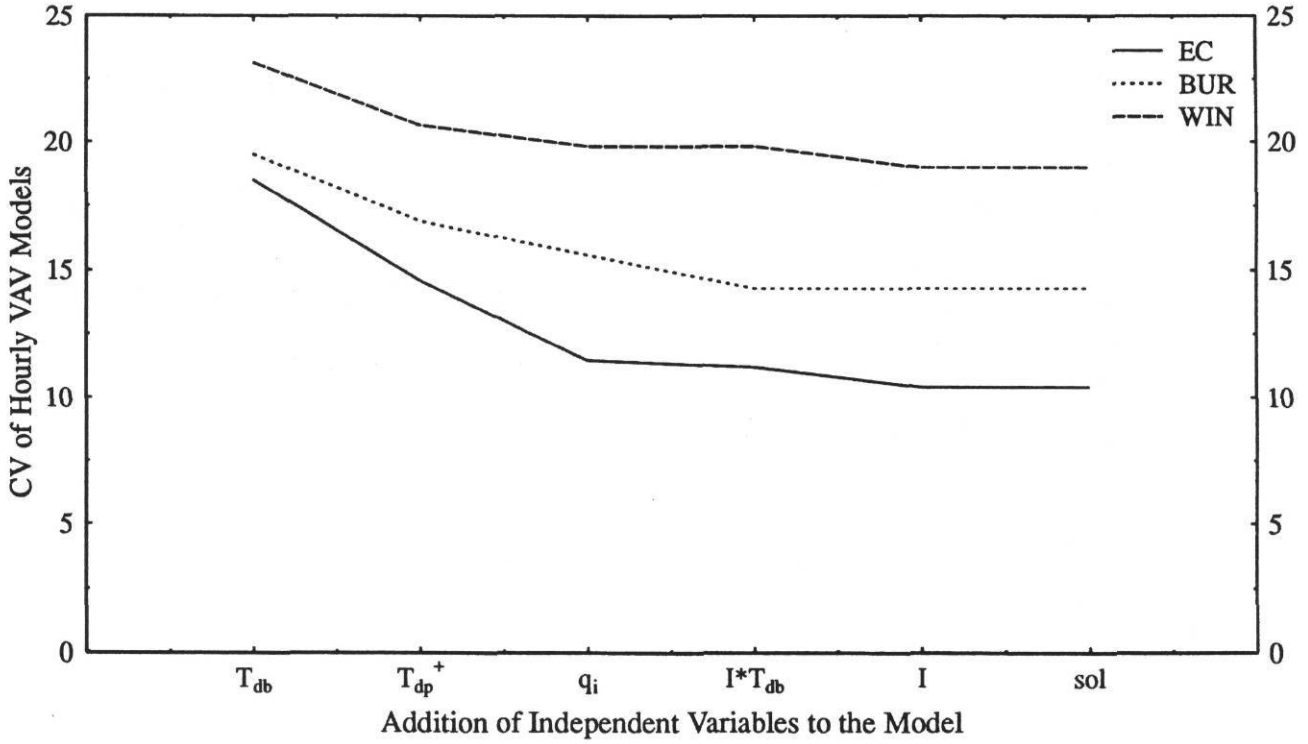
Piece-Wise Multiple Linear Model Above is a Function of:

T_o	Outdoor Dry-Bulb Temperature
T_{dp}^+	Positive Values of (T_{dp} - T_s)
T_{dp}	Outdoor Dew-Point Temperature
T_s	Surface Temperature of Cooling Coil
q_i	Internal Gains
T_{eb}	External Zone Balance Point Temperature

Change in CV With Addition of Independent Variables to VAV Models



Daily



Hourly

Energy Efficiency Index due to Mixing (EEM)

- Simultaneous Heating and Cooling of Air Streams due to Multiple Zones in Building

- $$EEM = \frac{\text{Single} - \text{Zone Building Load}}{\text{Actual Heating and Cooling Energy}} = \frac{|CW - HW|}{CW + HW}$$

  where CW: whole-building cooling energy use
  HW: whole-building heating energy use

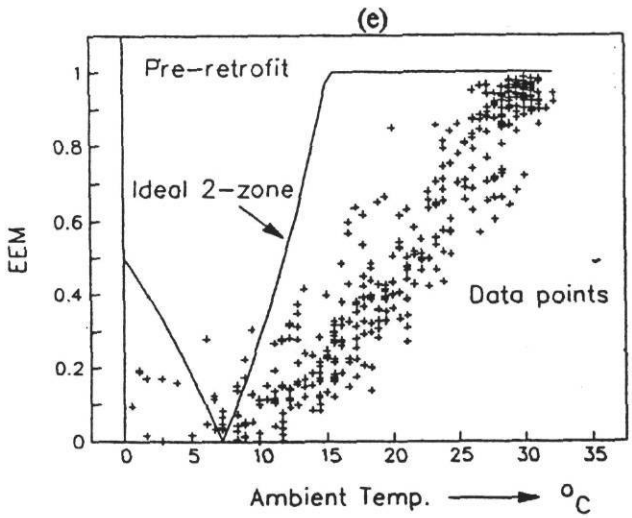
- EEM_{Ideal} (1-zone) = 1

- EEM_{Ideal} (2-zone) < 1

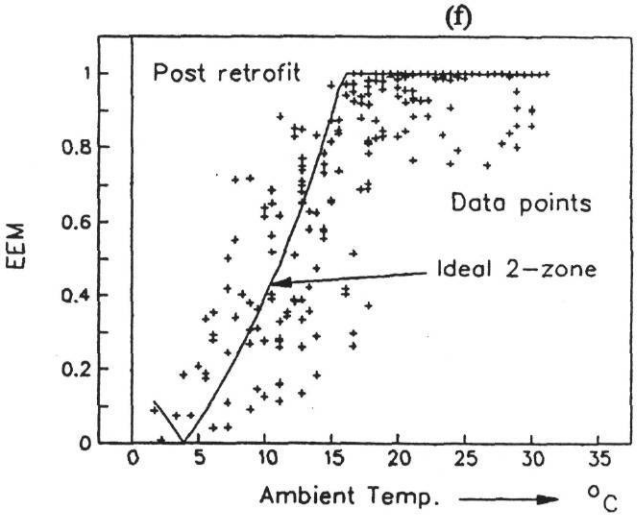
- Index can be used to rate HVAC performance on ABSOLUTE basis (similar to Carnot Efficiency for heat engines)

Building A

Pre-Retrofit

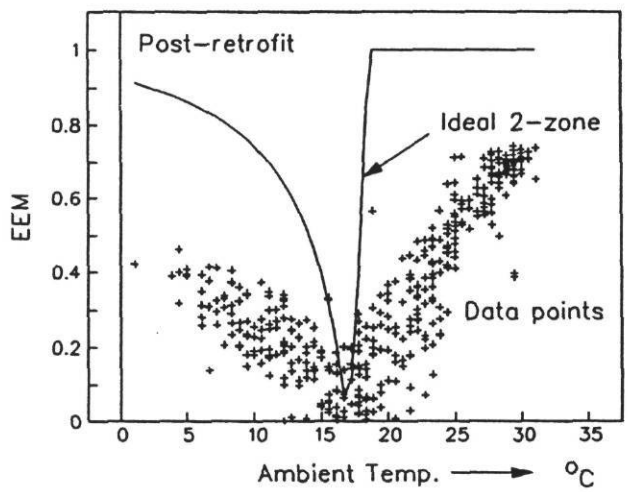


Post-Retrofit



Building B

Post Retrofit



Additional Analysis Development Initiated

- Fourier Series Modeling of Hourly Data
- Artificial Neural Net Modeling
- Demand Modeling of Chillers

LOANSTAR MONITORING & ANALYSIS PROGRAM

TASK D

ANALYSIS & SOFTWARE DEVELOPMENT: SAVINGS MEASUREMENT ACCOMPLISHMENTS

David E. Claridge, Ph.D., P.E.
Jeff Haberl, Ph.D., P.E.
Kelly Kissock
Jinrong Wang

Presentation to the MARC Meeting

by

David E. Claridge
Kelly Kissock

June 3, 1993

SAVINGS OVERVIEW

Savings determined at 24 sites representing 38 buildings

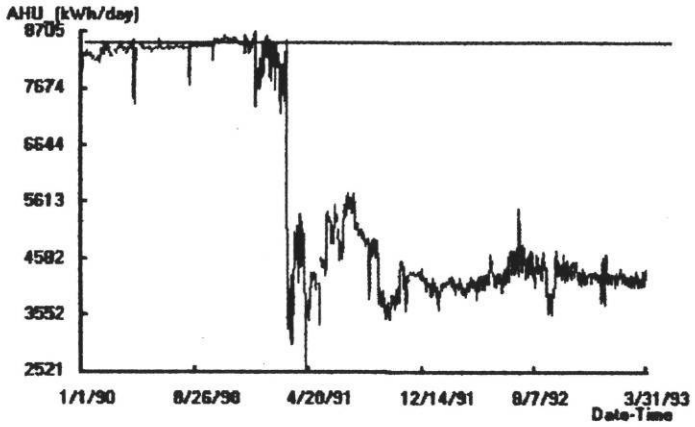
Types of Savings

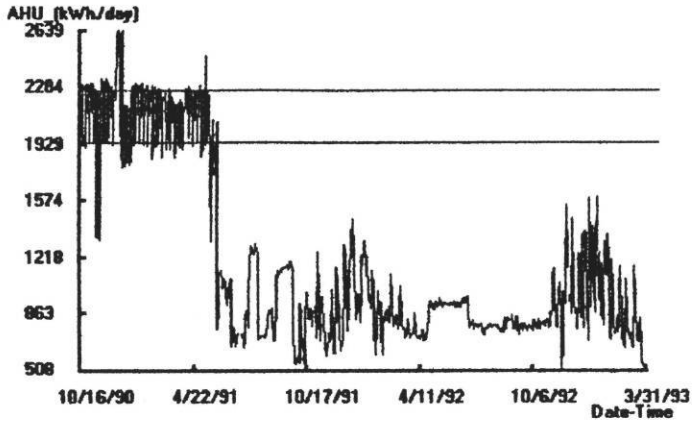
- Cooling (18 sites)
- Heating or Gas (20 sites)
- Air Handler Electricity (20 sites)
- Lighting Electricity (4 sites)
- Electrical Demand (3 sites)

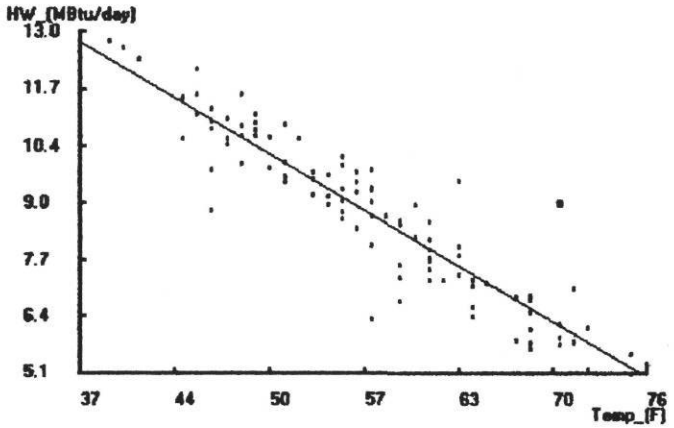
Savings Measurement Methodologies

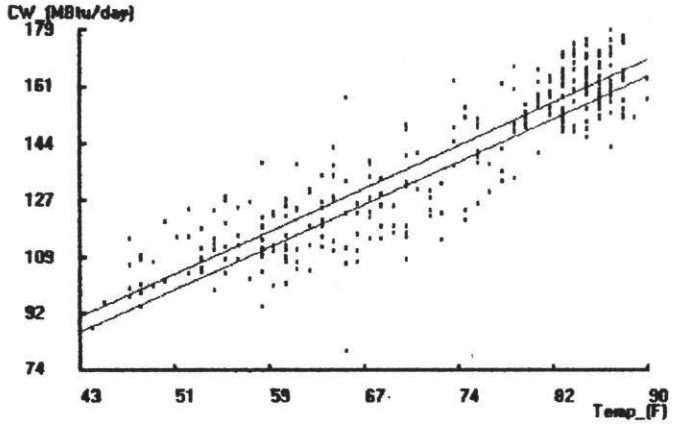
- Regression models of daily energy use (18 sites)
- Regression models of hourly energy use (2 sites)
- Utility billing data and hourly energy use (2 sites)
- Calibrated simplified systems models (2 sites)

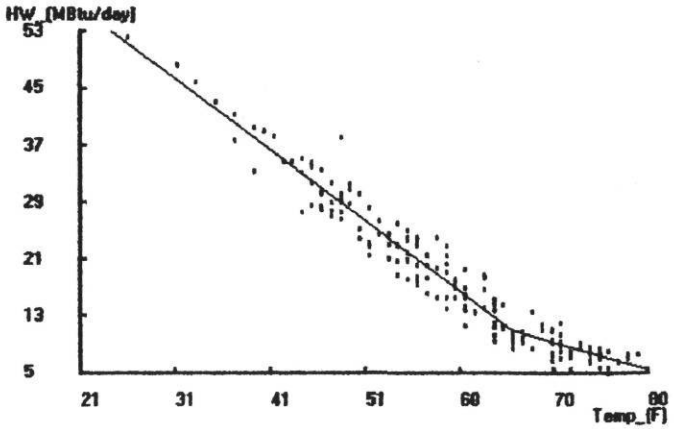
One, Two and Four Parameter Baseline Models for Savings Measurement

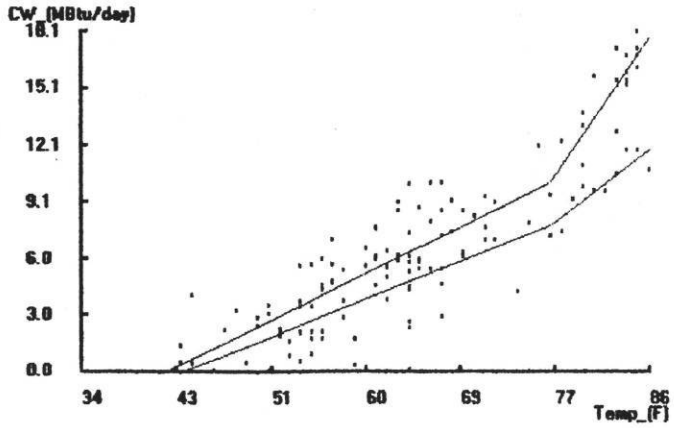












SAVINGS CALCULATION METHODOLOGIES

	Daily Regression Models	Hourly Regression Models	Utility Billing Data and Hourly Energy Use	Simplified Systems Models
ZEC	X			
EDB	X			
UTC				X
PCL				X
WAG	X			
WEL	X			
BUR	X			
NUR	X			
WIN	X			
RAS	X			
PAI	X			
WCH	X			
GAR	X			
GEA	X			
UNV		X		
BUS	X			
FNA	X			
MSB	X			
SHS			X	
VHS			X	
SIM	X			
DMS	X			
TDH	X			
WMH		X		

TYPES OF SAVINGS

	Cooling	Heating or Gas	Air Handler Electricity	Lighting Electricity	Electrical Demand
ZEC	X	X	X		
EDB	X	X	X	X	
UTC	X	X	X		
PCL	X	X	X		
WAG	X	X	X		
WEL	X	X	X		
BUR	X	X	X		
NUR	X	X	X		
WIN	X	X	X		
RAS	X	X	X		
PAI	X	X	X		
WCH	X	X	X		
GAR	X	X	X		
GEA	X	X	X		
UNV	X	X	X		
BUS	X	X	X		
FNA	X	X	X		
MSB				X	
SHS		X	X		X
VHS		X	X		X
SIM				X	
DMS				X	
TDH	X	X	X		
WMH					X

EModel

Description

- EModel is a new tool for the analysis of building energy use data.
- EModel integrates the previously laborious tasks of data processing, graphing and modeling in a user-friendly, M.S. Windows environment.
- EModel's built-in features allow for quick determination of baseline energy use for calculation of retrofit savings and identification of operational and maintenance problems.

