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Applying Energy Conservation Retrofits to Standard Army Buildings: Data Analysis and Recommendations

by
Eileen T. Westervelt
G. Russ Northrup
Linda K. Lawrie

This report describes the data analysis and recommendations of a project demonstrating the energy performance of theoretically based retrofit packages on existing standard Army buildings at Fort Carson, CO. Four standard designs were investigated: a motor vehicle repair shop, the Type 64 (L-shaped) barracks, an enlisted personnel mess hall, and a two-company, rolling-pin-shaped barracks for enlisted personnel. The tested conservation measures included envelope and system modifications.

Energy data were gathered and analyzed from 14 buildings. Based on measured savings and current costs of fuel and construction, none of the four original packages are life-cycle cost-effective at present, but two may become effective in the near future. Of higher priority for energy and cost savings is the improvement of building operations, in particular heat production and distribution systems, which lack efficiency and control. Followup work at the L-shaped barracks yielded substantial savings, with a saving-to-investment ratio of 5 to 1. Cost scenarios, energy models, and building simulations were developed for the original retrofits to assess applicability elsewhere and in the future.

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Eileen T. Westervelt, G. Russ Northrup, and Linda K. Lawrie

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13. ABSTRACT (Maximum 200 words)

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Energy data were gathered and analyzed from 14 buildings. Based on measured savings and current costs of fuel and construction, none of the four original packages are life-cycle cost-effective at present, but two may become effective in the near future. Of higher priority for energy and cost savings is the improvement of building operations, in particular heat production and distribution systems, which lack efficiency and control. Followup work at the L-shaped barracks yielded substantial savings, with a saving-to-investment ratio of 5 to 1. Cost scenarios, energy models, and building simulations were developed for the original retrofits to assess applicability elsewhere and in the future.

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FOREWORD

This work was performed for the U.S. Army Engineering and Housing Support Center (USAEHSC) under the Facilities Engineering Applications Program (FEAP) project "Energy Conservation Retrofits for Standard Designs." B. Wasserman, CEHSC-FU, was the Technical Monitor. Followup work in operations improvement was funded in part by the U.S. Army Forces Command (FORSCOM) under the reimbursable project "Assessment of Energy Savings Through Improved Operations of Heating Equipment." Naresh Kapoor, CFEN-RDF, was the Project Monitor.

This research was performed and coordinated by the Energy Systems Division (ES) of the U.S. Army Construction Engineering Research Laboratory (USACERL). Some statistical data analysis was done under contract by GARD division of Chamberlain National, where Neil Leslie and Roger Hedrick were Principal Investigators. Some economic analysis was done under contract by Research Associates, where Ben Sliwinski was Principal Investigator. Some improved operations work and data analysis were done under contract by Arthur D. Little, Inc., where Richard Caron was Principal Investigator. The revised BLAST analysis was done under contract by Lawrence Berkeley Laboratory, with Brandt Andersson and Dominique Domortier as Principal Investigators.

Appreciation is expressed to Larry M. Windingland, USACERL-ES, who was Principal Investigator during fiscal year (FY) 84 and FY85, and William R. Taylor, who was Principal Investigator during FY86. Eileen T. Westervelt was Principal Investigator in FY87-89. The authors thank the personnel at Fort Carson, CO, in particular Duane Schaap, Acting Director of Engineering and Housing; Stephen Snyder, Energy Coordinator; and Dick Hall, Chief of the Operations Division, for assistance during the project.

Dr. Gilbert R. Williamson is Chief of USACERL-ES. COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

EXECUTIVE SUMMARY

Since the Army's facility inventory consists of numerous standard designs, there is a high potential for savings by targeting specific retrofits for those building types and then applying these features to similar structures. The U.S. Army Construction Engineering Research Laboratory (USACERL) analyzed energy conservation options for four standard buildings: a dining facility, a vehicle repair shop, and two barracks buildings. This analysis identified which retrofit alternatives were the most economical for each facility. The proposed retrofits included envelope and system modifications. Different combinations of alternatives were identified for each design and climate. The theoretical estimates of Army-wide energy and cost savings were substantial at 2 x 10^{12} Btu* annually, which translated into more than $12 million in annual cost avoidance.

Due to the large number of buildings available for retrofit (more than 840 of the designs investigated) and the resulting high investment cost, a field testing program was initiated to confirm the effectiveness of the retrofit packages. The suggested retrofit packages were demonstrated at Fort Carson, CO under the Facilities Engineering Applications Program (FEAP). The conservation measures implemented (Table A) were considered proven in the private sector but unverified in the Army environment.

Four test/reference experiments were designed. For each building type, one building was retrofitted and two or three identical, but not retrofitted, buildings were identified as reference buildings.

Automated data collection equipment was installed in 14 buildings to record data for significant energy consumption parameters. Data were recorded on an hourly basis. The parameters recorded included energy used for heating, cooling, electricity, and domestic hot water, as well as interior and outdoor air temperatures. The energy data were collected and analyzed to determine energy savings attributable to the retrofit packages.

Several types of analysis were perfomed:

The first round of energy data analysis was a direct comparison of annual component energy consumption between the test building and the average consumption of the reference buildings. The difference in energy consumption was credited to the retrofit packages. Any structural, mechanical, or operational differences between the buildings other than the retrofit package changes were considered negligible.

A second round of energy data analysis attempted to compensate for measurable differences between the buildings—in particular, interior temperature trends and building occupancy. Linear regressions were run on the gathered data to model energy consumption as a function of the retrofit packages, building load, and operational conditions. Operational conditions were held constant while annual energy totals and savings were projected for each building category with representative weather conditions. Table B shows the final regression models.

The savings results from regression analysis were credited to the retrofits for the L-shaped barracks, the rolling-pin barracks, and the motor vehicle repair shop. Here, significant savings were identified for heating only. Direct comparison data were used for the dining facility for which statistical models could not be developed. Again, heating energy savings were the only energy differences assumed to be nonrandom. The credited savings achieved a substantial percentage of heating energy but significantly less than anticipated (Table C).

*A metric conversion table is shown on p 135.

Table A

Energy Conservation Measure Packages

L-Shaped Barracks-Initial	Replace Window Units Block Up Window Area Minimize Outdoor Air Intake Air Handling Units New Hot Water Heating System Controller Exterior Insulation
L-Shaped Barracks-Operation	Boiler Room Tune Up (Boiler Tune Up, Flue Damper, Clean Up Wiring, Repair Wires, Motor Steam Traps) New Heating Control System (New Reset Controls, Monitored Settings Boiler Control, Steam Valves) DHW Revamp (Isolate DHW function, check setpoint, shower heads)
Rolling-Pin Barracks	New Window Units How Water Heating System Controller Low Leakage Dampers for Air Handling Unit Outside Air Intake
Dining Halls	Programmable Thermostats Kitchen Hood Ventilating system Heating System Hot Water Temperature Reset Controller Replace Incandescent Lighting With Fluorescent Install Insulating Panels Over Window Ceiling Insulation Replace Entrance Doors
Motor Vehicle Repair Shops	Programmable Thermostats New Boiler Controller Partition Office From Vehicle Bays Replace Overhead Doors Insulate Window Area Interior Wall Insulation

Table B

Energy Consumption Regression Equations

L-Shaped Barracks - Gas:	
811 (87/88)*:	Gas = -8,625,504 - 488,705 x OAT + 589,370 x TALL + 1.049 x DHW
811 (86/87):	Gas = -9,327,695 - 589,970 x OAT + 620,333 x TALL + 3.984 x DHW
812 (86/87):	Gas = -92,651,150 - 727,207 x OAT + 1,865,736 x TALL + 4.630 x DHW
813 (87/77):	Gas = -63,614,755 - 761,587 x OAT + 1,544,064 x TALL + 3.910 x DHW
813 (86/87):	Gas = -62,407,438 - 764,174 x OAT + 1,584,589 x TALL + 1.900 x DHW
L-Shaped Barracks - Heating:	
811 (87/88)*:	Heat = -9,014,913 - 225,372 x OAT + 313,087 x TALL - 0.034 x DHW
811 (86/87):	Heat = -5,751,443 - 356,983 x OAT + 363,148 x TALL + 0.053 x DHW
812 (86/87):	Heat = -27,302,473 - 408,236 x OAT + 719,930 x TALL + 0.069 x DHW
813 (87/88):	Heat = -34,180,655 - 373,474 x OAT + 750,659 x TALL + 1.091 x DHW
813 (86/87):	Heat = -20,014,694 - 374,145 x OAT + 591,011 x TALL + 0.143 x DHW
Rolling-Pin Barracks:	
1363:	Heat = 10,998,625 - 254,382 x OAT + 83,651 x TALL - 1.126 x DHW
1663:	Heat = 32,145,206 - 271,148 x OAT - 134,688 x TALL + 0.921 x DHW
1666:	Heat = 27,817,445 - 58,271 x OAT - 171,558 x TALL - 0.376 x DHW
1667:	Heat = 44,087,963 - 93,878 x OAT - 396,278 x TALL + 0.420 x DHW
Motor Vehicle Repair Shops:	
633:	Gas = 10,178,663 - 210,526 x OAT + 67,716 x BayT + 4,197 x Elec
634:	Gas = 10,075,874 - 429,631 x OAT + 242,556 x BayT + 17,316 x Elec
635**:	Gas = 10,575,672 - 248,228 x OAT + 115,988 x BayT + 33,308 x Elec
636:	Gas = 3,118,149 - 348,736 x OAT + 263,965 x BayT + 74,901 x Elec

* The equation for Building 811 (87/88) should not be used to assess energy savings due to improved operations directly since it includes effects of the original retrofits.