Data Processing Capabilities

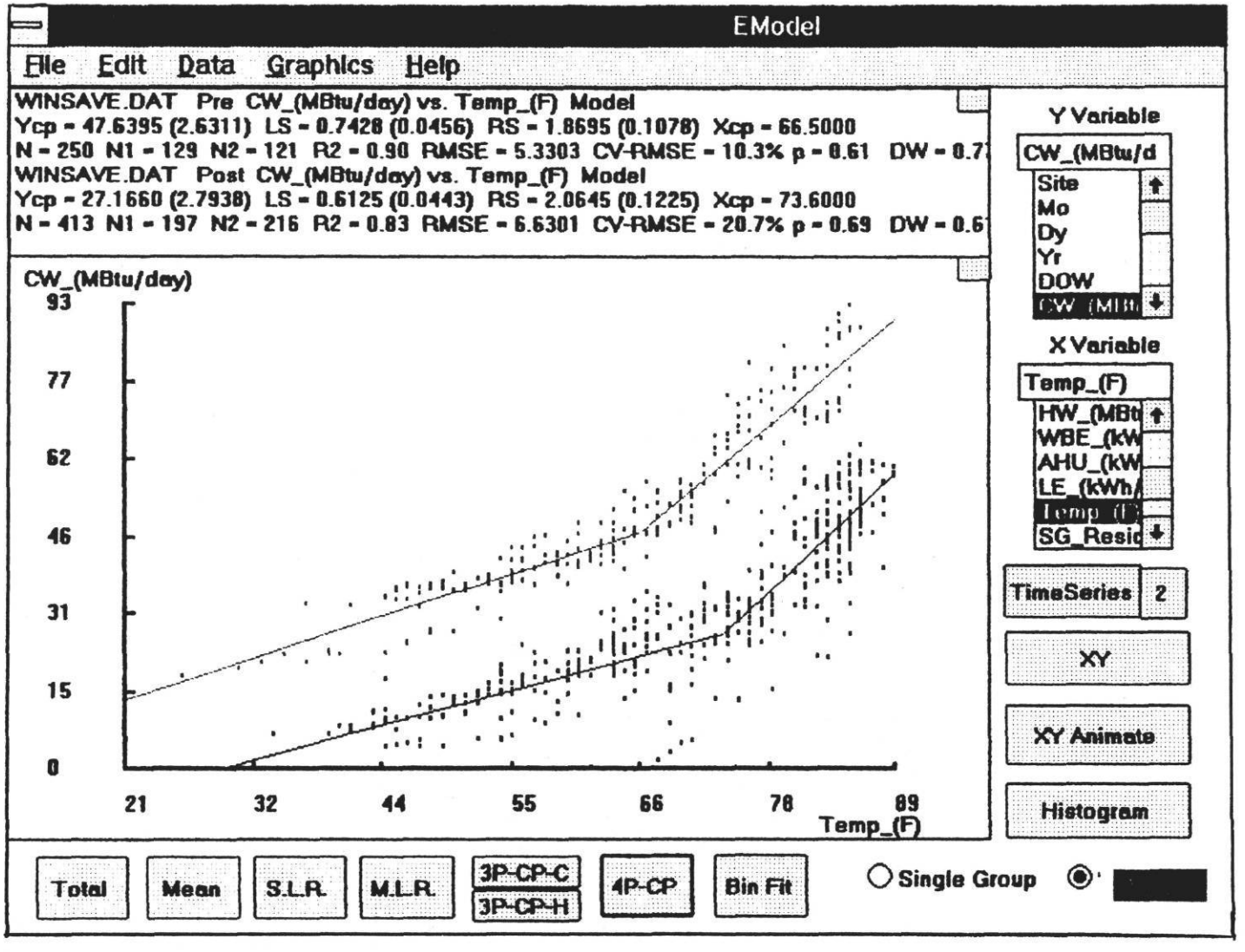
- Sub-set selection
- Weekday/weekend, calendar or user-defined grouping
- Automatic deletion of missing data
- Automatic calculation of model residuals
- Day of week calculation
- Modification of variables
- Creation of new variables

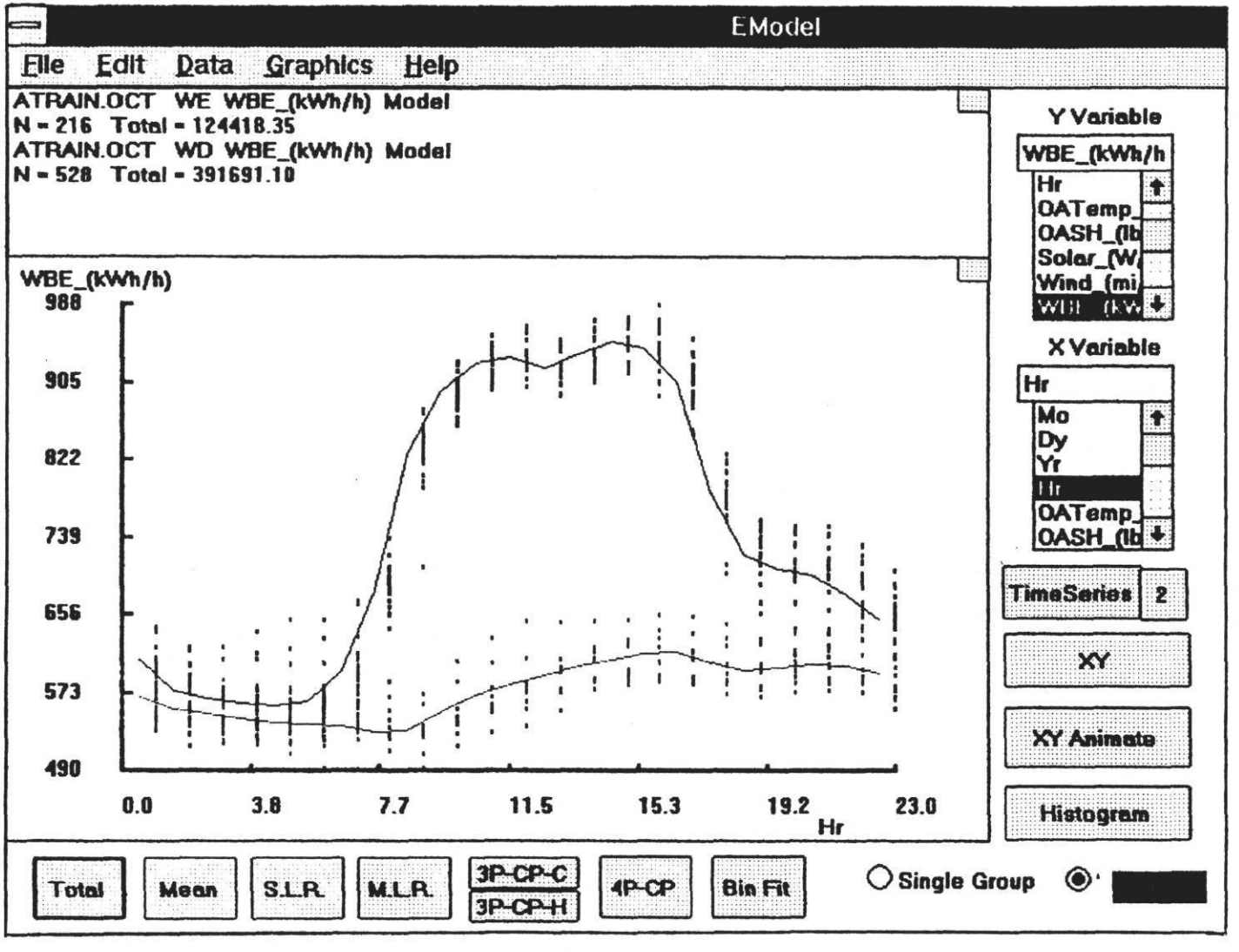
Graphical Displays

- Time series graphs
- Relational (XY) graphs
- Animated relational graphs
- Histograms

Modeling Capabilities

- Total
- Mean models
- Two, three and four parameter regression models
- Multiple regression models
- Bin-fit models


EModel
File Edit Data Graphics Help
WINSAVE.DAT Pre CW_(MBtu/day) vs. Temp_(F) Model
Ycp = 47.6395 (2.6311) LS = 0.7428 (0.0456) RS = 1.8695 (0.1078) Xcp = 66.5000
N = 250 N1 = 129 N2 = 121 R2 = 0.90 RMSE = 5.3303 CV-RMSE = 10.3% p = 0.61 DW = 0.7
WINSAVE.DAT Post CW_(MBtu/day) vs. Temp_(F) Model
Ycp = 27.1660 (2.7938) LS = 0.6125 (0.0443) RS = 2.0645 (0.1225) Xcp = 73.6000
N = 413 N1 = 197 N2 = 216 R2 = 0.83 RMSE = 6.6301 CV-RMSE = 20.7% p = 0.69 DW = 0.6
CW_(MBtu/day)
93
77
62
46
31
15
0
21
32
44
55
66
78
89
Temp_(F)
Y Variable
CW_(MBtu/d
Site
Mo
Dy
Yr
DOW
CW (MBt
X Variable
Temp_(F)
HW_(MBt
WBE_(kW
AHU_(kW
LE_(kWh/
Temp (F)
SG_Resid
TimeSeries
2
XY
XY Animate
Histogram
Total
Mean
S.L.R.
M.L.R.
3P-CP-C
3P-CP-H
4P-CP
Bin Fit
Single Group


EModel
File Edit Data Graphics Help
ATRAIN.OCT WE WBE_(kWh/h) Model
N = 216 Total = 124418.35
ATRAIN.OCT WD WBE_(kWh/h) Model
N = 528 Total = 391691.10
WBE_(kWh/h)
988
905
822
739
656
573
490
0.0
3.8
7.7
11.5
15.3
19.2
23.0
Hr
Y Variable
WBE_(kWh/h
Hr
OATemp_
OASH_(lb
Solar_(W
Wind_(mi
X Variable
Hr
Mo
Dy
Yr
Hr
OATemp_
OASH_(lb
TimeSeries
2
XY
XY Animate
Histogram
Total
Mean
S.L.R.
M.L.R.
3P-CP-C
3P-CP-H
4P-CP
Bin Fit
Single Group

OBJECTIVES

Task E: Reporting and Technology Transfer

- Disseminate LoanSTAR Results
  - Produce Monthly Energy Consumption Reports
  - Produce Annual Energy Consumption Reports
  - End-Use Database Development
- Increase the Renown & Effectiveness of LoanSTAR
  - Identify & Assist in Implementation of O&M Measures
  - Publish/Present/Distribute LoanSTAR Results

LOANSTAR MONITORING & ANALYSIS PROGRAM

TASK E PRESENTATIONS

O&M Identification & Implementation David E. Claridge

Reporting the Results David E. Claridge

Technology Transfer W. Dan Turner

TASK E

O&M IDENTIFICATION & IMPLEMENTATION

David E. Claridge, Ph.D.,
Jeff S. Haberl, Ph.D.,
John K. Houcek
Mingsheng Liu, Ph.D.,
Aamer Athar

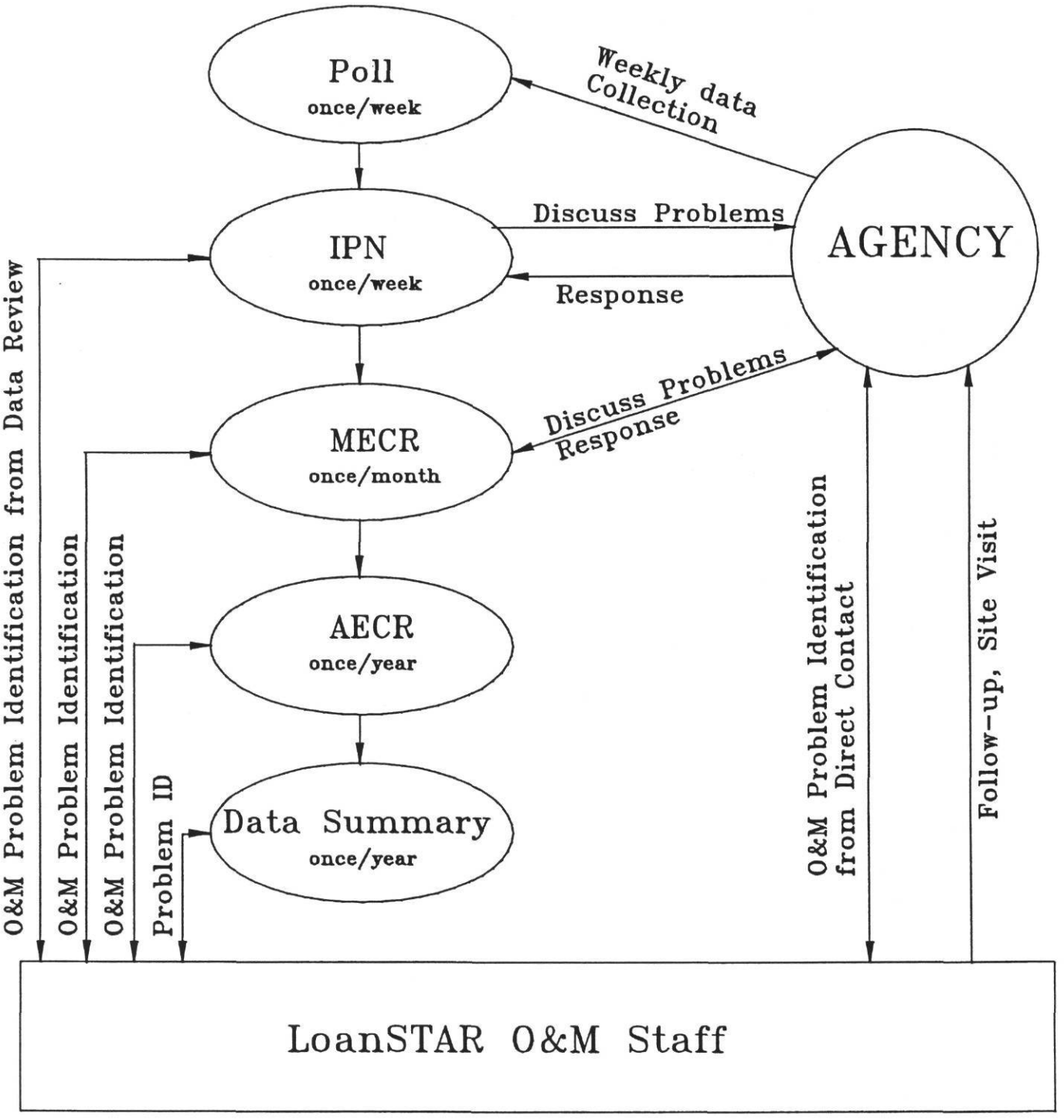
Presentation to MARC Meeting

David E. Claridge
June 2, 1993

O&M RESPONSIBILITIES

- **Develop Efficient Methodology & Procedures**
- **Review All Site Data for O&Ms**
- **Follow Up on O&M Opportunities Identified**
- **Continue Timely Feedback**

O&M IDENTIFICATION PROCEDURE



O&M FOLLOW-UP PROCEDURE AFTER PROBLEM IS IDENTIFIED

- Research Site from IPN, MECR, AECR, Site Notebook and Audit Report
- Telephone Site Contact and Advise of O&M Potential
- Mail or Fax Supporting Data
- Schedule Site Visit
- Site Visit
  - Interview Operator
  - Conduct Daytime Walk-through
  - Conduct Nighttime Walk-through
  - Perform Short Term Test
- Analyze Data
- Write Report
- Present Report
- Follow Up Report

CURRENT SITES FOR O&M FOLLOW-UP

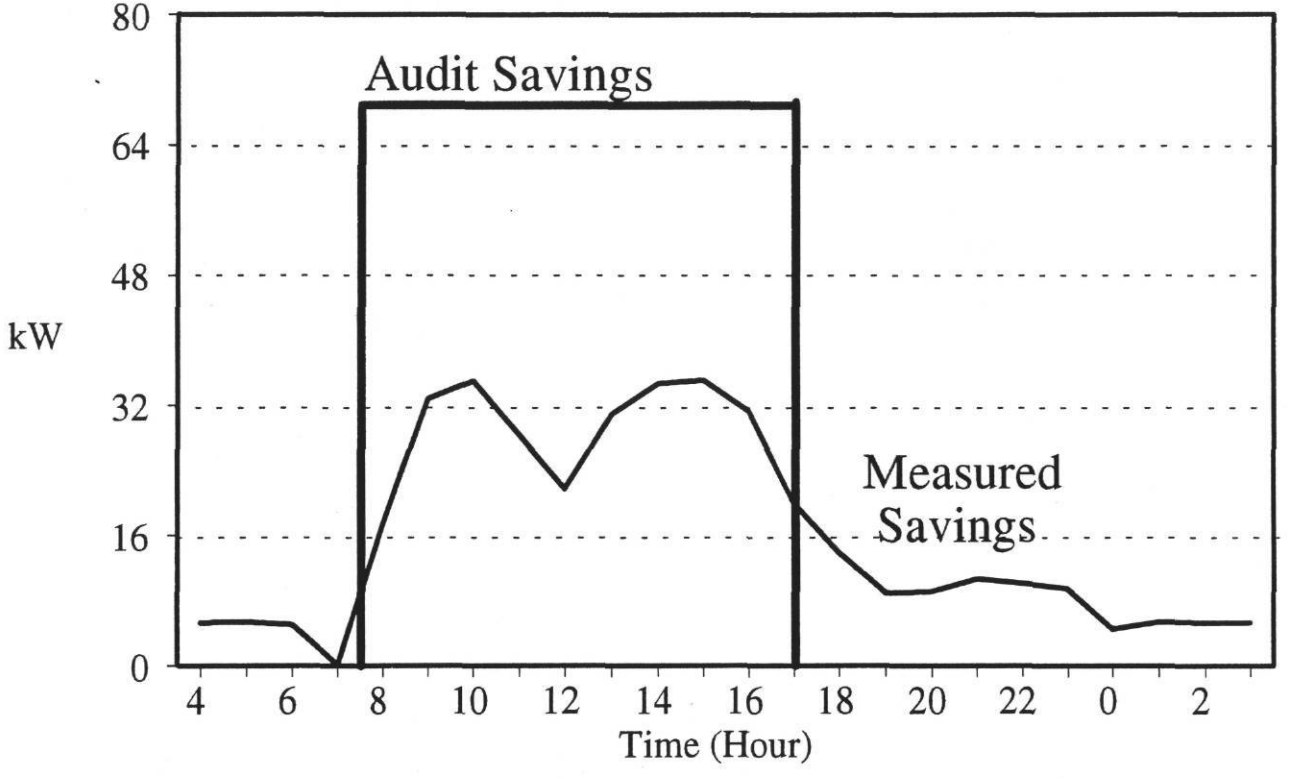
- **Capitol Complex - From MECR Analysis and Agency Request**

- **Fort Worth ISD - From AECR Analysis**

- **U. T. Austin - From IPN and Agency Request**

- **U. T. Arlington - From MECR Analysis and Agency Request**

Comparison of Audit and Measured Savings in a Typical School Day



SITE VISIT

- **Data Logger Confirmation→Good data quality**
  Method: check CT connection during daytime walk-through

- **Retrofit Confirmation→Installed & Operating**
  Method: check the status of HVAC systems and lighting fixtures during daytime walk-through

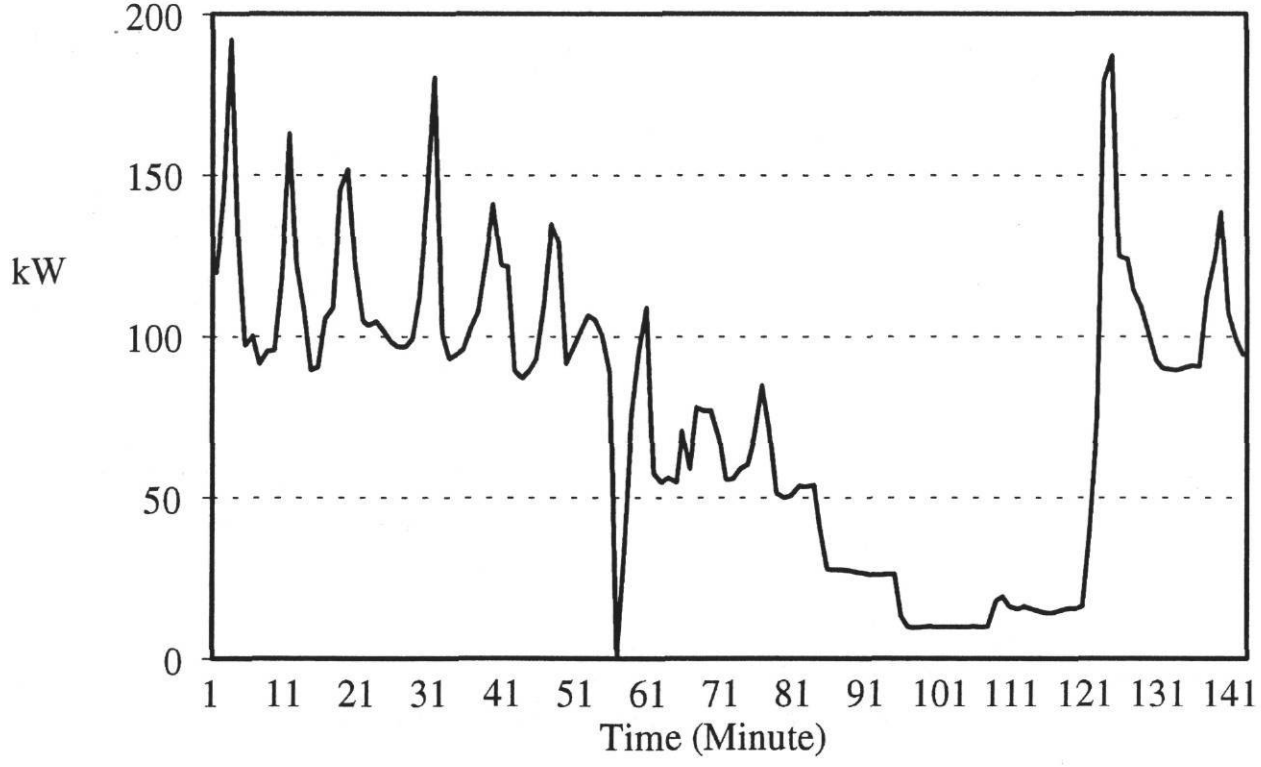
- **Operating Pattern Confirmation**
  Method: interview school teacher and building operator during daytime walk-through and inspect site during nighttime walk-through.

- **Improved Operating Pattern Confirmation**
  Method: perform short term test at night

- **Other O&M Opportunities**

Measured Other-than-lighting Electricity Consumption during Short-term Test

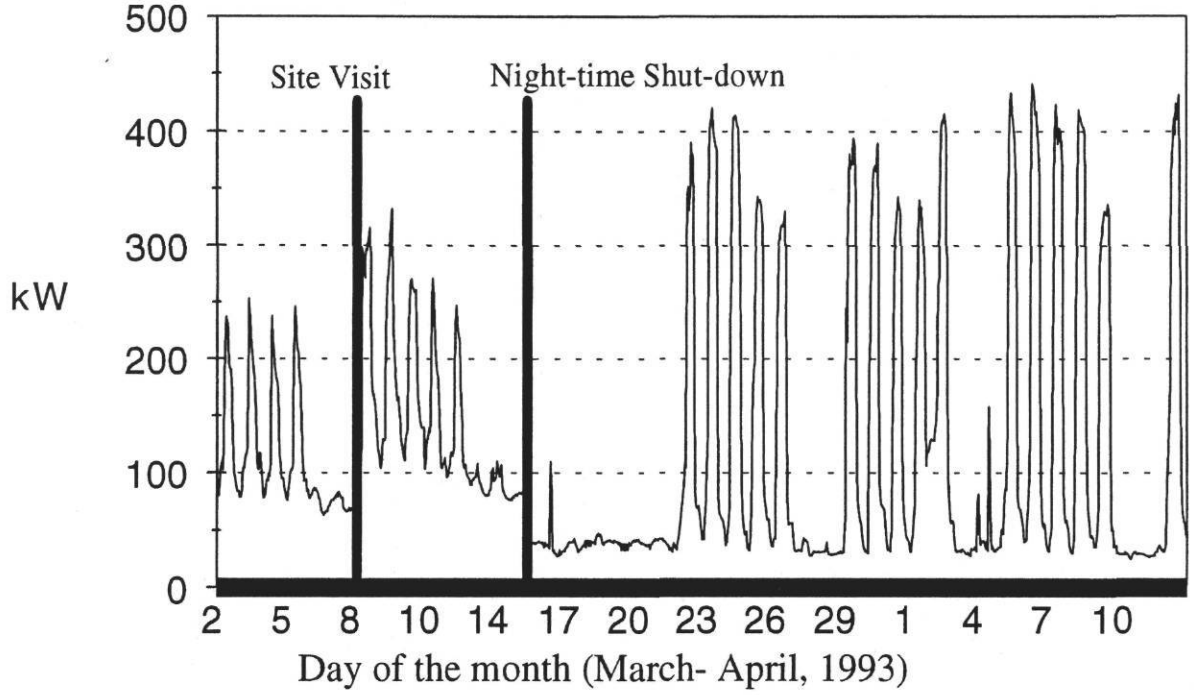
(8 March, 1993)



Summary of Annual Consumption and Annual Savings at Dunbar Middle School

		Utility Cost $/year	O&M Savings $/year	% Savings
HVAC	Electricity	$85,510	$32,248	37.7
	Gas	$9,591	$2,437	25.4
Lighting	Late Night		$2,452	11.1
	Evening	$22,185	$2,839	12.8
	Day-time		$481	2.2
Total		$117,280	$40,457	34.5

Measured O&M Savings at Dunbar Middle School



Note: Measured Whole Building Electricity Consumption from 2 March to 12 April at Dunbar Middle School. Note: site visit was performed on 8 March, 1993; Shut-down started on 15 March 1993.

O&M MEASURES SUMMARY

O&M OPPORTUNITY IDENTIFIED	LOCATIONS WHERE APPLICABLE
LIGHTS	
Lighting control	All sites except NUR, RAS, GAR
Delamp or reduce lighting levels when in excess of IES standard	JHR, ZEC, INS
Convert incandescent to compact fluorescent	ZEC, JHW
EQUIPMENT OPERATION	
Change zone HVAC setpoints	LBJ, WBT, SFA
Raise AHU cold deck temperature	LBJ, WBT, SFA
Lower AHU hot deck temperature	LBJ, WBT, SFA
Turn off AHUs at night	All Capitol Complex, DUN, SIM, RAS, GAR
Turn off HW pump in summer	ZEC, WBT
Repair leaky pipes, valves, and/or ductwork	SFA
Turn off steam valve during summer	PCL
OCCUPANT HABITS	
Turn off PCs and office machines	All Capitol Complex Buildings
Turn off lights	All sites except NUR, RAS, GAR
ADMINISTRATIVE	
Verify EMS operation, reprogram if necessary	DUN, SIM
Optimize custodial operations in the evenings	All Capitol Complex, DUN, SIM

CATEGORY 1

O&M Identified, Implemented and Savings Measured

Total Area Screened Under Category 1: 1 Million sq. ft

Site Name	O&M Measured Savings ($/yr.)	O&M Savings (%)
Zachry Eng. Center	2,700	1
Perry Castaneda Library	132,000	17
Garrison Hall	2,600	6
Dunbar Middle School	40,500	35
Total	*177,800*	*13*

CATEGORY 2

O&M Identified & Savings Calculated Not Yet Implemented

Total Area Screened Under Category 2: 2.7 Million sq. ft

Site Name	Estimated O&M Savings ($/yr.)	O&M Savings (%)
State Capitol Complex (10 buildings)	486,000	12
Zachry Eng. Center	17,300	4
R. A. Steindam Hall	9,300	22
Sims Elementary School	16,700	30
Total	*529,300*	*11*

CATEGORY 3

O&M Potential Identified from Data

Total Area Under Investigation:
7.6 Million sq. ft

- **UT Austin** — **13 Buildings**
- **FWISD** — **43 Schools**
- **UT Arlington** — **3 Buildings**
- **Victoria ISD** — **2 Schools**
- **UTHSC Houston** — **2 buildings**
- **State Capitol** — **2 Buildings**

O&M Summary

Category	Area (ft^2)	Number of Buildings	Annual Energy Cost ($/yr.)	O&M Savings (%)	O&M Savings (% of Retrofit Savings)
1	954,848	4	1,368,955	13	29
2	2,686,946	13	4,339,408	11	49
Total	3,641,794	17	5,708,363	12	47

O&M SUMMARY

- $705,057/yr. Identified and Implemented or in Process
- Over 90% of LoanSTAR Buildings Benefit from O&M Follow-up
- Appears Probable that O&M Follow-up will ultimately increase LoanSTAR Savings by 40% or More

LOANSTAR MONITORING & ANALYSIS PROGRAM

TASK E

REPORTING THE SAVINGS

David E. Claridge, Ph.D., P.E.
Jeff Haberl, Ph.D., P.E.
Aamer Athar
Ron Chambers
Srinivas Katipamula, Ph.D.
Kelly Kissock
Robert Sparks

Presentation to the MARC Meeting

by

David E. Claridge

June 3, 1993

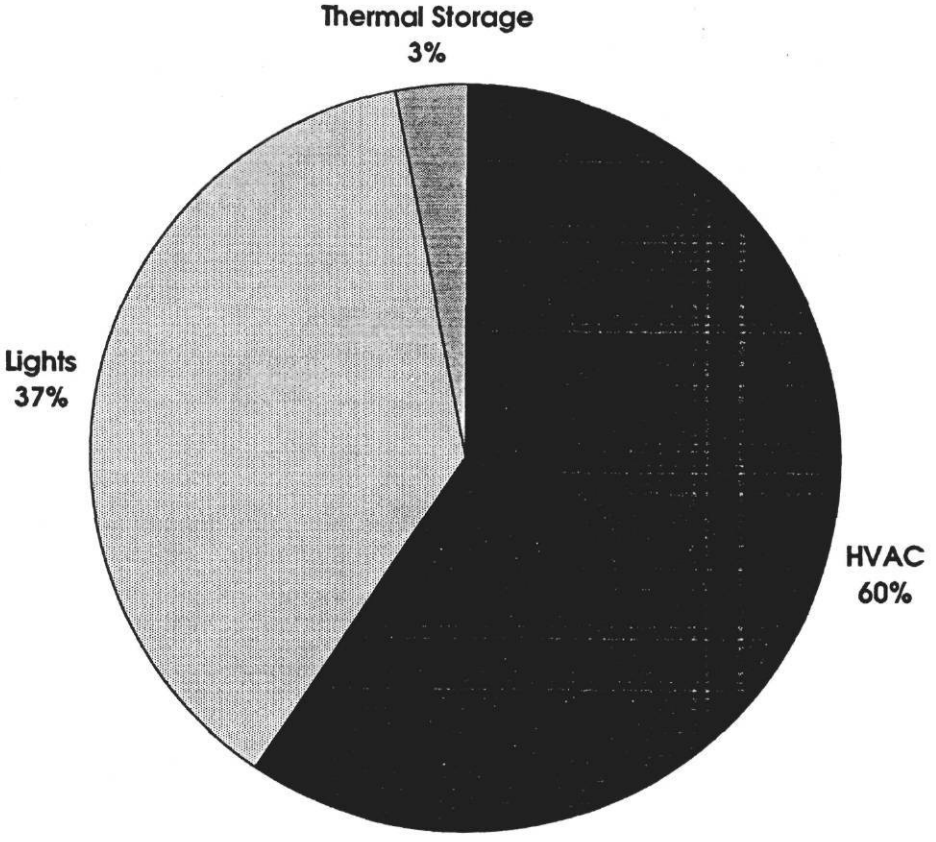
REPORTING OUTLINE

- Reporting Summary
- Air Handler Savings
- End-Use Data
- 1992 Annual Energy Consumption Report