** Building 635 was not included in the calculation of energy savings because the regression equation did not show good predictive power, and energy consumption characteristics appeared to be inconsistent with the other control buildings.

NOTE: These equations use DAILY values. Gas, Heat, and DHW are the total daily consumption in Btu. Elec is total daily consumption in kWh. OAT, TAIL, and BayT are daily average temperatures.

Table C

Energy Savings of the Retrofits and Expected Savings

Building	Energy Saved (MBtu)	% of Component Baseline	Savings Expected (MBtu)	% of Expected
633(MP)	744	41	1040	72
822(LS)	1973	27	3339	59
811op(LSop)	1741	28	2000	87
1361(DH)	64	24	3620	1.8
1363(RP)	1777	41	3343	53

Key: MP = Motor Vehicle Repair Shop
LS = L-Shaped Barracks
LSop = L-Shaped Barracks w/Improved Operations
DH = Enlisted Personnel Dining Facility
RP = Rolling-Pin Shaped Barracks

Notes: baseline consumption refers to the average consumption of the reference buildings for the component energy which was saved (here the component energy is heating for all original retrofits and heating and dhw consumption for the LSop retrofit). Expected savings of the original retrofits are from the BLAST runs of CERL TR E-183. Expectations for LSop were from simplified engineering calculation.

Detailed review of the data, coupled with onsite observation, suggested that the potential savings from the retrofits were being compromised due to operational conditions in the buildings. Further, opportunities for large energy savings were not being exploited. Of particular concern were the heat production and distribution systems, which lacked efficiency and control.

The L-shaped barracks was targeted for further investigation. A detailed inspection of barracks operational conditions was conducted. The following conditions existed: (1) the building was overheated due to inadequate equipment, improperly set equipment, and inappropriate actions of occupants and operators, and (2) space and domestic hot water (DHW) heating system efficiencies were low due to standby losses and control strategies.

Remedies were implemented to (1) improve the temperature control in the building and (2) increase the efficiencies and decrease the loads of the space and DHW heating systems. Modifications included equipment replacement, augmentation, and tune-up, along with control strategy changes.

Economic analysis was conducted on the retrofit packages. Actual costs and new estimates of the original packages' construction costs for the project year and the current year were reviewed. New cost estimates were prepared because actual implementation costs were more than expected and because market conditions could have changed since the project year.

The economic results indicated that, based on actual construction costs and measured savings, the retrofit at the rolling-pin barracks and the L-shaped barracks improved operations retrofit meet the (ECIP) criterion of savings-to-investment ratio (SIR) ≥ 1 for the year implemented. Using project year estimated costs for the original retrofits, the motor pool retrofit meets this criterion. With current year estimated costs and current fuel prices, none of the original retrofits meet the ECIP criterion. (Table D shows current year economics.)

Market scenarios were developed to examine under what conditions the four retrofit packages would meet the ECIP criterion of SIR ≥ 1.0. Parameters examined were construction cost, annual energy savings, fuel cost, and annual nonenergy savings. The scenarios were examined by developing an equation expressing the relationship between the parameters when the ECIP criterion is satisfied.

The market scenarios indicate that, even with the low energy savings achieved, the original retrofits have some merit. Examination of 25-year life scenarios allowed USACERL to calculate, for the current year cost estimates, what natural gas prices would have to be for the retrofits to have an SIR = 1. These prices are listed in Table E; information for the improved operations retrofit with a 15-year life scenario

Table D

Current Year Cost-Effectiveness of Retrofits

Building	Project Life (years)	Fiscal Year	SIR	Simple Payback (years)
633(MP)	25	89	0.99	23
811(LS)	25	89	0.46	49
811op(LSop)	15	88	5.14	2.8
1361(DH)	25	89	.04	502
1363(RP)	25	89	.78	29

Key: MP = Motor Vehicle Repair Shop
LS = L-Shaped Barracks
LSop = L-Shaped Barracks w/Improved Operations
DH = Enlisted Personnel Dining Facility
RP = Rolling-Pin Shaped Barracks

Table E

Gas Energy Prices for SIR = 1.0

Building	Natural Gas Cost
633(MP)	3.13
822(LS)	6.69
811op(LSop)	.70
1361(DH)	87.18
1363(RP)	3.99

Key: MP = Motor Vehicle Repair Shop
LS = L-Shaped Barracks
LSop = L-Shaped Barracks w/Improved Operations
DH = Enlisted Personnel Dining Facility
RP – Rolling-Pin Shaped Barracks

LSop was estimated with 1987 prices, all other packages were estimated with 1988 prices.

is included. Except for the retrofit at the dining hall, all of the retrofits could possibly become cost-effective in the near future. (Current average cost for natural gas at Fort Carson is $3.11/MBtu.) This projection assumes, of course, that a contract solicitation would result in contract costs no higher than the current cost estimates.

Successful building energy consumption models were developed with the statistical analysis for the L-shaped and rolling-pin barracks and the motor repair shop. These models of baseline and retrofit building heating energy consumption will allow evaluation of energy savings for the same retrofit packages at other locations.

Results from the improved operations retrofit at the L-shaped barracks were most encouraging. Improvements in interior temperature trends, control capabilities, system part-load efficiencies, and heating and DHW loads resulted in substantial fuel savings. Energy savings from improved operations almost equaled savings from the original retrofit, which was much more costly. However, continued return on investment requires some upkeep of the mechanical equipment, informed responses to heating calls, repair of equipment as it fails, and lack of vandalism to any of the installed equipment.

As a concluding measure for the project, a new series of building simulations was produced using the Building Loads Analysis and System Thermodynamics (BLAST) computer program. The models developed can be used as beginning building descriptions for the four standard designs investigated to assess whether similar (or other) retrofit packages might be effective on similar buildings.

The insights gained during this project were valuable and stressed the need for a comprehensive energy program. That is, several factors--building envelope, building controls, mechanical operations, and the actions of operators and occupants--together bring about the total building energy consumption. The entire building system needs to be assessed and remedied appropriately to bring buildings to their full potential energy effectiveness.

It is recommended that building operations be assessed and improved at all buildings where energy conservation is a concern. An overview of the improvements made to the L-shaped barracks is included in this report. Detailed information on the changes made will be published as a separate Technical Report. These or similar changes could be used to advantage in other L-shaped barracks buildings or facilities with similar heating/ DHW systems. Also, the concepts evaluated in this project could be used to develop conservation strategies for different building types.

Routine maintenance and repair of mechanical equipment at installations needs to be reviewed and improved. Some specific areas to check include boiler tune-up, control and air compressor servicing, steam trap repair, air-bound hydronic heating systems, and radiator dampers. A review of the local definition of "broken" equipment is in order. "Totally inoperative" is too strict a definition. "Insufficiently operating" is a more reasonable compromise and would ultimately be more cost-effective.

Much of the opportunity for improved operations depends on adequate operator education and coordination. Job-specific training programs for operators that include guidelines for troubleshooting heating, ventilation, and air-conditioning systems need to be implemented or improved. The technical skills of building operators should be tested as part of a training program. An in-building log of service calls, including problems reported and responses taken, should be kept. A designated staff should be named exclusively for making adjustments to building control.

It is necessary for each installation to have at least one controls expert on staff, which may require hiring one or training existing personnel. This person would be responsible for making (or at least overseeing) all controls adjustments. The potential for monetary savings with appropriately set and maintained building controls is substantial and justifies the expense of a trained controls engineer.

Occupant education may be a key to achieving results. Simple occupant modifications such as clothing and bedding adjustments, strategic furniture positioning, and passive humidification can greatly enhance occupant comfort. Making select occupants aware of heating control capabilities that do exist in buildings could increase interior comfort and decrease service calls.

Maintaining or improving building comfort should be a primary goal when reviewing energy conservation options. Drastic measures for energy conservation such as the disabling of heating, ventilation, or DHW do cut energy costs, but increase other (albeit less quantifiable) costs as occupant morale and healthy conditions are compromised.

The original retrofit packages were not cost-effective based on energy savings alone; however, other nonenergy benefits were achieved that were not quantified in dollars. These include improved functioning, appearance, comfort, productivity, and morale, and decreased maintenance. If buildings are being renovated or repaired, the items used in these retrofit packages, which have a bias toward energy conservation, should be considered. The energy savings may not justify the entire cost of the implemented products but may well justify the incremental cost over less expensive, nonenergy conservative options.

Finally, the applicability of the implemented retrofits should be reviewed as fuel and construction costs change. If the calculated payback periods are acceptable within a reasonable margin of error, then the retrofit measures should be implemented.

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APPLYING ENERGY CONSERVATION RETROFITS TO STANDARD ARMY BUILDINGS: DATA ANALYSIS AND RECOMMENDATIONS

1 INTRODUCTION

Background

Each major Army installation needs many buildings of the same functional type, such as barracks, motor repair shops, and mess halls. To minimize design and construction costs, the Army has often developed and used standardized designs for construction of these common buildings, with minor variations in design made to accommodate an installation's mission and location.

Many of these buildings were constructed with little emphasis on energy efficiency; hence, identification of economically attractive, energy-conserving building modifications (or retrofits) offers the possibility of substantial cost savings. Since the buildings were constructed using standard designs, energy conservation measures could be standardized to apply to many buildings at multiple Army installations.