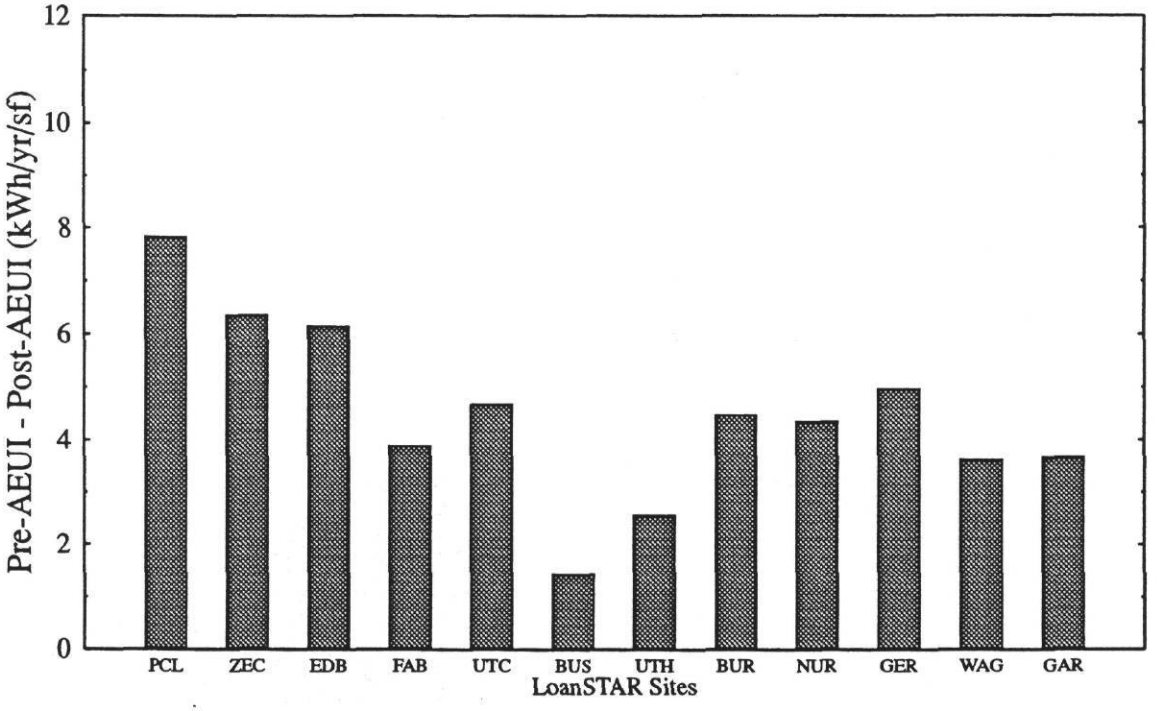
REPORTING SUMMARY

- Monthly Energy Consumption Reports to 51 Sites at 20 Locations
- Annual Energy Consumption Report to 50 sites at 19 locations
- Voyager Software at 7 locations for 15 sites
- Inspection Plots Distributed on a Request Basis
- Monthly Follow-up with Agencies

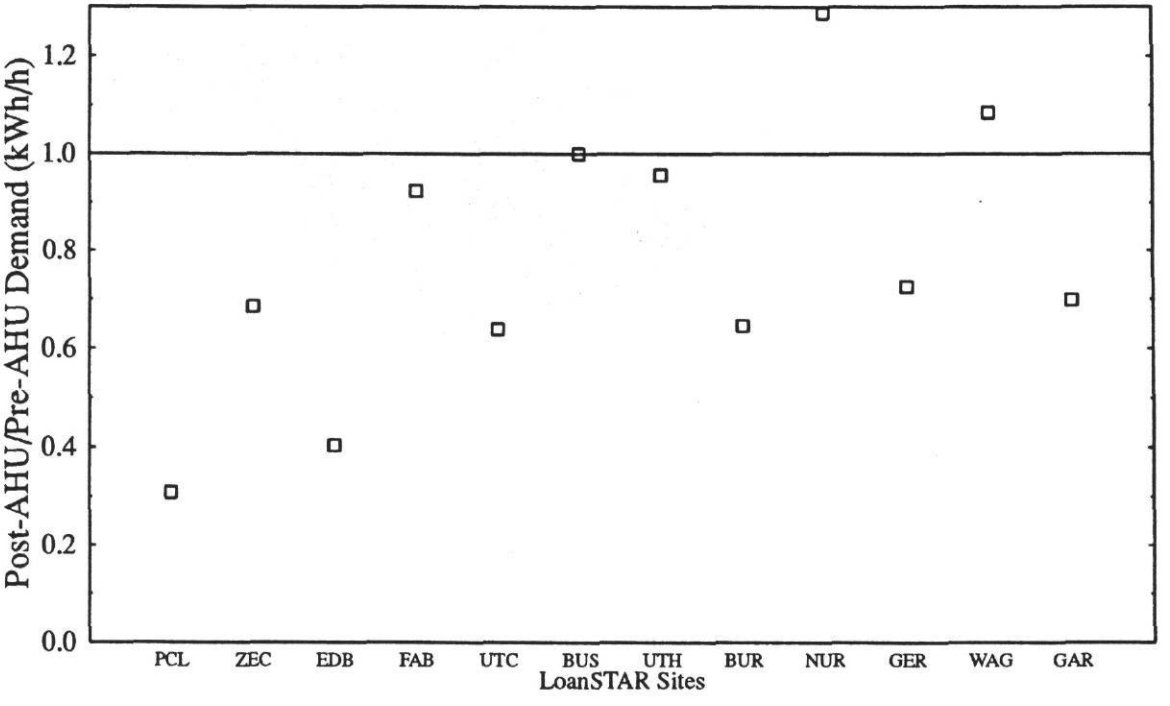
Total Measured Reduction in Electricity Demand (2 MW)



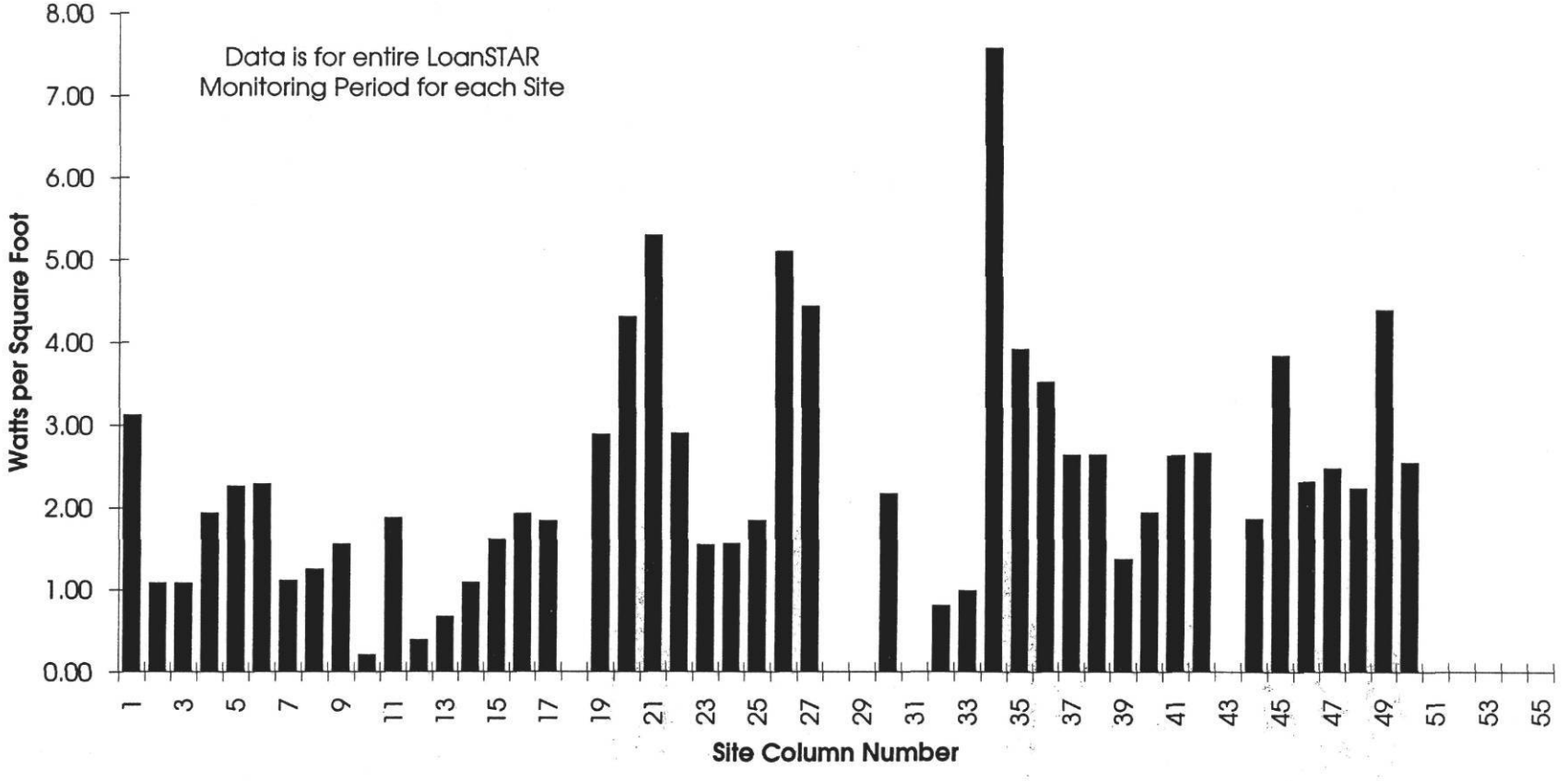
Electricity Energy Savings From HVAC Retrofits



Hourly AHU Electricity Demand Reduction From Retrofits



WHOLE BUILDING ELECTRIC



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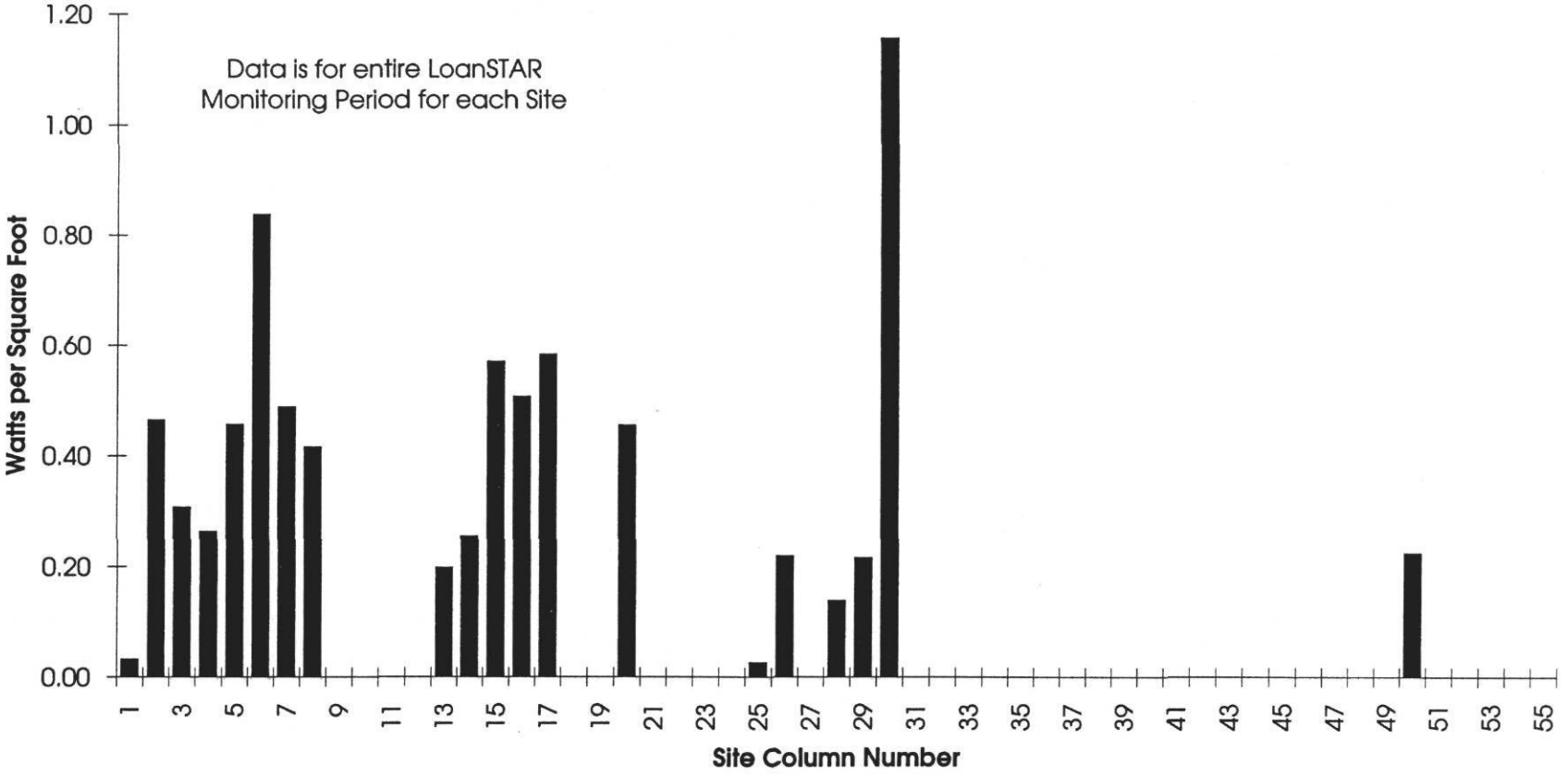
AIR HANDLER UNITS ELECTRIC



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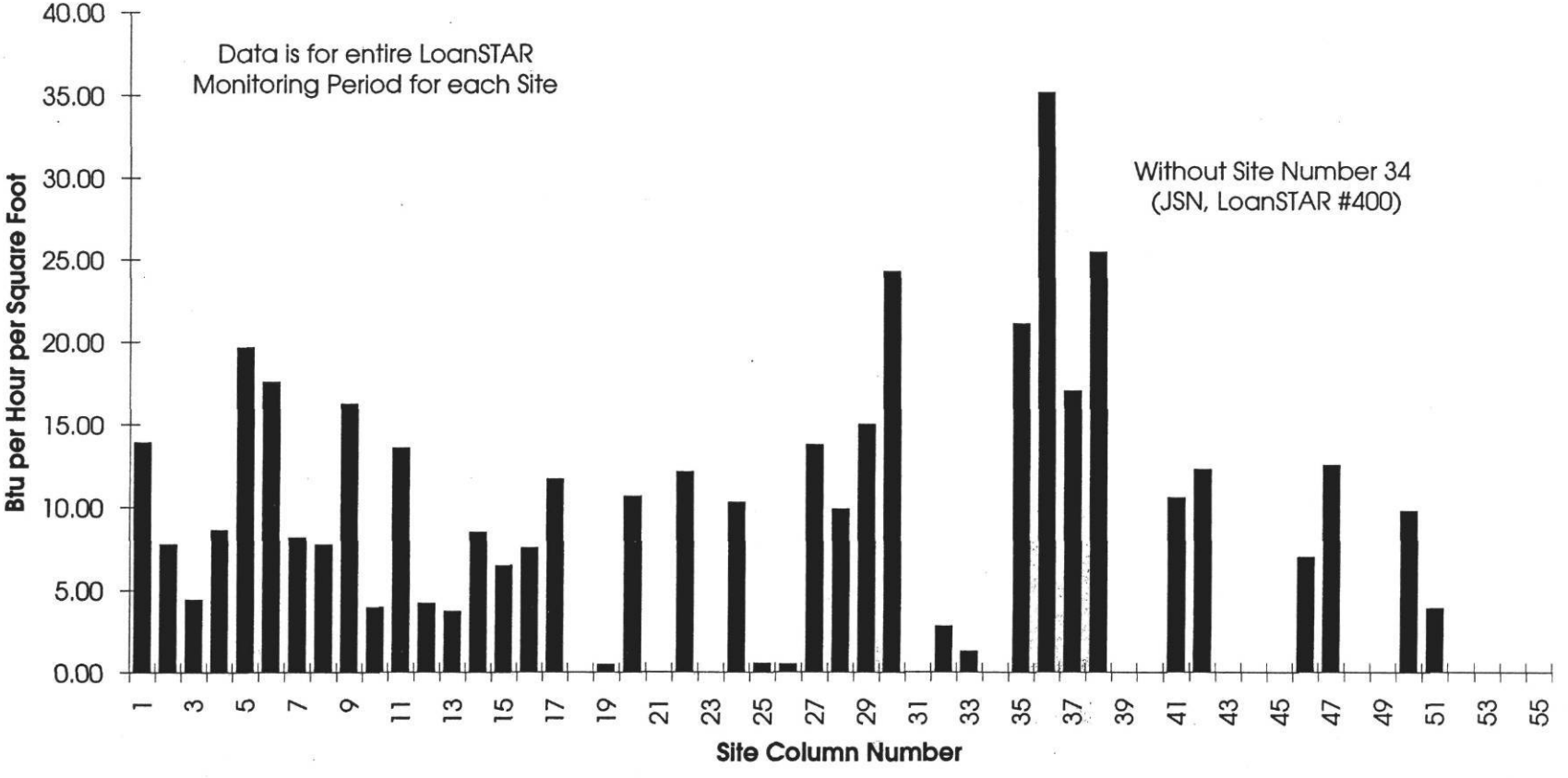
CHILLIED WATER ENERGY