To test this concept, the U.S. Army Construction Engineering Research Laboratory (USACERL) performed computer-based energy analysis with the Building Loads Analysis and System Thermodynamics (BLAST)[1] Program. This analysis resulted in retrofit packages[2] for increasing the energy efficiency of four categories of standard building designs: a vehicle repair shop, a Type 64 (L-shaped) barracks, an enlisted personnel dining facility, and a "rolling-pin"-shaped barracks (Figures 1 througn 4). The Army has more than 840 of these particular buildings.*

The suggested retrofit packages consist of groups of selected energy conservation alternatives, with some flagged as appropriate only in specified climates. This "standardization"** in retrofit packages has several benefits. For example, standardization has been shown to reduce design and construction costs. It enables quantity procurements, interchangeability of parts, and the opportunity for installations to share experiences. In addition, standardization of retrofits improves the quality of facility maintenance as product and system familiarity increase.

The retrofit packages are envelope and system modifications that include energy conservation measures (ECMs) such as wall or ceiling insulation, window replacement or reduction, air-handling equipment adjustment, control replacements, lighting replacement, and others. Table 1 gives a complete list of the retrofits selected for each building type.

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[1] D.C. Hittle, *The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0, User's Manual, Vols I and II*, Technical Report (TR) E-153/ADA072272 and ADA0722730 (U.S. Army Construction Engineering Research Laboratory [USACERL], June 1979); D. Herron, G. Walton, and L. Lawrie, *Building Loads Analysis and System Thermodynamics (BLAST) Program User's Manual--Vol I Supplement, Version 3.0*, TR E-171/ADA099054 (USACERL, March 1981).

[2] D.C. Hittle, R.E. O'Brien, and G.S. Percivall, *Analysis of Energy Conservation Alternatives for Standard Army Buildings*, TR E-183/ADA129963 (USACERL, March 1983).

* A survey of major installations showed 399 L-shaped barracks, 257 rolling-pin barracks, 103 dining facilities, and 83 motor repair shops. (Source: USACERL TR E-183.)

** Note that applied retrofits vary with location of the building, but are selected from a standard list for each building type.

Figure 1. Exterior view: motor vehicle repair shop.

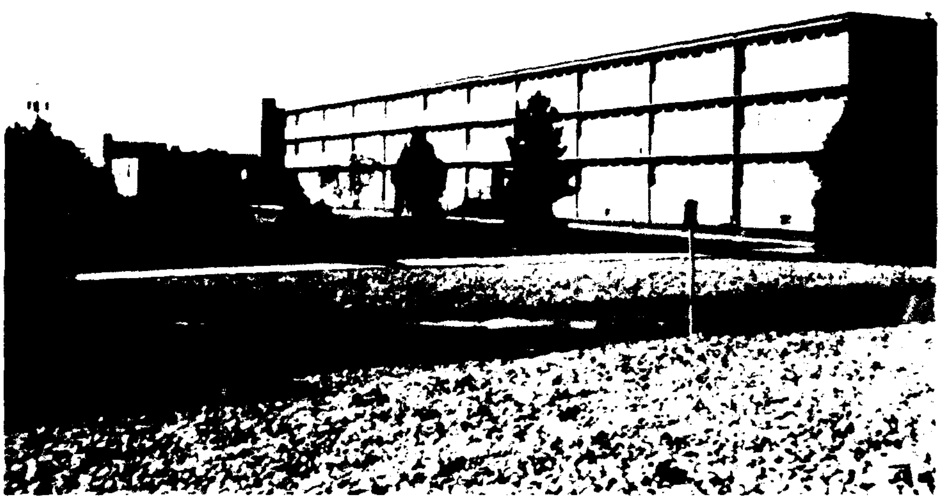

Figure 2. Exterior view: L-shaped barracks.

Figure 3. Exterior view: dining hall.

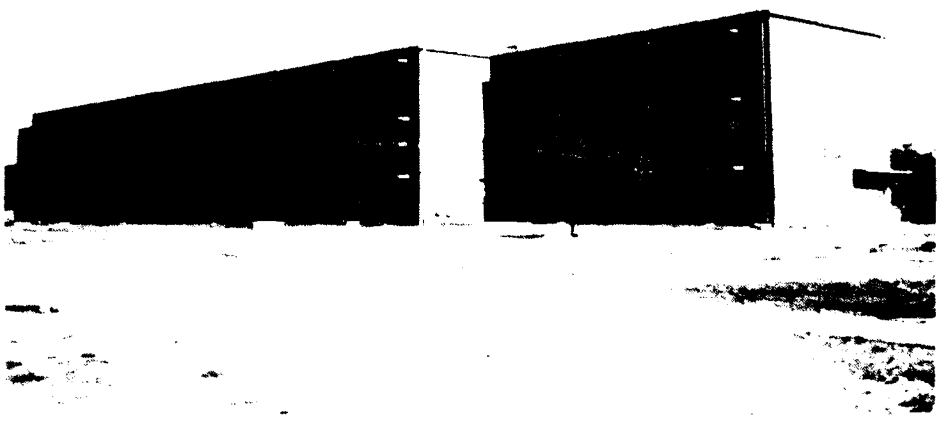

Figure 4. Exterior view: rolling-pin barracks.

Table 1

Energy Conservation Measure Packages

Facility Type	Retrofit
L-Shaped Barracks--Initial	Replace window units Block up window area Minimize outdoor air intake by air-handling units Install new hot water heating system controller Install exterior insulation
L-Shaped Barracks--Operations	Conduct Boiler room tune-up (boiler tune-up, flue damper, clean up wiring, repair wires, motor, steam traps) Install new heating control system (new reset controls, monitored settings, boiler control, steam valves) Revamp DHW System (isolate DHW function, check setpoint, shower heads)
Rolling-Pin Barracks	New window units Install hot water heating system controller Install low-leakage dampers for air-handling unit outside air intake
Dining Halls	Install programmable thermostats Kitchen hood ventilating system Heating system hot water temperature reset controller Replace incandescent lighting with fluorescent Install insulating panels over windows Add ceiling insulation Replace entrance doors
Motor Vehicle Repair Shops	Install programmable thermostats Install new boiler controller Partition office from vehicle bays Replace overhead doors Insulate window area Add interior wall insulation

Due to the large number of buildings available for retrofit and the resulting high investment cost, a field testing program was initiated to confirm the effectiveness of the retrofit packages. Such tests allow for the verification of initial assumptions and recommendations, as well as provide an opportunity for modifications to design and adjustments to priorities in subsequent retrofits based on lessons learned. The test design and initial data collection are described in detail in a USACERL Interim Report.[3]

Objective

The objective of this project was to field-test the energy performance of retrofit packages for four standard building groups. The objective of followup work was to field-test operational improvements to the L-shaped barracks.

Approach

The work progressed through the following steps:

1. USACERL Technical Report E-183, *Analysis of Energy Conservation Alternatives for Standard Army Designs*, was reviewed to determine the recommended retrofits and the data requirements.

2. Four standard design building groups were identified for investigation: a vehicle repair shop, an L-shaped barracks, an enlisted personnel dining facility, and a rolling-pin barracks.

3. Fort Carson, CO, located southeast of Colorado Springs, was selected as the site for the field test.

4. Final retrofit designs were completed to accommodate site-specific constraints.

5. For each building type, one building was retrofitted and two or three identical, but not retrofitted, buildings were identified as baseline, control buildings. In total, 14 buildings were chosen. Table 2 lists the test group buildings for each type and identifies the retrofit and control buildings.

6. Automated data collection equipment was installed in each building to record significant energy consumption parameters: energy usage (Btus for electricity, gas, and heated and chilled water) and building load (indoor and outdoor temperatures).

7. Starting in early 1986, hourly energy use data were collected from the 14 buildings.

8. Direct comparison energy savings were determined through a side-by-side comparison of observed energy usages.

9. The data were analyzed statistically to assess energy savings while compensating for building operational differences and to create a simple building model for determining energy savings elsewhere.

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[3] E.T. Westervelt, G.R. Northrup, and E.O. Allen, *Applying Energy Conservation Retrofits to Standard Army Buildings: Project Design and Initial Energy Data*, Interim Report (IR) E-88/08/ADA198953 (USACERL, July 1988).

Table 2

Test Group Buildings

Facility Type	**Building No./Year**	**Test Configuration**
L-Shaped Barracks	811 (86/87)	Retrofit (Initial Package)
	811 (87/88)	Retrofit (Improved Operations)
	812 (86/87)	Control
	813 (86/87)	Control
	813 (87/88)	Control
Rolling-Pin Barracks	1363	Retrofit
	1663	Control
	1666	Control
	1667	Control
Dining Halls	1361	Retrofit
	1369	Control
	1669	Control
Motor Vehicle Repair Shops	633	Retrofit
	634	Control
	635	Control
	636	Control

10. The cost-effectiveness of the demonstrated packages was studied and the market conditions (fuel and material costs) under which the retrofits should be implemented were determined.