TOT-CWE.XLC 4/20/93

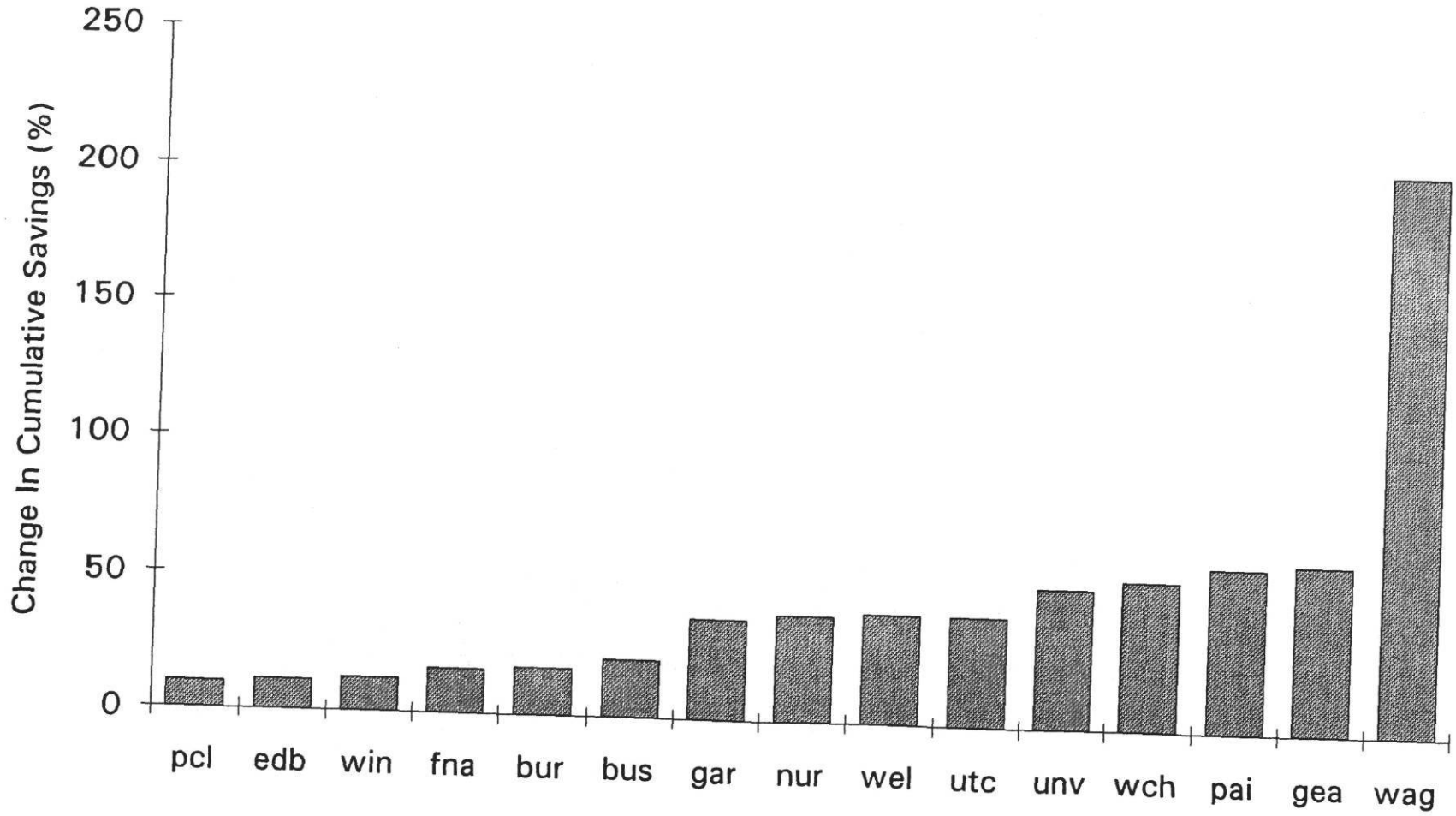
LoanSTAR Monitoring and Analysis Program

Annual Energy Consumption Report©

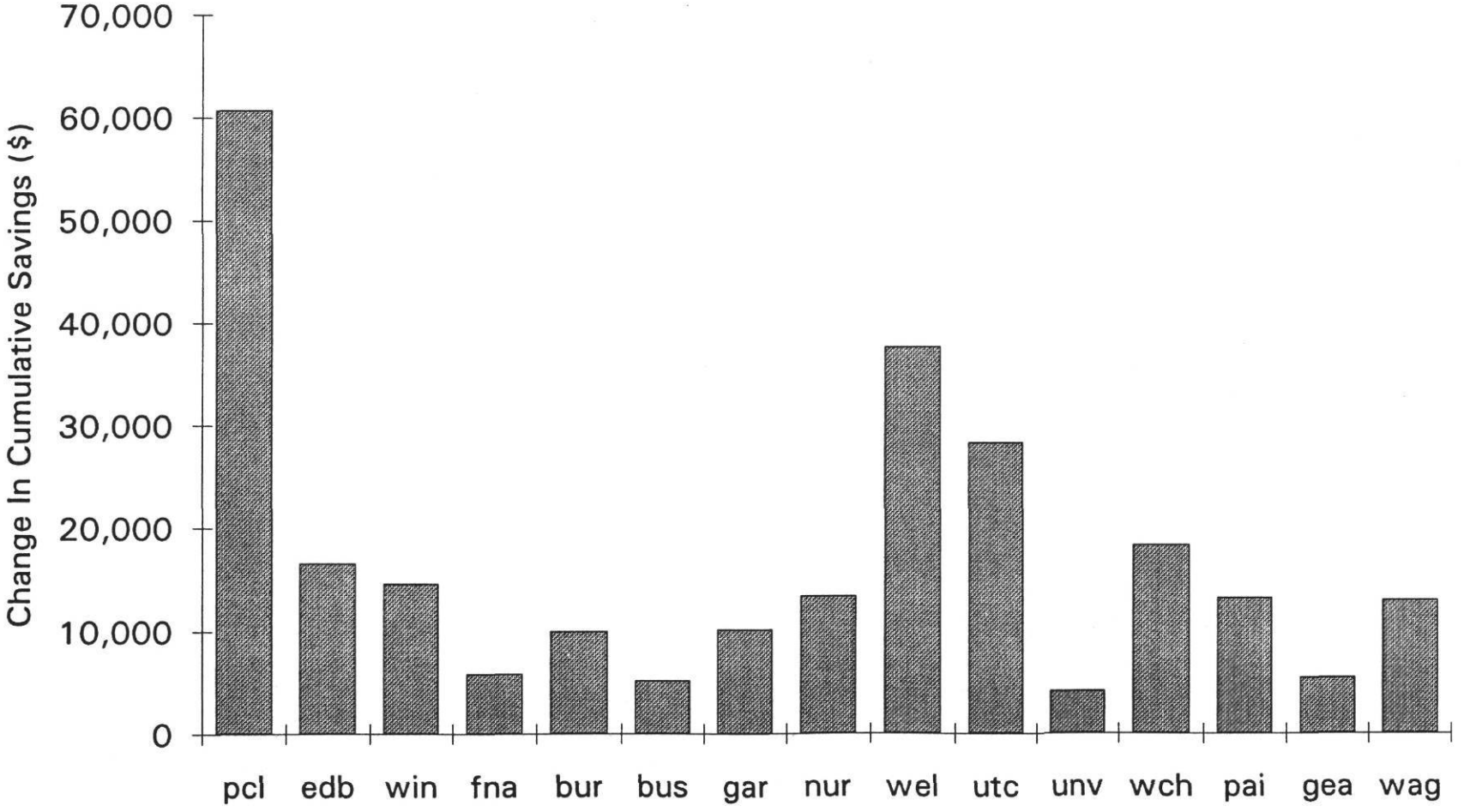
1992

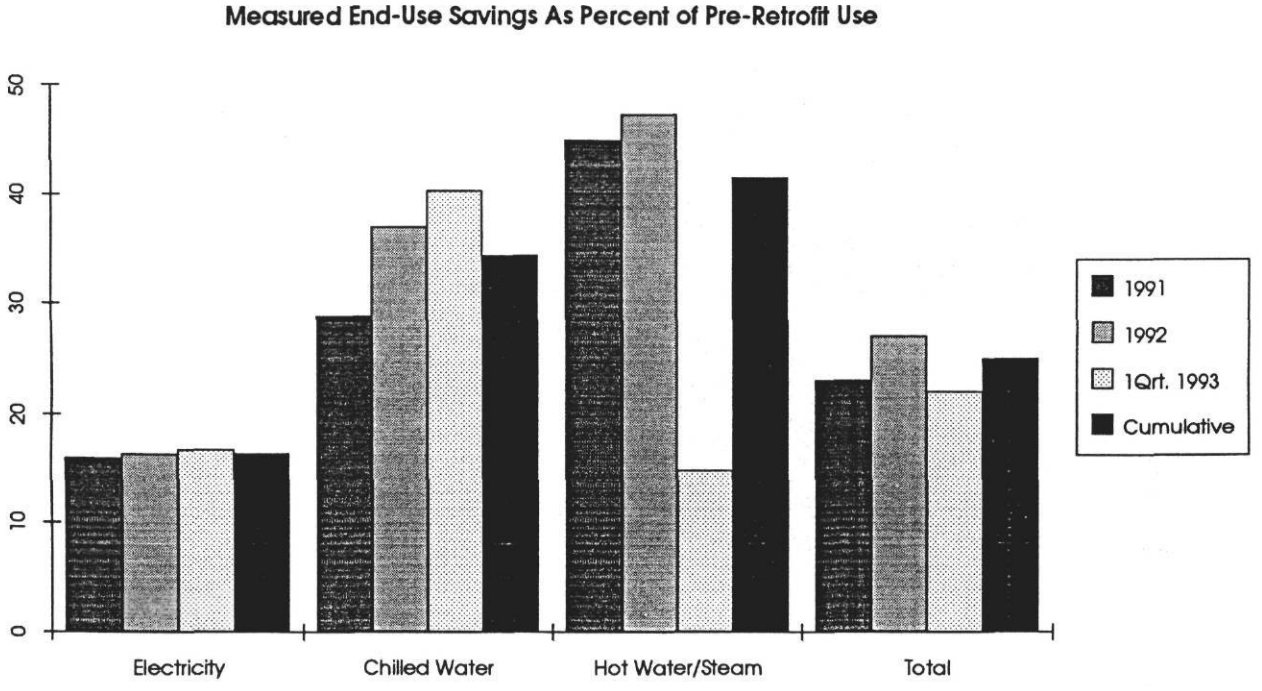
Submitted to the
Texas Governor's Energy Office
by the
Monitoring Analysis Task
David E. Claridge, Principal Investigator

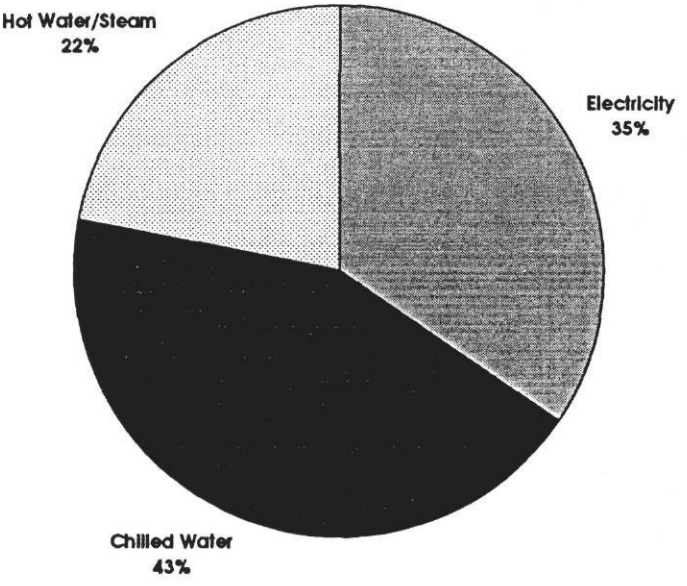
Changes In Cumulative Chilled Water Savings Due to Flow Adjustment (Start of Data - December, 1992)



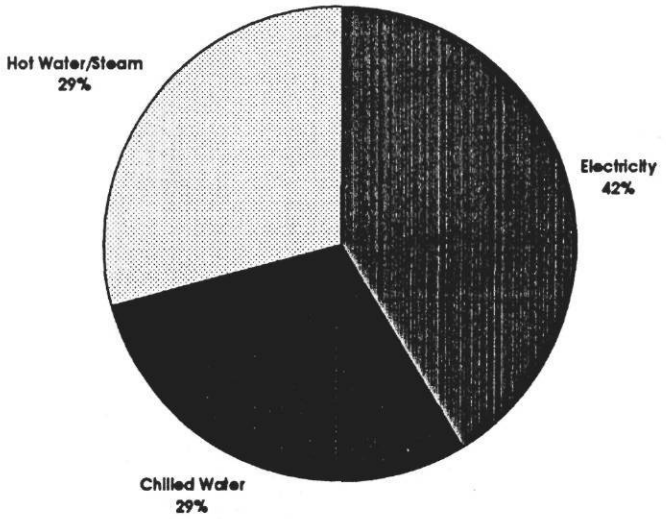
Changes In Cumulative Chilled Water Savings Due to Flow Adjustment (Start of Data - December, 1992)



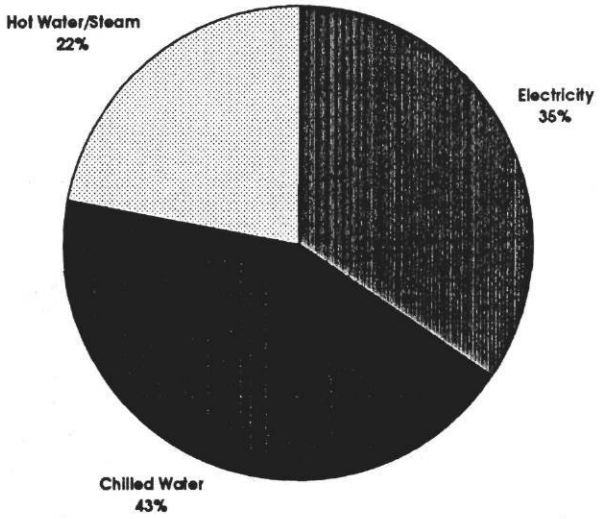

Measured End-Use Savings As Percent of Pre-Retrofit Use
50
40
30
20
10
0
Electricity
Chilled Water
Hot Water/Steam
Total
1991
1992
1Qrt. 1993
Cumulative


Measured End-Use Savings As Percent of Total Savings
Hot Water/Steam
22%
Electricity
35%
Chilled Water
43%

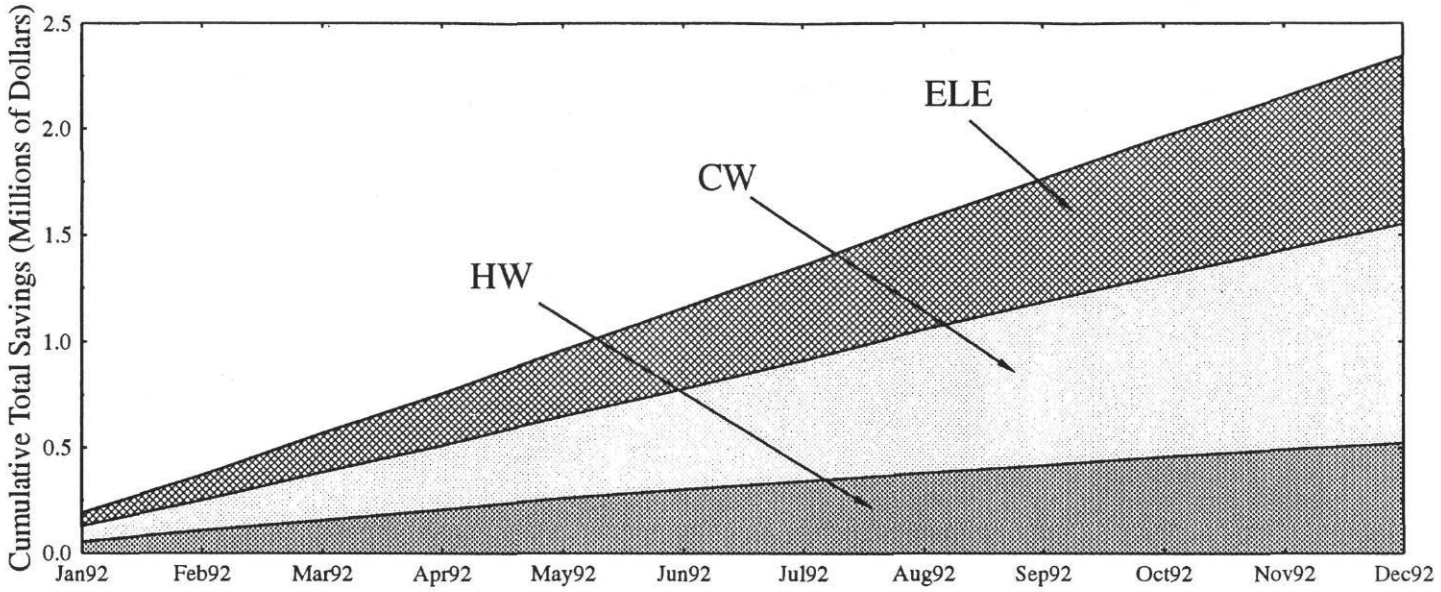
End-Use Savings As Percent of Total Savings

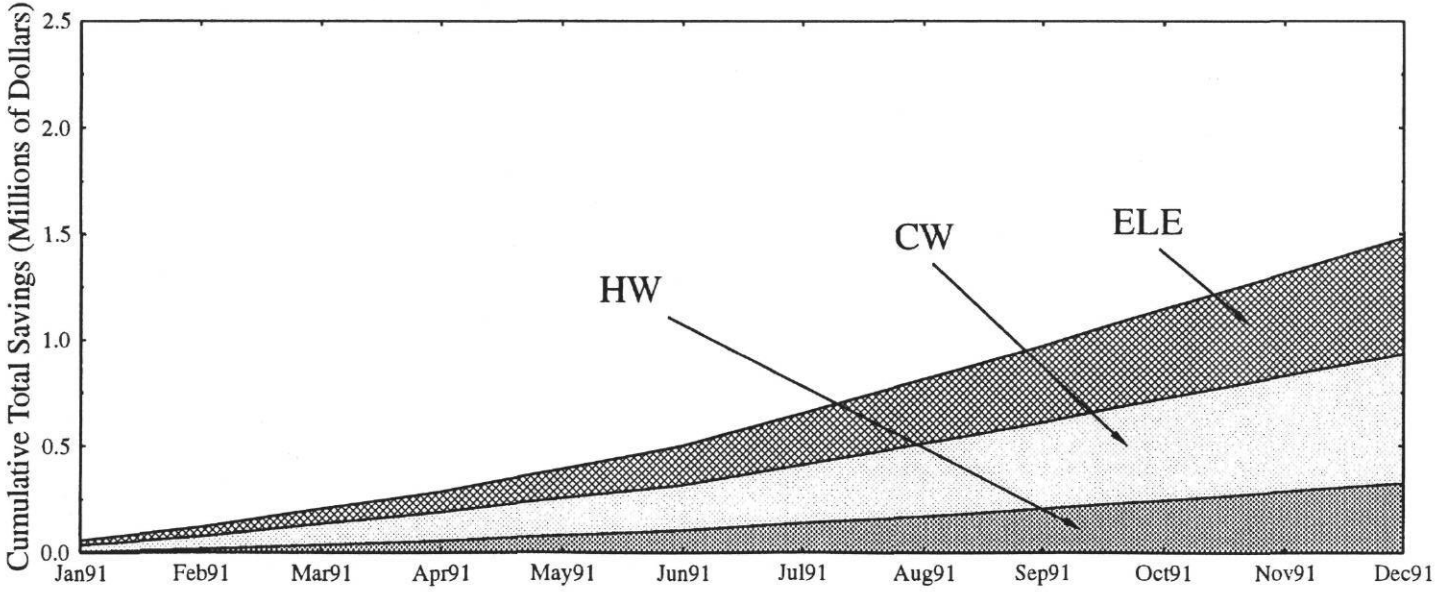


Audit Estimated (24 Sites)



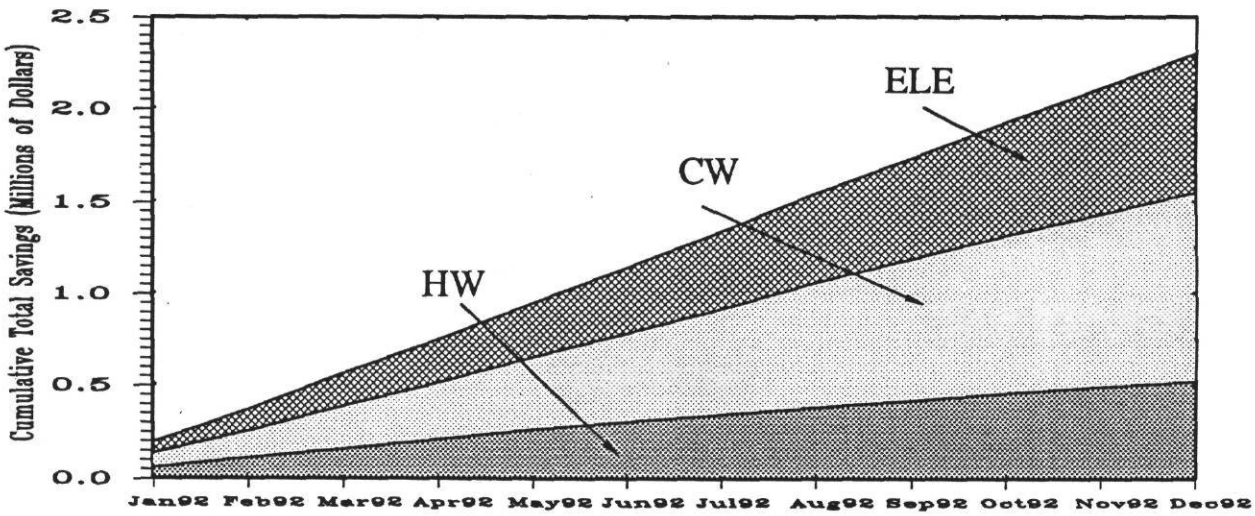
Measured (24 Sites)


Cumulative Total Savings (Millions of Dollars)
2.5
2.0
1.5
1.0
0.5
0.0
ELE
CW
HW
Jan92
Feb92
Mar92
Apr92
May92
Jun92
Jul92
Aug92
Sep92
Oct92
Nov92
Dec92


Cumulative Total Savings (Millions of Dollars)
2.5
2.0
1.5
1.0
0.5
0.0
HW
CW
ELE
Jan91
Feb91
Mar91
Apr91
May91
Jun91
Jul91
Aug91
Sep91
Oct91
Nov91
Dec91

Texas LoanSTAR Monitoring and Analysis Program
Annual Energy Consumption Report
1992 Summary of Measured Energy Consumption and Savings

	Electricity	Chilled Water	Hot Water /Steam	Total
Pre–Retrofit Use	$4,601,000	$2,790,000	$1,107,000	$8,498,000
Post–Retrofit Use	$3,832,000	$1,761,000	$583,000	$6,176,000
Measured Savings	$750,000	$1,029,000	$524,000	$2,303,000
% of Pre–Retrofit Use	16.3	36.8	47.2	27
% of Total Measured Savings	32.6	44.7	22.7	100
Audit Estimated Savings	$883,453	$550,779	$537,167	$1,908,583



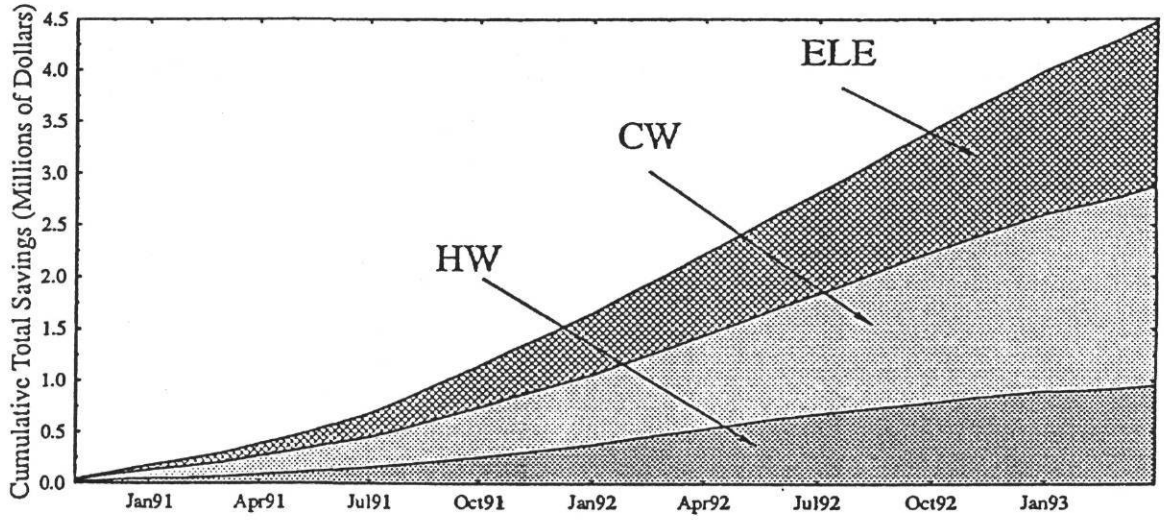
Comments

The cumulative pre- and post-retrofit energy costs by end-use (electricity, chilled water and hot water/steam) and the cumulative total energy costs for the twenty-four sites where retrofits are complete are shown in the table above. The pre-retrofit energy costs reflect the costs had the individual retrofits not been installed in the twenty-four sites. They are the sum of the energy costs represented by the dashed lines on page 2 of the individual site reports. In some sites the retrofit was completed in the middle of the year, in such cases it would be the sum of the dashed line in the post-retrofit period and the solid line in the pre-retrofit period.

The post-retrofit energy costs are the measured data from each site. They are the sum of the energy costs represented by the solid lines on page 2 of the individual site reports. The third row in the table above shows the cumulative savings by end-use and the cumulative total savings for the twenty-four sites. The fourth row shows the end-use savings as a percent of the total savings. The last row shows the savings estimated by the audit firms for the twenty-four sites. The graph shows the cumulative total savings in millions of dollars for all twenty-four sites.

Texas LoanSTAR Monitoring and Analysis Program
Energy Consumption Report
October 1990 – March 1993 Summary of Measured Energy Consumption and Savings

	Electricity	Chilled Water	Hot Water /Steam	Total
Pre–Retrofit Use	$9,208,000	$5,612,000	$2,309,000	$17,129,000
Post–Retrofit Use	$7,674,000	$3,687,000	$1,353,000	$12,714,000
Measured Savings	$1,514,000	$1,925,000	$956,000	$4,395,000
% of Pre–Retrofit Use	16.4	34.3	41.4	25.8
% of Total Measured Savings	34.4	43.8	21.8	100
Audit Estimated Savings	$1,483,000	$1,049,000	$1,039,000	$3,571,000



Comments

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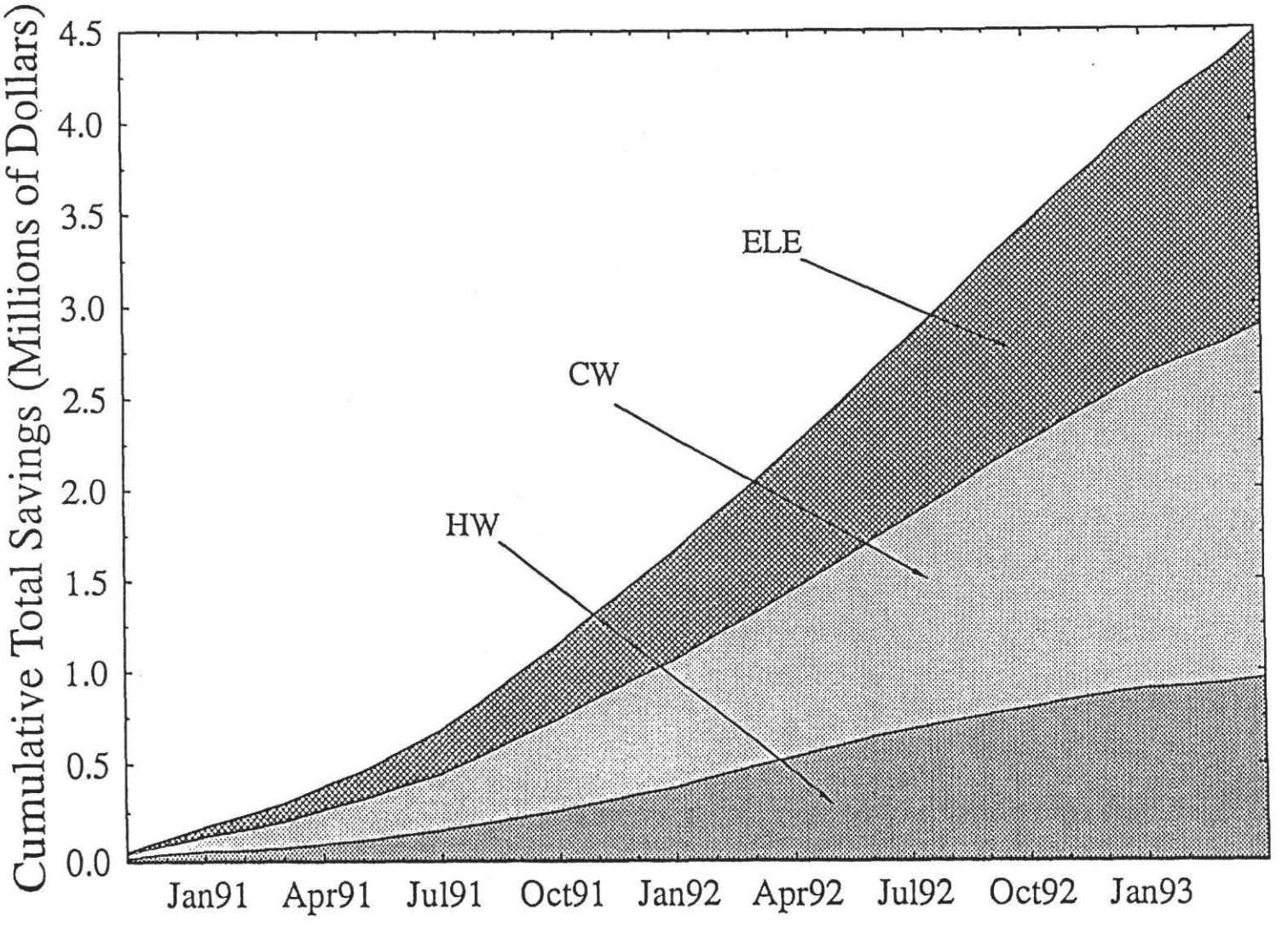
Cumulative Savings From LoanSTAR Retrofits: March 1993