11. New BLAST analyses, reflecting as-built, properly operated building conditions, were performed.

Tests on the rolling-pin barracks, dining halls, and motor repair shops ran until mid-1987. The L-shaped barracks testing continued until mid-1988. During summer 1987, additional retrofits were installed in one building type, the L-shaped barracks, in response to interim findings that suggested building operations were compromising the savings of the initial retrofits. The additional work included:

12. Improvement of building operations at the retrofit L-Shaped Barracks.

13. Collection of energy data.

14. Data analysis.

Scope

This report details Steps 8 through 11 above and followup Steps 12 through 15. The first seven steps are the subject of USACERL Interim Report E-88/08. Specifically, the Interim Report covers: (1) the impetus for the project--expected improvements in energy and cost efficiency as predicted in USACERL Technical Report E-183 and the numerous benefits of the work effort; (2) the retrofit packages, including details of the demonstration site, each of the building categories, the retrofits theoretically suggested, those actually employed, and the qualitative insights gains in product selection and application; (3) the experimental procedure, including an overview of the test-reference experiment, the determination, acquisition, and organization of the data set, the data cleanup strategy, and the first attempt at annual energy projection; (4) the initial data analysis, including direct energy comparison, apparent energy savings, and insights on building operational trends; (5) plans for future work in interpreting the energy data; (6) interim conclusions; (7) the hardware for energy monitoring and data acquisition; and (8) the computer software for data acquisition and analysis report.

Organization of Report

Chapter 2 presents the energy results for the retrofit packages. It includes both direct energy comparisons and statistically compensated energy comparisons. Chapter 3 reviews the economic analysis of the data, including life-cycle cost-effectiveness determinations. Chapter 4 contains notes on building and retrofit performance, including some graphs of the gathered data. Chapter 5 describes the additional work on operational improvements at the L-shaped barracks. Chapter 6 details the revised BLAST analyses of the buildings reflecting the retrofit conditions. Chapter 7 provides the conclusions and recommendations of the entire work effort.

Mode of Technology Transfer

Information from this study will be included in technology transfer media such as a FEAP Decision Sheet, the *DEH Digest*, and Energy Awareness Seminars. Specifications for the retrofits will be available on an as-needed basis. (Formal distribution packages will be prepared if demand is high enough.) Information may be distributed in EIRS Bulletins.

2 ENERGY RESULTS

This chapter reviews the energy results of this experiment. It includes a description of the data collected, a compilation of annual energy use data for direct comparison, and a statistical savings analysis.

The first round of energy analysis is a direct comparison of component energy consumption for the test building and the average consumption of the reference buildings on an annual basis. The difference in energy consumption is credited to the retrofit packages. Any structural, mechanical, or operational differences between the buildings other than the retrofit package changes are assumed negligible.

Attempts to compensate for measurable differences between the buildings that may be affecting the energy results are addressed in the statistical analysis section. Included in that section are energy models for the building categories that help estimate expected savings at other locations.

The Data Set

Energy Parameters Monitored

Data were collected on component energy use (heating, cooling, electricity, and domestic hot water) and interior and exterior temperature trends. Each building type investigated has different energy systems; thus, the data collected for analyses vary accordingly. The energy data for each building, and what those data represent, are listed below.

- Motor vehicle repair shop:
  - Electricity (lighting, fans, compressors, tools, appliances, etc.)
  - Gas (boiler for space heating).
- L-shaped barracks:
  - Electricity (lighting, fans, appliances, etc.)
  - Gas (boilers--space heating and domestic hot water (DHW); direct-fired water heater--DHW
  - Heat delivered to individual heating zones
  - Total heat delivered to building (sum of zones 1, 2, and 3)
  - Energy in DHW
  - Heat removed in chilled water (central plant)
  - Heat total for the barracks wing (singled out to allow easier comparison with the energy predictions of the BLAST runs, which did not include the mess hall wing [zone 3]).

- Dining hall:
  - Electricity (lighting, fans, appliances, etc.)
  - Gas (cooking)
  - Heat (circulating hot water from central plant)
  - Steam (kitchen use)
  - Energy in DHW.
- Rolling-pin barracks:
  - Electricity (lighting, fans, appliances, etc.)
  - Heat (circulating hot water from central plant)
  - Energy in DHW.

Time and data information, air temperatures, and select statistical functions were also logged. Energy totals are referenced as accumulated data, and temperature data as analog data in some of the data analysis discussions. A complete list of all variables in the data set is included in Appendix A.

Data Organization

Automated metering equipment gathered and transferred computer data to USACERL for analysis. Data were recorded on an hourly basis. In addition, periodic manual meter readings were taken on energy parameters where local readouts were available (gas, electricity, gallons of condensate, and gallons of DHW). These data were usually taken on a monthly basis.* Meters independent of the automated metering system were not installed for Btu counts on heating, cooling, and DHW. Thus, these data are available only in the hourly data base.

The hourly data base for the monitoring period is extensive, but not 100 percent complete. Various events resulted in loss of hourly data. These events included power outages, lightning, floods, steam line breaks, downtime to calibrate instruments, pest infestation, time offline to transfer files, mechanical and electrical failures of instrumentation, recording devices, and telephone lines, and assorted human errors. Due to gaps in the data, various methods were developed to estimate intermediate totals for both direct and statistical comparisons. These methods are discussed below in their respective sections.

Direct Comparison

Season/Week Model

The season/week model is one method for annual comparison of energy data from the less than complete hourly data base. Missing energy data are estimated from a model week of hourly energy consumption for several defined energy seasons.

*Periodic meter readings were not always taken on the first of each month. In these cases, monthly totals were prorated.

Technique. Selection of "seasons" is the first step in season/week modeling. A season is any period of weeks during which all buildings of a given type behave in a similar manner. Seasons were determined empirically for each building type and component energy use (heating, cooling, electricity). Energy consumption and related parameters were graphed against time. Periods with consistent usage trends were used as initial season definitions. Discernible trends included steady increases, declines, relatively stable periods, and periods of great fluctuation. Season definition was then refined to choose groups of weeks for which energy data varied around a similar mean. This technique resulted in one to six energy seasons per year for each component energy usage. In addition, certain seasons were defined to isolate periods during which a building was not behaving in a normal manner. This process would typically isolate periods of suspected instrument or heating system failure.

As a simplified example of season definition, heating Btu values could be (but were not necessarily) modeled with four seasons, depending on the heating system's percentage on-time during a given day. As the example in Figure 5 shows, there is a period of 100 percent on-time in the middle of winter, a period of 0 percent on-time from mid-May to mid-September, and two shoulder seasons in which on-time varies. The analysis would have to consider each season separately because each will typically react in a different manner.

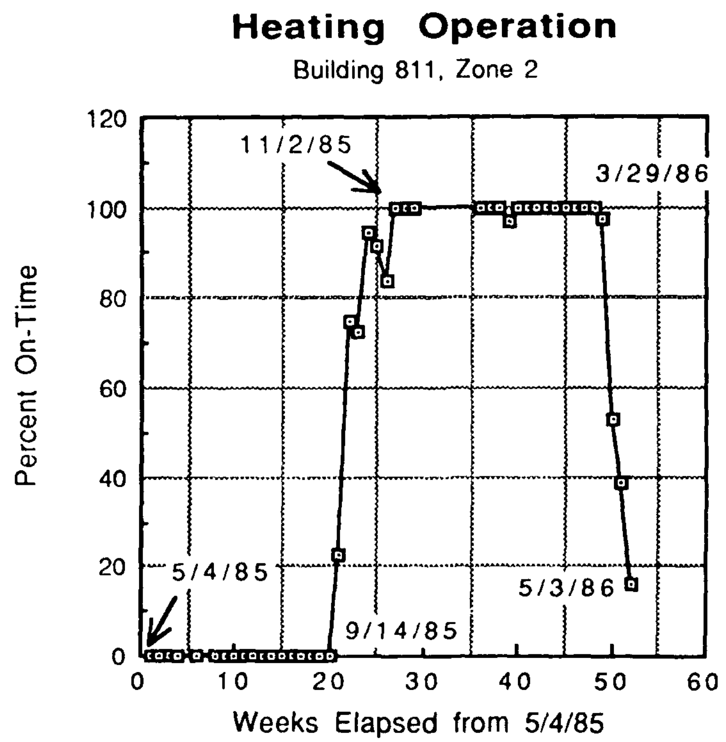

Figure 5. Example season definition for the season/week model.

The weekly building performance is modeled hourly by averaging the data for a corresponding hour for all weeks during a season. Summing the energy use over the model week and then multiplying by the number of weeks in that season will give the total energy use for that season. Conceptually, this procedure accounts for all missing data in the season by substituting it with the corresponding hours from the model week for that season. The energy used during all seasons for 1 year is the annual energy usage.

Season/Week Model vs. Earlier Attempts. Initial attempts at direct comparison (presented in Interim Report E-88/08) used cruder methods of estimating annual energy consumption from the hourly data set. The mean hourly energy consumption for a week was used to estimate any missing data points during a week. The mean weekly consumption for the year was used to estimate an entire week of missing data.

Current methods of energy estimation with the season/week model offer many refinements from earlier efforts. The season/week method captures variations in energy use due to the time of day, day of the week, and week of the year. Included in these variations are periodic usage patterns for when building is occupied vs. unoccupied, when it is morning vs. night, weekday vs. weekend, summer vs. winter, or when the energy system is in a part-load vs. full-load condition.

Season/Week Model vs. Meter Readings. To assess the accuracy of the season/week model, annual energy estimates of the model using the hourly data base were compared with manual meter readings of electricity and gas for the L-shaped barracks. Tables 3 and 4 summarize this information.

For the natural gas comparison, the model is off by 2.6 percent in the worst case (the 1987-88 heating year for Bldg 813). However, the observed error amounts to a fraction of a percent difference in the savings summary.