	Electricity	Chilled Water	Hot Water /Steam	Total
Measured Savings	$1,514,000	$1,925,000	$956,000	$4,395,000
% of Pre-Retrofit Use	16.4	34.3	41.4	25.8
% of Total Measured Savings	34.4	43.8	21.8	100
Audit Estimated Savings	$1,483,000	$1,049,000	$1,039,000	$3,571,000

Table 1
Types of LoanSTAR Information Disseminated

Type	Total
# MECRs/AECRs to agencies with buildings in LoanSTAR	384
# MECRs/AECRs to agencies without buildings in LoanSTAR	111
# Monitoring Workbooks issued	83
# Data and Software/software information requests	528
# Total requests for reprints of papers and reports through May 1993	1535

Table 2
Organizations Receiving LoanSTAR Information

Type	Total
# Texas agencies (state & local governments, school districts, etc.	414
# Utility requests (Texas and outside the state)	81
# Academic requests (Texas and outside the state)	76
# Private industry/engineer requests	367
# State agency requests outside Texas States: Arizona, California, Colorado, Georgia, Florida, Minnesota, Pennsylvania, Oregon, Wisconsin	70
# National Lab or other Federal Government requests	371
# International requests Countries: Australia, Belgium, Brazil, Canada, Cuba, France, Guatemala, Holland, Hong Kong, Israel, Italy, Japan, Mexico, New Zealand, Norway, P.R. China, Sweden, Singapore, Russia, United Kingdom	57
# Total organizations/individuals receiving information through May 1993	1436

FUTURE DIRECTION
TASK 1

- Continue reviews, guideline/format revision, and training as required by the Energy Office
- In the past, Task 1 has been involved in
  - Eliminating independent ECRM calculations
  - Eliminating M&O calculations
  - Introducing Category I (limited calculation) ECRMs

FUTURE DIRECTION
TASK 1

- Short payback items - installation decisions clearly based on "professional judgment"
- Supported by limited calculations

- Paybacks near limit - gray area
- Supporting calculations required

- Long payback items - installation decisions clearly based on "professional judgment"
- Usually no calculations supplied

TASK A
FUTURE DIRECTIONS

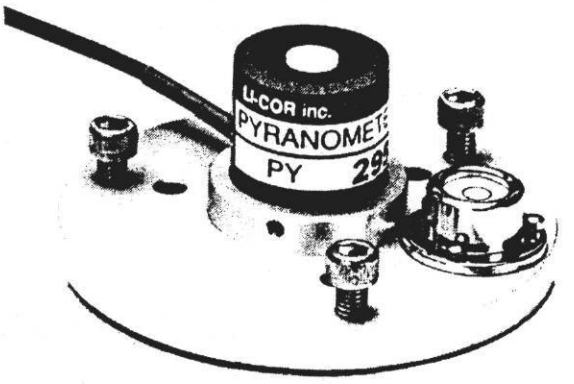
- NCAT will close Texas office July 15

- Focus for next 3 to 6 months will be
  - Maintenance
  - Recalibration
  - Documentation

FUTURE DIRECTIONS
TASK B

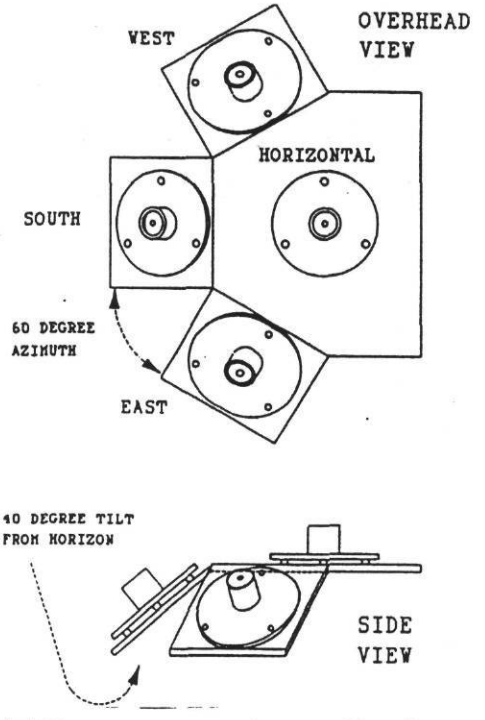
- The project for the summer is the testing of meters in "field type" locations.
  - A 4" elbow section has been constructed and meters will be tested at various locations downstream of the elbow.
  - Meters will be tested immediately following other obstructions such as temperature sensors and orifice plates.
  - Depending on 4" results, tests may be conducted in large pipe sizes.
- We are still having some flow irregularities at higher velocities (75 fps) in the 8" and 10" pipes due to the configuration of the test sections.
  - May require modification of test loop.
- Complete Temperature-Humidity Mapping Tests

Pyranometer with shadow band to eliminate beam radiation (source: Eppley Laboratories)



LI-COR LI-200SA Pyronameter Sensor (source: LI-COR)

Epply Normal Incidence Pyrheliometer mounted on an altazimuth tracking mount. (source: Epply Laboratories)



Multi Pyranometer Array Configuration (source: Curtiss, 1992)

TASK C & D - FUTURE DIRECTION

- Continue to explore advanced data displays for data browsing and diagnostics, and develop remote browsing capabilities for the LoanSTAR database using the internet and dial-up facilities.

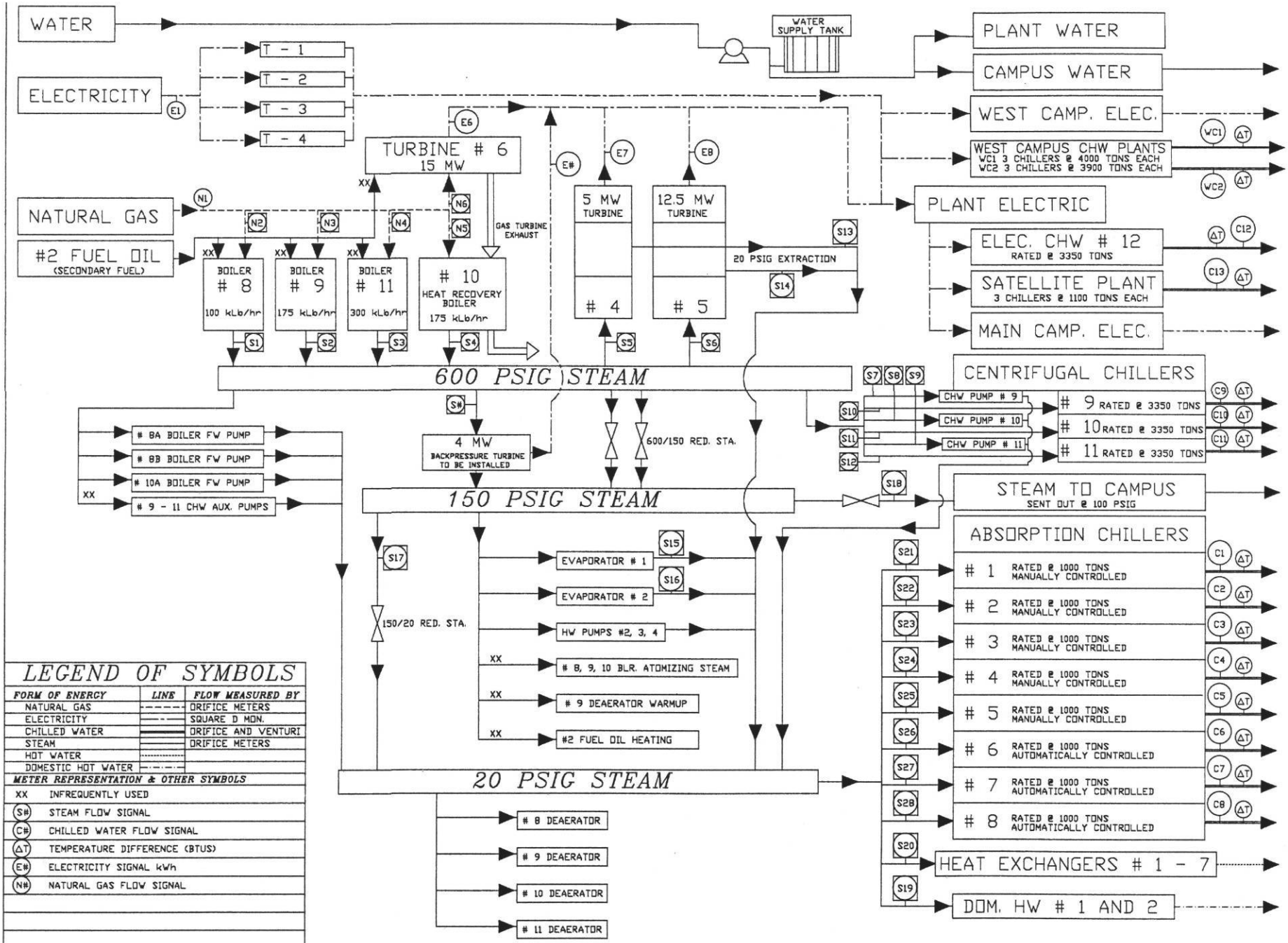
- Develop and test LoanSTAR routines for polling and archiving data from stand-alone, portable battery powered loggers (Campbell, Synergistics).

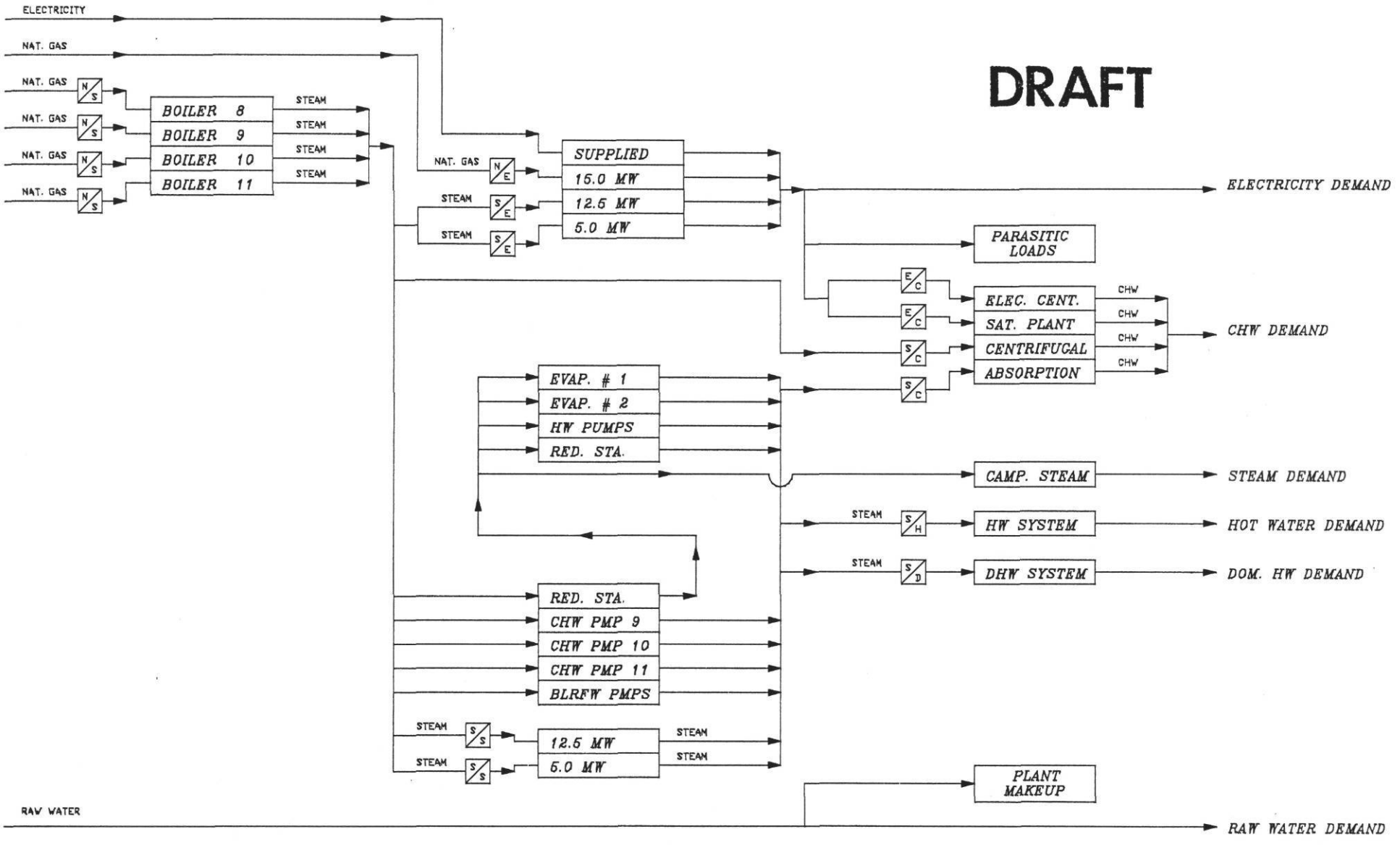
- Develop and implement Informix/SAS IPN, implement iComment and continue development of the Basic On-line Inspection NotebooK (BOINK).

- Develop dynamic range checking for incoming data, machine learning and neural network capabilities for checking incoming data.

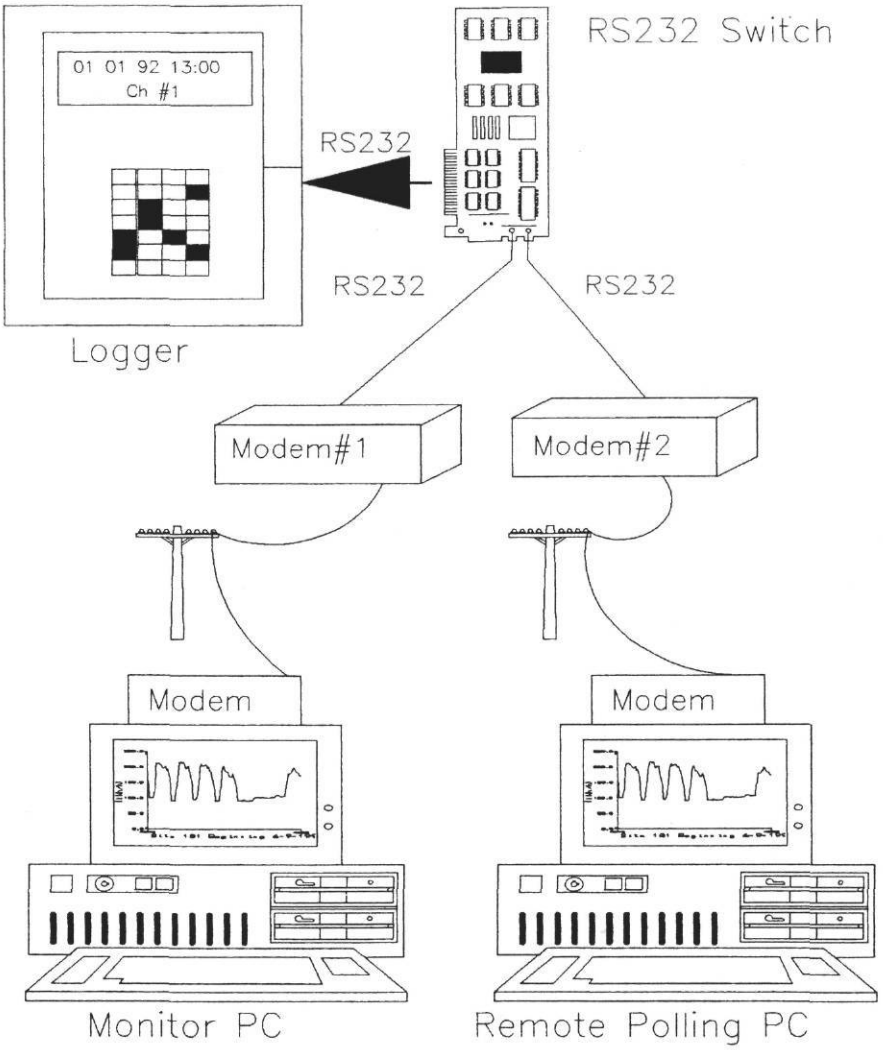
TASK C & D - FUTURE DIRECTION (CONT.)