Table 3

L-Shaped Barracks: Metered vs. Modeled Gas Consumption, June 1986 Through June 1988

		Energy Totals				Percent Savings Summary		
Energy Type	Date	Bldg 811 MBTU	Bldg 812 MBTU	Bldg 813 MBTU	Mean Ref MBTU	811 vs 812 (%)	811 vs 813 (%)	811 vs Mean Ref (%)
Metered Electric	86-87:	692.5	828.4	763.1	795.7	16.4%	9.3%	13.0%
	87-88:	790.2	762.6	771.7	767.2	-3.6%	-2.4%	-3.0%
	86-88 Total:	1482.7	1591.0	1534.8	1562.9	6.8%	3.4%	5.1%
Modeled Electric	86-87:	678.0	811.9	738.9	775.4	16.5%	8.2%	12.6%
	87-88:	769.2	749.8	770.7	760.2	-2.6%	0.2%	-1.2%
	86-88 Total:	1447.1	1561.7	1509.5	1535.6	7.3%	4.1%	5.8%
Difference Gas	86-87:	2.1%	2.0%	3.3%	2.6%			
	87-88:	2.7%	1.7%	0.1%	0.9%			
	86-88 Total:	2.5%	1.9%	1.7%	1.8%			

Key

Building 811 == Test	86-87 is June 1986 - May 1987
Building 812 == Reference	87-88 is June 1987 - May 1988
Building 813 == Reference	86-88 is June 1986 - May 1988
1 MBtu == 10^6 Btu	

Table 4

L-Shaped Barracks: Metered vs. Modeled Electrical Consumption, June 1986 Through June 1988

Energy Type	Date	Bldg 811 MBTU	Bldg 812 MBTU	Bldg 813 MBTU	Mean Ref MBTU	811 vs 812 (%)	811 vs 813 (%)	811 vs Mean Ref (%)
		Energy Totals				**Percent Savings Summary**		
Metered Gas	86-87:	6235.1	8644.8	7905.3	8275.0	27.9%	21.1%	24.7%
	87-88:	4592.9	7688.8	7530.7	7609.8	40.3%	39.0%	39.6%
	86-88 Total:	10828.0	16333.6	15436.0	15884.8	33.7%	29.9%	31.8%
Modeled Gas	86-87:	6150.7	8552.7	7755.4	8154.1	28.1%	20.7%	24.6%
	87-88:	4540.1	7581.5	7338.6	7460.0	40.1%	38.1%	39.1%
	86-88 Total:	10690.8	16134.2	15094.0	15614.1	33.7%	29.2%	31.5%
Difference Gas	86-87:	1.4%	1.1%	1.9%	1.5%			
	87-88:	1.2%	1.4%	2.6%	2.0%			
	86-88 Total:	1.3%	1.2%	2.3%	1.7%			

Key

Building 811 == Test	86-87 is June 1986 - May 1987
Building 812 == Reference	87-88 is June 1987 - May 1988
Building 813 == Reference	86-88 is June 1986 - May 1988
1 MBtu == 10^6 Btu	

When comparing electrical consumption, the worst-case error for the season model is 3.3 percent (1986-87 heating year for Bldg 813). The error in the model accounts for as much as a 2.4 percent difference in the savings summary. However, when this occurs, the savings is so small that it is uncertain if a difference exists. This observation will be pursued further in the statistical analysis section.

Annual Energy Data

Data Summaries Presented. Tables 5 through 8 present data on annual energy use observed at the building site. For each building type, data are included for the test building and each reference building as well as the average value of the reference buildings. The data are either manual meter readings or results of season/week modeling, as appropriate.

Included in these tables are the percentage difference in energy use between the test building and the average use of the reference buildings. Equivalently, this is the apparent savings (or loss if the percentage difference is negative) due to the retrofits by direct comparison of the annual energy totals.

Detailed review of the data suggested that this difference in energy use could not be exclusively credited (or shouldered) by the retrofit. That is, other differences between the buildings, not including the retrofits were affecting the energy totals. Some measurable differences included interior temperature settings and building occupancy or usage rates. Statistical review of the data attempted to adjust for these differences as discussed below.

Table 5

Motor Pool Test/Reference: Direct Comparison of Site Energy Consumption, June 1986 Through May 1987

Annual Energy Totals

Energy Type	Bldg 633 MBTU	Bldg 634 MBTU	Bldg 635 MBTU	Bldg 636 MBTU	Mean Ref MBTU	Percent Difference --- Appearent Savings
Gas *	1061.0	1498.0	1328.0	1838.0	1622.3	34.6%
Electricity *	64.0	83.0	15.0	56.0	36.0	-77.6%

* from meter readings

Key

Floor Space = 4800 Sq.Ft.	Building 633 == Test
1 MBtu == 10^6 Btu	Building 634 == Reference
1 KBtu == 10^3 Btu	Building 635 == Reference
1 Kwh == 3413 Btu	Building 636 == Reference

Table 6

L-Shaped Barracks Test/Reference: Direct Comparison of Site Energy Consumption, June 1986 Through May 1988

Annual Annual Energy Totals

Energy Type	Date	Bldg 811 MBTU	Bldg 812 MBTU	Bldg 813 MBTU	Mean Ref MBTU	Percent Difference --- Appearent Savings
Gas Btus	86-87:	6150.7	8552.7	7755.4	8154.1	24.6%
	87-88:	4540.1	7581.5	7338.6	7460.0	38.1%
Heat, all	86-87:	2012.5	2600.6	2383.8	2492.2	19.2%
zones	86-87:	1022.5	2338.2	2279.8	2309.0	55.1%
Cooling	86:	174.0	367.3	191.5	279.4	37.7%
	87:	98.9	0.0	235.9	117.9	-
Electricity	86-87:	678.0	811.9	738.9	775.4	12.6%
	87-88:	769.2	749.8	770.7	760.2	-
DHW	86-87:	732.3	815.0	806.4	810.7	-
	87-88:	646.3	683.5	551.8	617.6	-

Key

1 KBtu == 10^3 Btu	Building 811 == Test	
1 MBtu == 10^6 Btu	Building 812 == Reference	
1 Kwh == 3413 BTU	Building 813 == Reference	
86-87 is June 1986 - May 1987	1986-87 HDD ==	5968
87-88 is June 1987 - May 1988	1987-88 HDD ==	6095

Table 7

Dining Hall Test/Reference: Direct Comparison of Site Energy Use (Annualized Data)

Annualized Energy Totals *

Energy Type		Bldg 1361 MBTU	Bldg 1369 MBTU	Bldg 1669 MBTU	Mean Ref MBTU	Percent Difference --- Apparent Savings
Elec	1986-87	33.6	87.3	23.5	55.4	
Gas (cooking)	1986-87	3120.5	199.1	758.5	478.8	
Heat	1986-87	122.6	250.9	71.9	161.4	24.1%
Steam (Cooking)	1986-87	4148.7	57.0	4407.2	2232.1	
Dhw	1986-87		100.5			

Notes:

* This data was annualized from data from Weeks 8609-18 and 8709-18.
  Heating was projected by dividing the season usage by the seasonal heating degree days and multiplying by the annual heating degree days for 1986-87 heating season.
  Because electricity, gas, steam and domestic hot water are independent of degree days, these data types have been projected by the average daily use during the sample season multiplied by 365.

Key:

Floor Space =	10620	
1 MBtu == 10^6 Btu		Building 1361 == Test
1 KBtu == 10^3 Btu		Building 1369 == Reference
1 Kwh == 3413 Btu		Building 1669 == Reference
Spring Heating Degree Days:		1368.87
Fall/Winter Heating Degree Days:		4605.48

Table 8

Rolling-Pin Barracks Test/Reference: Direct Comparison of Site Energy Use, August 1986 Through July 1987

Annual Energy Totals

Energy Use	Bldg 1363 MBTU	Bldg 1663 MBTU	Bldg 1666 MBTU	Bldg 1667 MBTU	Mean Ref MBTU	Percent Difference --- Apparent Savings
Electricity	633.1	128.4	42.1	640.3	270.3	-134.2%
Heating	1406.3	2624.2	2861.0	2420.4	2635.2	46.6%

Key

Floor Space = 40698 Sq.Ft.	Building 1363 == Test
1 Kwh == 3413 Btu	Building 1369 == Reference
1 MBtu == 10^6 Btu	Building 1666 == Reference
1 KBtu == 10^3 Btu	Building 1667 == Reference

Differences in consumption due to random variations, rather than retrofit measures, are also discussed in the statistical section. This analysis supports differences in heating and gas as the only energy savings attributable to the original retrofit packages.

Cautions in Data Interpretation. Although building operational findings are detailed in Chapter 4, a few conditions warrant attention now. Cooling data were gathered for the two barracks types investigated; however, the interpretation is uncertain. There are several reasons for concern. The cooling water provided from the central plant was relatively high in temperature (~65 °F) and could not meet the building loads. Cooling was sufficiently low level that all throttling control had been disabled at the buildings. Interior temperatures usually floated with outdoor temperatures. In some buildings, no cooling took place during the entire test period. Further, where cooling did occur, water flow was erratic and often far below pump capacities. It is speculated that much of the observed flow was pitch-, pressure-, or convective-induced rather than pumped. Of prime concern was the lack of connection between building loads and cooling provided. This situation led to ambiguous, and eventually abandoned, savings estimates.

Annual cooling totals are listed for the L-shaped barracks for instructive purposes only. They were estimated with a season/day model as opposed to a season/week model due to nonintuitive fluctuations from day to day in the season/week model. Although similar efforts were attempted for the rolling-pin barracks, no model could be developed to extrapolate seasonal cooling totals from the gathered data.

Two of the dining halls had no heating provided during the fall season. Since it is reasonable to assume that buildings will be conditioned to some degree of comfort, annual heating data were extrapolated from spring season data by heating degree days for all the dining halls. Because electricity, gas, steam, and DHW are independent of weather conditions, these data types were projected by the average daily use during the sample season, multiplied by the number of days in a year.

Detailed Energy Data. Appendix B contains detailed energy data. Included are partial energy consumption breakouts, additional energies that were metered but not affected by the retrofit, source energy comparisons, and various permutations of the energy data including saving summaries, savings per square foot, use per square foot, and comparisons with original BLAST savings estimates. Source energy refers to energy use (in fossil fuel) at the source of power and heat production.

Improved Operations Data. Energy data from the improved operations retrofits at the L-shaped barracks are presented in Tables 9 through 11. Table 9 shows the savings of the initial retrofit package with gas and heating totals normalized to the 1987-88 heating season by heating degree days. Table 10 shows the incremental savings from improved operations and Table 11 gives the savings of the total retrofit effort (initial retrofit plus improved operations).

Summary

The savings in total building energy observed by direct comparison for the original retrofits is a substantial percentage of baseline consumption for all building categories: between 17 and 35 percent. Most of these savings can be credited to reductions in heating consumption of 19 to 47 percent. Savings in electrical consumption were inconsistent, with results ranging between 11 and -134 percent. Absolute magnitudes (in Btu) of the energy saved for all buildings were considerably less than original savings estimates, however (4 to 73 percent of anticipated Btu; see Appendix B). Further, variations in operational conditions and in energy totals between baseline buildings suggested the need for closer data inspection. Refinements to energy savings totals are outlined in the statistical analysis section.

Table 9

Savings of Initial L-Shaped Barracks Retrofit Package, Normalized to 1987-88 Heating Season

	Annual Energy Totals				Energy Savings	Percent Savings
Energy Type	Bldg 811* MBTU	Bldg 812* MBTU	Bldg 813* MBTU	Mean Ref* MBTU	811* -vs- Mean Ref* MBTU	811* -vs- Mean Ref* MBTU
Gas:	6281.6	8734.7	7920.5	8327.6	2046.0	24.6%
Heating Total:	2055.4	2655.9	2434.5	2545.2	489.9	19.2%
DHW:	747.9	832.4	823.6	828.0	80.1	9.7%

Notes:

Building 811 == Test
Building 812 == Reference
Building 813 == Reference

86-87 is June 1986 - May 1987
87-88 is June 1987 - May 1988

1 KBtu == 10^3 Btu
1 MBtu == 10^6 Btu

1986-87 HDD = 5968
1987-88 HDD = 6095

* These data are from 1986-87, and have been normalized to the 1987-88 heating season.

Table 10

Incremental Savings of Improved Operations

	Annual Energy Totals		Energy Savings	Percent Savings
Energy Type	Bldg 811 MBTU	Bldg 811* MBTU	811 -vs- 811* MBTU	811 -vs- 811* MBTU
Gas:	4540.1	6281.6	1741.5	27.7%
Heating Total:	1022.5	2055.4	1032.9	50.3%
DHW:	646.3	732.3	86.0	11.7%

Notes:

Building 811 == Test
Building 812 == Reference
Building 813 == Reference

86-87 is June 1986 - May 1987
87-88 is June 1987 - May 1988

1 KBtu == 10^3 Btu
1 MBtu == 10^6 Btu

1986-87 HDD = 5968
1987-88 HDD = 6095

* These data are from 1986-87, and have been normalized to the 1987-88 heating season.

Table 11

Savings of Total L-Shaped Retrofit: Initial Retrofit Plus Improved Operations

	Annual Energy Totals		Energy Savings	Percent Savings
Energy Type	Bldg 811 MBTU	Mean Ref* MBTU	811 -vs- Mean Ref* MBTU	811 -vs- Mean Ref* MBTU
Gas:	4540.1	8327.6	3787.5	45.5%
Heating Total:	1022.5	2545.2	1522.7	59.8%
DHW:	646.3	828.0	181.7	21.9%

Notes:

Building 811 == Test	86-87 is June 1986 - May 1987
Building 812 == Reference	87-88 is June 1987 - May 1988
Building 813 == Reference	
1 KBtu == 10^3 Btu	1986-87 HDD = 5968
1 MBtu == 10^6 Btu	1987-88 HDD = 6095

* These data are from 1986-87, and have been normalized to the 1987-88 heating season.

Savings from improved operations were most encouraging, with a 28 percent reduction in gas use from the previous season, adjusted for weather conditions. Energy savings by percentage and Btu met simplified engineering estimates.

Statistical Analysis

Objective

The objective of statistical analysis was to quantify the effect of building retrofits on energy consumption while adjusting for differences in operational conditions between the test and control buildings for each of the original four retrofit packages. No statistical adjustments were made for the improved operations package since operational differences were part of the retrofit.

Approach

Identifying the effects of retrofit changes on building energy consumption involved a rigorous treatment of the hourly data. The statistical analysis required to quantify these effects included: data manipulation, missing data treatment, generation of summary statistics, regression and graphical analysis, development of predictive models, calculation of annual savings, and application of t-tests.

Hourly data were manipulated to produce a daily data set that made use of as much of the gathered data as possible. In this process, instances of missing data were addressed.

Summary statistics of the resultant data set were generated to review the overall characteristics of the data and assess relationships between variables.

Linear regressions were run on the gathered data to model energy consumption as a function of the retrofit packages, building load, and operational conditions. Graphical analysis aided in model development. Once predictive models for energy consumption were developed, operational conditions were held constant while annual energy totals and savings were projected for each building category.

In some instances, no simple regression equation could be developed to model an energy consumption; thus, no adjustments could be made for operational conditions. In these cases, direct comparison numbers offered the best indicator of energy savings. To support the direct comparison savings calculations, t-tests were performed to determine if the differences in energy totals were real and nonrandom.

Data Manipulation/Missing Data Treatment

The hourly data required substantial manipulation before statistical analysis since the time period of interest for the regressions was daily. Variations in hourly data due to equipment cycling and temperature setpoint changes, etc., would mask correlations with outdoor temperature and other variables.

The process for converting the data set from hourly to daily format was complicated by missing or invalid data. The causes of missing data (e.g., various equipment and human shortcomings) were discussed earlier. The invalid data occurred when data were downloaded from the data acquisition system to local computers via telephone line at night. During the downloading process, data acquisition stopped, resulting in a loss of data. In addition, however, the data acquisition process restarted at an unknown time, rendering the next value for accumulated data, such as gas consumption, ambiguous. The accumulated data needed to be collected over an exact time period since the information desired was actually the consumption rate, and 1000 Btu in 1 hr is much different from 1000 Btu in 1.5 hr. Analog data, such as temperature, were not affected by this problem. In addition to missing data, the downloading procedure caused the minute of the hour at which hourly data were recorded to change after each interrogation, making 1 day's data less than or greater than 24 hr, depending on the new time of the hourly acquisition.

Two methods were used to treat missing data. The first method simply deleted all daily data with less than 24 observations. This method was used on the motor vehicle repair shops. Graphs of data were generated and predictive models were developed. During the analysis, it was discovered that invalid and lost data due to the interrogation procedure (described above) were observed in some of the days containing 24 observations. Further, the size of the working data set was smaller than had been expected. For these reasons, a second method of missing data treatment was developed to detect bad data points and allow use of a significantly higher portion of the data set.

The second missing data treatment method involved an averaging technique in which missing data were replaced with the average of the same parameter for the surrounding few hours. Each 24-hr period, beginning at 11 p.m., was divided into active and inactive periods. The active period was from 6 a.m. to 10 p.m. (17 hr). The inactive period was from 11 p.m. to 5 a.m. (7 hr). Missing data, up to 2 hr in each period, were replaced with the average of the nonmissing data in the active or inactive period. Using this technique, more than 65 percent of the data was used in all cases.

Specifically, the missing data procedure involved:

1. Split full data set of hourly data into accumulated and analog data files to isolate accumulated data.

2. Delete records for which the time step was not equal to 1 hr (e.g., 1.5 hr) from the accumulated data file. This eliminated all accumulated data points after interrogations.

3. Rejoin hourly files to retain as many values for analog data as possible.

4. Aggregate hourly data into active and inactive periods, summing accumulated data and averaging analog data over the period.

5. Within each period, prorate accumulated sums according to the amount of available data (e.g., multiply sum by 7/5 for 5 hr of available data in the inactive period to obtain prorated sum for the full 7-hr period).

6. Adjust analog data such that when the values for the two daily periods are averaged together the daily average is correct. (Since the inactive period is 7 hr long, and the active period is 17 hr, averaging together the average temperatures for the two periods would give the inactive value higher weight. Multiplying by 7/12 and 17/12 before averaging the values together results in the correct daily average.)

7. Aggregate active and inactive periods into 24-hr daily periods starting during the hour beginning at 11 p.m. Accumulated data are summed over the day and the weighted average analog data for each period are averaged over the day. This technique ensured that each day consisted of exactly 24 hr of data, irrespective of the actual number of hourly observations or at what point during each hour the observation was taken.