- Modify and implement POLLC180 for use within 15-minute data.
- Expand LoanSTAR monitoring/analysis capabilities to the whole-campus level.
- Develop and prototype the LoanSTAR Monitor to facilitate real time operator feedback.
- Automate savings Calculations
- Investigate polling directly with the Unix server.
- Develop and implement Level-0 database and reporting.


WATER
ELECTRICITY
NATURAL GAS
#2 FUEL OIL
(SECONDARY FUEL)
T - 1
T - 2
T - 3
T - 4
WATER SUPPLY TANK
PLANT WATER
CAMPUS WATER
WEST CAMP. ELEC.
WEST CAMPUS CHW PLANTS
WC1 3 CHILLERS @ 4000 TONS EACH
WC2 3 CHILLERS @ 3900 TONS EACH
PLANT ELECTRIC
ELEC. CHW # 12
RATED @ 3350 TONS
SATELLITE PLANT
3 CHILLERS @ 1100 TONS EACH
MAIN CAMP. ELEC.
TURBINE # 6
15 MW
GAS TURBINE EXHAUST
5 MW TURBINE
12.5 MW TURBINE
4
5
20 PSIG EXTRACTION
BOILER # 8
100 klb/hr
BOILER # 9
175 klb/hr
BOILER # 11
300 klb/hr
10 HEAT RECOVERY BOILER
175 klb/hr
600 PSIG STEAM
4 MW
BACKPRESSURE TURBINE TO BE INSTALLED
600/150 RED. STA.
150 PSIG STEAM
150/20 RED. STA.
20 PSIG STEAM
8A BOILER FW PUMP
8B BOILER FW PUMP
10A BOILER FW PUMP
9 - 11 CHW AUX. PUMPS
EVAPORATOR # 1
EVAPORATOR # 2
HW PUMPS #2, 3, 4
8, 9, 10 BLR. ATOMIZING STEAM
9 DEAERATOR WARMUP
#2 FUEL OIL HEATING
8 DEAERATOR
9 DEAERATOR
10 DEAERATOR
11 DEAERATOR
CENTRIFUGAL CHILLERS
CHW PUMP # 9
CHW PUMP # 10
CHW PUMP # 11
9 RATED @ 3350 TONS
10 RATED @ 3350 TONS
11 RATED @ 3350 TONS
STEAM TO CAMPUS
SENT OUT @ 100 PSIG
ABSORPTION CHILLERS
1 RATED @ 1000 TONS MANUALLY CONTROLLED
2 RATED @ 1000 TONS MANUALLY CONTROLLED
3 RATED @ 1000 TONS MANUALLY CONTROLLED
4 RATED @ 1000 TONS MANUALLY CONTROLLED
5 RATED @ 1000 TONS MANUALLY CONTROLLED
6 RATED @ 1000 TONS AUTOMATICALLY CONTROLLED
7 RATED @ 1000 TONS AUTOMATICALLY CONTROLLED
8 RATED @ 1000 TONS AUTOMATICALLY CONTROLLED
HEAT EXCHANGERS # 1 - 7
DOM. HW # 1 AND 2
LEGEND OF SYMBOLS
FORM OF ENERGY | LINE | FLOW MEASURED BY
NATURAL GAS | ORIFICE METERS
ELECTRICITY | SQUARE D MDN.
CHILLED WATER | ORIFICE AND VENTURI
STEAM | ORIFICE METERS
HOT WATER
DOMESTIC HOT WATER
METER REPRESENTATION & OTHER SYMBOLS
XX INFREQUENTLY USED
(S#) STEAM FLOW SIGNAL
(C#) CHILLED WATER FLOW SIGNAL
(ΔT) TEMPERATURE DIFFERENCE (BTUS)
(E#) ELECTRICITY SIGNAL kWh
(N#) NATURAL GAS FLOW SIGNAL



ENERGY SYSTEMS LABORATORY	
DATE : 4/26/93 BY: RODNEY BEASLEY, J. HABERL	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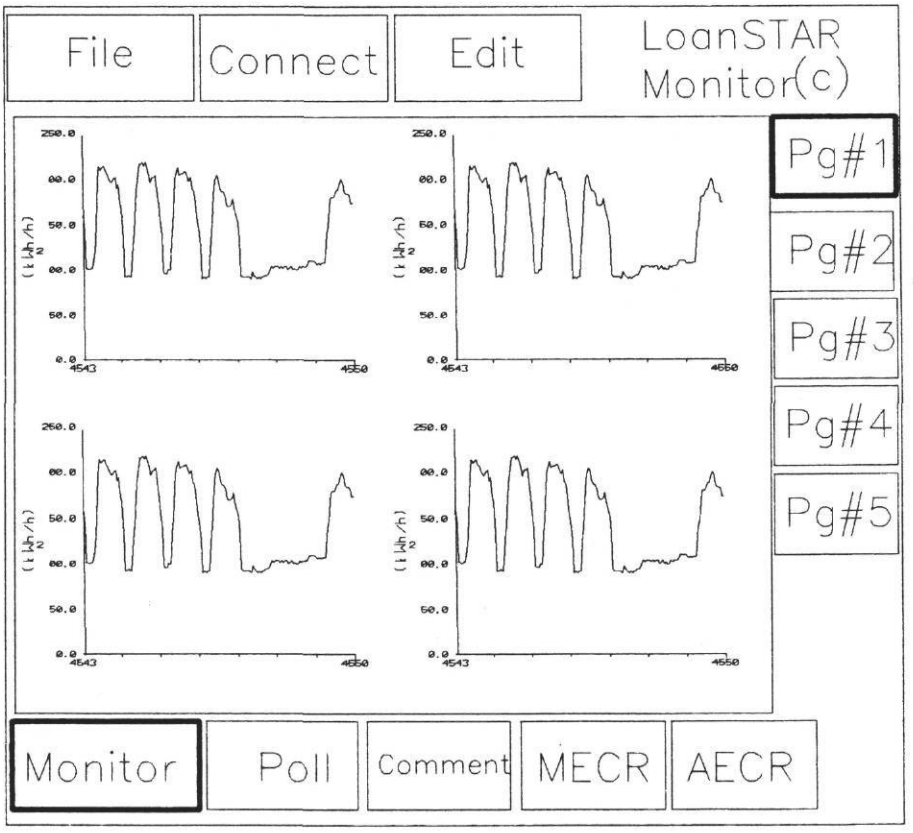
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LoanSTAR
Monitor(c)
Pg#1
Pg#2
Pg#3
Pg#4
Pg#5
Monitor
Poll
Comment
MECR
AECR

TASK 6 - FUTURE DIRECTION

- Continue with the LoanSTAR Monitoring Workshop (Co-sponsored by USDOE).
  > Dallas, TX, Fall 1993.

- Continuation of the development and testing of prescreening indices (Co-sponsored by USDOE, and USEPA).

- Develop improved audits using advanced indices (Co-sponsored by USDOE and USEPA).

FUTURE DIRECTIONS

Task D - Analysis

EModel - Refine and fully implement use of EModel
- Add capability to EModel for calibrated post retrofit-to-monthly pre retrofit models

Neural net models - further evaluate capability

Fourier series models - Develop diagnostic capability with Fourier series models for O&M identification

VAV Retrofit Behavior - Analyze behavior of VAV retrofits and develop diagnostics for improved audits (EPA cofunding)

Energy Efficiency index for Mixing (EEM) - Refine EEM and develop its application for O&M diagnostics and audit diagnostics (DOE cofunding being sought)

FUTURE DIRECTIONS

Task E - Reporting

MECR - Continue to publish and distribute MECR and add sites as needed

AECR - Publish and distribute 1993 AECR with sites added as needed

Task E - O&M Identification and Implementation

O&M Implementation

- Implement O&M Measures Identified at Capitol Complex
- Implement O&M Measures Identified at ZEC and TU sites

O&M Identification

- Complete Identification and Seek Implementation of O&M Measures at 43 additional Fort Worth ISD Schools
- Identify O&M Measures at UT Arlington
- Investigate O&M Measures at UT Austin
- Check Remaining sites where Retrofits in Place for O&Ms

O&M Methodology

- Refine and Systematize Methodology for Identifying and Implementing O&M Measures

LoanSTAR-related Publications
Published in 1992 - 1993

1. Haberl, J. S., Beasley, R. C, and Thompson, D. L., 1993. "Characterizing Steam and Chilled Water Use for a Large Campus in Central Texas, : *ASHRAE Transactions: Symposia,* Vol. 99, Part 2, pp. TBA.

2. Haberl, J. S., Belur, R., Sparks, R., Kissock, J. K., and Campbell, S., 1993. "Exploring New Data Displays for Facility Energy Data," *Proceedings of the Industrial Energy Technology Conference,* Houston, TX, March 24-25, pp. 257-265.

3. Haberl, J. S., Bronson, J. D., Hinchey, S. B., and O'Neal, D. L., 1993. "Graphical Tools to Help Calibrate the DOE-2 Simulation Program", *ASHRAE Journal,* Vol. 35, pp. 27-32.

4. Haberl, J. S., Kissock, J. K, Belur, R., and Sparks, R., 1993. "Improving the Paradigm for Displaying Complex Building Energy Consumption Data," *Solar Engineering 1993 - Proceedings of the ASME-ASES Solar Energy Conference,* Washington, D.C., April 4-9, 1993, pp. 455-464.

5. Katipamula, S., Reddy, T. A., and Claridge, D. E., 1993. "Use of Daily and Hourly Empirical Models to Predict/Model Energy Use in Commercial Buildings," Draft Paper to be submitted to *Energy & Buildings.*

6. Kissock, J. K, Reddy, T. A., Haberl. J. S., and Claridge, D. E., 1993. "EModel: A New Tool for Analyzing Building Energy Use Data," *Proceedings of the Industrial Energy Technology Conference,* Houston, TX, March 24-25, pp. 237-241.

7. Kissock, J. K, Reddy, T. A., Fletcher, D., and Claridge, D. E., 1993. "The Effect of Short Data Periods on the Annual Prediction Accuracy of Temperature-Dependent Regression Models of Commercial Building Energy Use," *Solar Engineering 1993 - Proceedings of the ASME-ASES Solar Energy Conference,* Washington, D.C., April 4-9, 1993, pp. 455-464.

8. Nutter, D. W., Britton, A. J., and Heffington, W. M., 1993. "Five Common Energy Conservation Projects in Small and Medium-sized Industrial Plants," *Proceedings of the Industrial Energy Technology Conference,* Houston, TX, March 24-25, pp. 112-120.

9. O'Neal, D. L., Bryant, J. A., Haberl, J. S., and Claridge, D. E., 1993. "Instrumenting Buildings to Determine Retrofit Savings: Murphy's Law Revisited," *Proceedings of the Industrial Energy Technology Conference,* Houston, TX, March 24-25, pp. 244-52.

10. Reddy, T. A., Kissock, J. K, Katipamula, S., and Claridge, D. E., 1993. "An Energy-Efficient Index to Evaluate Simultaneous Heating and Cooling Effects in Large Commercial Buildings," Draft Paper to be submitted to for publication.

11. Reddy, T. A., and Claridge, D. E., 1993. "Using Synthetic Data to Evaluate Multiple Regression and Principal Component Analyses for Statistical Modeling of Buildings Energy Consumption," Draft Paper to be submitted to *Journal of Solar Energy Engineering*.

12. Robinson, J., Bryant, J. A., and Turner, W. D., 1993. "Insertion Paddlewheel Flowmeters: An Evaluation After Two Years of Use," *Proceedings of the Industrial Energy Technology Conference,* Houston, TX, March 24-25, pp. 253-256.

13. Ruch, D. K., Kissock, J. K, and Reddy, T. A., 1993. "Model Identification and Prediction Uncertainty of Linear Building Energy Use Models With Autocorrelated Residuals, *Solar Engineering 1993 - Proceedings of the ASME-ASES Solar Energy Conference,* Washington, D.C., April 4-9, 1993, pp. 465-474.

14. Abbas, M., Athar., A., Challa, V., Haberl, J. S., Claridge, D. E., 1992. "Texas LoanSTAR Monitoring and Analysis Program: Characterizing LoanSTAR Building and Energy Consumption," *Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates,* Dallas, TX, May 13-14, pp. 178-187.

15. Athar, A., M. Abbas, Challa, V., Haberl, J. S., Claridge, D. E., 1992. "Texas LoanSTAR Monitoring and Analysis Program: Improving the Performance of Retrofits by Providing Operator Feedback from Measured Data," *Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates,* Dallas, TX, May 13-14, pp. 188-198.

16. Belur, R., Kissock, J. K., Haberl, J. S., 1992. "Exploring and Enhanced Data Viewing Facility for Building Operators," *Proceedings of the ACEEE Summer Study,* August, pp. 3.33 - 3.36.

17. Bronson, D., Hinchey, S., Haberl, J. S., O'Neal, D. L., 1992. "A Procedure for Calibrating the DOE-2 Simulation Program to Non-Weather Dependent Loads, *ASHRAE Transactions: Symposia,* Vol. 98, Part 1, pp. 636-652.

18. Bryant, J., O'Neal, D. L., 1992. "Calibration of Relative Humidity Transducers Used in the LoanSTAR Program," *Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates*, Dallas, TX, May 13-14, pp. 229-233.

19. Claridge, D. E., Haberl, J. S., Sparks, R., Lopez, R., Kissock, J. K., 1992. "Monitored Commercial Building Energy Data: Reporting the Results," *ASHRAE Transactions: Symposia,* Vol. 98, Part 1, pp. 881-889.

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24. Katipamula, S., Claridge, D. E., 1992. "Use of Simplified System Models to Measure Retrofit Energy Savings," *Solar Engineering 1992-Proceedings of the 1992 ASME-JSES-KSES International Solar Engineering Conference*, Maui, Hawaii, April 5-9, pp. 349-360.

25. Katipamula, S., Reddy, T. A., Claridge, D. E., 1992. "Disaggregating Cooling Energy Use of Commercial Buildings into Sensible and Latent Fractions from Whole-Building Monitored Data: Methodology and Advantages," *Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates*, Dallas, Texas, May 13-14, pp. 247-256.

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27. Katipamula, S., Claridge, D. E., 1992. "Importance of Monitoring Air Handler Performance," *Proceedings of ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, Vol. 3, American Council for an Energy Efficient Economy, Washington, D.C., pp. 161-164.

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41. Wu, J. X., Reddy, T. A., Claridge, D. E., 1992. "Statistical Modeling of Daily Energy Consumption in Commercial Buildings Using Multiple Regression and Principal Component Analysis," *Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates*, Dallas, Texas, May 13-14, pp. 155-164.