8. Construct daily average outdoor air temperature data file for all buildings using data from the L-shaped barracks files. Using hourly outdoor air temperature data from the three L-shaped barracks, averages for each hour were calculated from whichever values were available. Some hours were therefore based on data from one building, some from all three. The new average temperatures were then aggregated into daily values, using as few as 20-hr of data.

9. Merge daily data from building files with daily outdoor air temperature data into the final data set used in subsequent statistical analysis.

To demonstrate that the above manipulations did not result in excessive chronological skewing of the data sets, frequency distributions of number of days were generated and included in the final data sets by month of the test period for each building. These plots are included in Appendix C.

Summary Statistics

Summary statistics were developed for all pertinent dependent and independent variables contained in the aggregated data sets for each building using the SPSS computer program.[4] Statistics included

[4]N.H. Nie, et al., *Statistical Package for the Social Sciences*, 2nd ed. (McGraw-Hill, 1975).

mean, standard deviation, minimum, maximum, and number of observations. Correlation and covariance matrices were also generated for variables included in the regression analysis models. These statistics and matrices are included in Appendix D.

Regression and Graphic Analysis

Predictive Model Development. The first step in energy model development was to identify dependent and independent variables. Potential dependent and independent variables were selected from the variables included in the data sets. The dependent variables included component energy consumptions that might be affected by the retrofits. The independent variables selected were those which most directly indicate an aspect of building operation that is known to affect energy consumption: space temperatures, occupancy, and weather conditions. DHW energy was included since it was expected to be directly related to actual building occupancy. In addition, electrical use was tested as an independent variable at the dining halls as an indicator of occupancy. Tables 12 through 15 list candidate dependent and independent variables that were selected for use in the SPSS regression runs.

Using the aggregated, treated data set for each building, a series of regressions was performed to identify variables that predict the effect of retrofit changes on energy consumption. Grahical analysis techniques were applied selectively to identify outliers and provide visual interpretation of results. The regression and graphical analyses were iterative. Bad data points identified using graphical analysis were deleted from the relevant data set and regressions were rerun using the new data set. In general, data were classified as "bad" only if they were obviously wrong. Examples include a series of days with identical, very high values and data that are many orders of magnitude greater than the surrounding values. Also, some consumption data were found to be in different units and were corrected to common units. Graphical analysis was also useful in identifying seasonal trends, changes over time, and data clusters that might require separate treatment. Some instances of these types of items were identified, particularly in the case of the dining halls. The data clusters found were, however, random occurrences, and further analysis was not possible. Also identified was a trend of increasing electricity consumption over time in the motor repair shops.

The regression analysis procedure involved stepwise regressions (procedure STEPWISE in SPSS) and multiple regressions using a specified set of variables (procedure ENTER in SPSS). Before running any regression procedure, data points were selected for inclusion in the procedure on the basis of various criteria. The most significant of these was that the value of the dependent variable not be zero. Also, for heating and cooling consumption, limits on daily average outdoor air temperature were imposed: below 65 °F for heating and above 65 °F, 70 °F, or 75 °F for cooling. Multiple temperature limits were tried for cooling to try to improve correlation. With these conditions imposed on the included data, a series of regressions was performed as follows:

1. Run stepwise regressions for all relevant dependent variables against all relevant independent variables for each building using the STEPWISE command in SPSS.

2. Tabulate the results of the stepwise regression for each dependent variable as the next independent variable is included. The tabulation shows the variables and resultant R^2 of the new regression. This step identifies significant variables and their incremental effect on the predictive power of the regression.

3. Graph results when the correlation coefficient is unusually poor to determine whether bad data or another effect is masking a potentially good model.

Table 12

Dependent and Independent Variables:
L-Shaped Barracks

Dependent Variables	Independent Variables
Electric Use	Date
Gas Use	1st Floor East Temperature
Btu Cooling	1st Floor West Temperature
	2nd Floor East Temperature
	2nd Floor West Temperature
	3rd Floor East Temperature
	3rd Floor West Temperature
	Mess Hall Temperature
	TAll - Average of 7 Space Temperatures
	TDrm - Average of 6 Space Temperatures Not Including Mess Hall
	Btu Circulating Domestic Hot Water
	OATAv - Average of Outdoor Temperatures as Measured at Bldgs 811, 812, and 813

Table 13

Dependent and Independent Variables:
Rolling-Pin Barracks

Dependent Variables	Independent Variables
Electric Use	Date
Btu Heat	1st Floor Temperature
Btu Cooling	2nd Floor Temperature
	3rd Floor Temperature
	TAll - Average of 3 Space Temperatures
	Btu Circulating Domestic Hot Water
	OATAv - Average of Outdoor Temperatures as Measured at Bldgs 811, 812, and 813

Table 14

Dependent and Independent Variables: Motor Repair Shops

Dependent Variables	Independent Variables
Electric Use	Date
Gas Use	North (Office) Temperature
	South (Bay) Temperature
	OATAv - Average of Outdoor Temperatures as Measured at Bldgs 811, 812, and 813

Table 15

Dependent and Independent Variables: Dining Halls

Dependent Variables	Independent Variables
Electric Use	Date
Gas Use	Space Temperature
Btu Heat	Btu Circulating Domestic Hot Water
Btu Steam	Electric Use
	Btu Steam
	OATAv - Average of Outdoor Temperatures as Measured at Bldgs 811, 812, and 813

4. Whenever the data set is changed, rerun stepwise regressions based on results of graphical analysis.

5. Select common independent variables for each building type based on results of stepwise regressions; enter combinations of variables in a series of multiple regressions using the ENTER command in SPSS.

6. Tabulate the resulting R^2 for each regression by building.

7. Select the independent variable set with the best average R^2 across buildings in a building type to allow common comparison of predictive models across buildings.

8. Run regressions with the selected variable set for each building in a building type to generate the predictive regression equation.

9. Calculate standard error, tolerance, correlation coefficient, variance-covariance matrix, and correlation matrix for the selected independent variables. The standard error is a measure of the likely variation of actual occurrences at a given set of conditions, and is used to calculate the confidence limit at the mean for the regression. The tolerance of each variable ($1-R^2$) measures the multicollinearity of the independent variables with the other variables in the equation. Multicollinearity occurs when independent variables are direct linear combinations of each other. If this occurs, the resulting regression equation is invalid. As long as the tolerance is above 0.01, the regression equation is meaningful. Interdependence (the value of multiple variables being influenced by a common factor) can occur between variables that are not multicollinear without affecting the validity of the regression. The variance-covariance matrix and correlation matrix further describe the relationships between the independent variables. The variance-covariance matrix is useful for matrix multiplication to determine confidence intervals. The correlation matrix contains correlation coefficients between pairs of variables. The correlation coefficient measures the strength of association between variables. The results of this step are included in Appendix D.

10. Calculate 95 percent confidence limits for the mean at each actual data point using the standard error from step 9 and the appropriate t-statistic for the actual data set.

11. Plot results of predicted versus actual consumption, including the confidence limits, for each building to visually demonstrate the predictive power of the model. These plots are included in Appendix E.

12. Plot predicted values for each building in a building type along with predicted values and confidence limits for a control building. Use the control building actual data set with the regression equation from the comparison building to graphically depict the differences between buildings, especially the significance of the energy savings in the retrofit buildings. These plots are also included in Appendix E.

Late in the analytical process, occupancy data* were added to the data sets for the barracks and dining halls (Appendix F). The regressions described in steps 1 through 4 were rerun to include occupancy. Occupancy was not a good predictor for any of the building types, and the analysis was terminated. Appendix G shows the results of the regressions using occupancy data from step 4 for all buildings and dependent variables.

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*Best estimate from Fort Carson housing authority and actual conditions.

Regression results for cooling, electricity, and dining hall heating did not show sufficient correlation to allow model development. Tables listing attempts at model development, including independent variables entered into the regression equations for these dependent variables by SPSS and the resulting R^2 values also are in Appendix G.

Regression analysis did successfully identify predictive equations for gas consumption in the L-shaped barracks and motor repair shops, and heating consumption in the L-shaped barracks and rolling-pin barracks. These equations are listed in Table 16. A mathematical model of the L-shaped barracks after the operational retrofit (1987-88) is included for completeness, but should not be used to assess energy savings due to improved operations directly, since this model includes effects of the original retrofits as well.

Once a functional relationship was developed between energy consumption and independent variables, expected annual savings were estimated. Representative (dummy) values were input for the independent variables. The resulting energy consumption was multiplied by the time of occurrence of that representative independent variable set.

The basis of these estimates was the Facility Design and Planning Engineering Weather Data,[5] which is a list of annual and monthly temperature distributions by 5 °F temperature bins (i.e., ranges) for cities throughout the United States and selected international locations.

To adjust annual energy totals for the differences in operation between buildings, operational parameters such as indoor air temperature and DHW were set to a constant value across a building category. The constant value selected was the average for each building over the period of interest (e.g., summer values for indoor air temperature were excluded from the average indoor temperature in the heating energy consumption models).

Annual energy consumption for each building was predicted as follows:

1. Determine average daily values of independent variables related to building operations for the cases included in the regression. Add these dummy cases to a data set of the mean value of each temperature bin. Use SPSS to calculate a predicted value of daily energy consumption and standard error of estimate for each dummy data case.

2. Use the predicted energy consumption value for each of the dummy cases based on bin temperature data. Divide the predicted daily consumption by 24 to convert to an hourly value.

3. Multiply the consumption by the number of hours per season in each bin.

4. Sum the results from each temperature bin to obtain annual consumption based on average historical weather conditions. An example calculation is included in Appendix H.

Annual savings due to retrofits were estimated by comparing the results of the control buildings with the results of those retrofit buildings. Since factors relating to building operation and occupancy were held constant, the savings shown represent the effect of retrofits on energy consumption. The calculations of

[5] Technical Manual (TM) 5-785, *Engineering Weather Data* (Headquarters, Department of the Army [HQDA], 1 July 1978).

Table 16

Energy Consumption Regression Equations

L-Shaped Barracks - Gas:

811 (87/88):**	Gas = -8,625,504 - 488,705 x OAT + 589,370 x TAll + 1.049 x DHW
811 (86/87):	Gas = -9,327,695 - 589,970 x OAT + 620,333 x TAll + 3.984 x DHW
812 (86/87):	Gas = -92,651,150 - 727,207 x OAT + 1,865,736 x TAll + 4.630 x DHW
813 (87/88):	Gas = -63,614,755 - 761,587 x OAT + 1,544,064 x TAll + 3.910 x DHW
813 (86/87):	Gas = -62,407,438 - 764,174 x OAT + 1,584,589 x TAll + 1.900 x DHW

L-Shaped Barracks - Heating:

811 (87/88):**	Heat = -9,014,913 - 225,372 x OAT + 313,087 x TAll + 0.034 x DHW
811 (86/87):	Heat = -5,751,443 - 356,983 x OAT + 363,148 x TAll + 0.053 x DHW
812 (86/87):	Heat = -27,302,473 - 408,236 x OAT + 719,930 x TAll + 0.069 x DHW
813 (87/88):	Heat = -34,180,655 - 373,474 x OAT + 750,659 x TAll + 1.091 x DHW
813 (86/87):	Heat = -20,014,694 - 374,145 x OAT + 591,011 x TAll + 0.143 x DHW

Rolling-Pin Barracks:

1363:	Heat = 10,998,625 - 254,382 x OAT + 83,651 x TAll - 1.126 x DHW
1663:	Heat = 32,145,206 - 271,148 x OAT - 134,688 x TAll + 0.921 x DHW
1666:	Heat = 27,817,445 - 58,271 x OAT - 171,558 x TAll - 0.376 x DHW
1667:	Heat = 44,087,963 - 93,878 x OAT - 396,278 x TAll + 0.420 x DHW

Motor Vehicle Repair Shops:

633:	Gas = 10,178,663 - 210,526 x OAT + 67,716 x BayT + 4,197 x Elec
634:	Gas = 10,075,874 - 429,631 x OAT + 242,556 x BayT + 17,316 x Elec
635:***	Gas = 10,575,672 - 248,228 x OAT + 115,988 x BayT + 33,308 x Elec
636:	Gas = 3,118,149 - 348,736 x OAT + 263,965 x BayT + 74,901 x Elec

*Note: these equations use DAILY values. Gas, heat, and DHW are the total daily consumption in Btu. Elec is total daily consumption in kWh. OAT, TAll, and BayT are daily average temperatures.

**The equation for building 811 (87/88) should not be used to assess energy savings due to improved operations directly since it includes effects of the original retrofits.

***Building 635 was not included in the calculation of energy savings because the regression equation did not show good predictive power and energy consumption characteristics appeared to be inconsistent with the other control buildings.

predicted energy consumption and savings, along with the values used for the factors other than outdoor air temperature, are included in Appendix E.

The range of expected savings was calculated as follows:

1. Use the standard error of the estimate for each of the dummy cases based on bin temperature data. Square the standard errors, divide by 24 to convert from daily to hourly values, and multiply by the number of hours per season in the temperature bin.

2. Sum the results of step 1 across all the bin temperatures.

3. Find the square root of the sum, and multiply by the T-statistic. The T-statistic in this case is 1.96 for an infinite number of cases at the 95 percent confidence level. This value is the uncertainty in the predicted energy consumption for the building. Appendix H contains a sample calculation of steps 1 through 3.

4. Calculate the range of annual energy consumption for each building by adding and subtracting the uncertainty to the predicted annual energy consumption value. This results in a high and a low prediction for each building, as well as an expected value, which is the predicted annual energy consumption. Appendix E shows these calculations.

5. Find the baseline high, low, and expected consumption by averaging the values for the control buildings. Calculate the range of expected savings by comparing the three energy consumption values for the retrofit with the baseline. The expected savings are found by subtracting the expected consumption for the retrofit building from that for the baseline. The high savings figure is derived by subtracting the low retrofit consumption from the high baseline consumption. The low savings figure is found by subtracting the high retrofit consumption from the low baseline consumption. The resulting range shows the minimum savings, expected savings, and maximum savings in MBtu and percent associated with each retrofit. Again, these calculations can be found in Appendix E.

The savings range information was useful for determining if the savings observed in retrofit buildings were significant under all expected conditions.

Using Predictive Models at Other Locations. Using bin data for other locations, the economic attractiveness of the retrofits can be evaluated throughout the United States. The other independent variables (interior temperature, DHW, electricity) should be held to the average values, as indicated in Appendix E. Inserting the bin temperatures and the other variables into the regression equations gives an expected daily consumption at that temperature for that building. This value should then be divided by 24 and multiplied by the number of hours in the season at that bin temperature. Summing across all bins gives the expected annual consumption. The procedure is then repeated for each of the baseline buildings and the retrofit building. Averaging the baseline buildings and subtracting the retrofit building consumption gives the expected annual energy savings for the new location.

T-Tests

The t-test was used to try and show if the differences in energy consumption between buildings were statistically significant. Although the main objective of t-test application was to support direct comparison savings in cases for which regression models could not be developed, data from all component energies were tested.

The purpose of a t-test is to test the hypothesis that two data samples are from the same population, i.e., that they are the same, differentiated only by random variations. If the hypothesis is not proven, it can be concluded that the samples are from different populations, and that the differences between them are due to a real, nonrandom, difference.

The t-test requires that the variance of the samples being tested is shown to be homogeneous, with 95 percent confidence. This result is obtained using an Independent-Samples Test. This test calculates the F value, which measures the homogeneity of the variances. If there is 95 percent confidence that they are homogeneous, then the t-test can be applied; otherwise, a t-test would be invalid. This testing proceeds pairwise, with each building and dependent variable being tested against the same dependent variable for all other buildings of the same type. The t-test results are ignored for building pairs that fail the Independent-Samples Test.

For meaningful conclusions to be drawn, t-test results must be available for most of the buildings being compared, i.e., the retrofit building vs. most of the baseline buildings. Several situations can arise. If it is shown that the retrofit building is significantly different from the baseline buildings, and the baseline buildings are not significantly different from each other, it would clearly indicate that any reduction in energy consumption can be attributed to the retrofit package. If the retrofit building is shown to be different from the baseline buildings, but the baseline buildings are also different from each other, then no definite statistical conclusion can be drawn. This latter situation occurred for the heating data of the rolling-pin barracks. However, the large savings shown by regression analysis strongly suggests a real, nonrandom difference. Finally, if it is shown that the differences between the retrofit building and the baseline buildings are not statistically significant, then any differences between the energy consumption could be due to randomness, and attributing them to the retrofit package is unsupportable.

Appendix I provides the results of the Independent-Samples Tests and t-tests for all building types and dependent variables, including those for which regression analysis was apparently successful.

Results

Table 16 shows the final regression equations developed for each of the buildings, except the dining halls, for which no simple relationships could be found. These equations can be used to calculate predicted energy consumption using bin temperature data, with the other independent variables held constant. Comparing predicted energy consumption of the retrofit buildings with that of the control buildings provides predicted energy savings for each of three tests, plus intermediate heating energy consumption savings for one test. Tables showing energy prediction and savings calculations are included in Appendix E.

The predicted energy savings are shown in Table 17 in terms of Btu and percentage savings. Upper and lower limits on savings were calculated using confidence interval data for each building as generated from the regression procedure. Appendix E also includes plots of actual energy consumption vs. predicted, with the 95 percent confidence interval on the mean shown as well.

Energy savings for cooling, electricity, or dining hall heating that could have resulted from the retrofit packages could not be predicted based on the data sets. Regression results for these dependent variables did not show sufficient correlation to allow model development.

T-tests were run on all independent variables for all buildings. The results of these tests are shown in Appendix I. For most energy consumption data, no useful results were obtained from the t-test. Good

Table 17

Retrofit Package Energy Savings by Regression

Building	MBtu Savings			Percentage Savings		
	Expected	Min	Max	Expected	Min	Max
L-Shaped Barracks - Gas	1973	1944	2002	26.7%	26.3%	26.0%
L-Shaped Barracks - Heating	590	570	610	22.8%	22.1%	23.5%
Rolling-Pin Barracks	1066	1055	1078	40.8%	40.5%	41.2%
Motor Repair Shops	744	718	771	31.9%	30.9%	32.8%
Dining Halls	No Conclusion					

results were obtained in the case of heating for the rolling-pin barracks and gas consumption for the L-shaped barracks. For these cases, the t-test showed that statistically significant differences between the retrofit and control buildings exist, supporting the conclusion reached through regression analysis.

Conclusions

Successful heating consumption models were developed for the L-shaped barracks, the rolling-pin barracks, and the motor vehicle repair shops. These models of baseline and retrofit buildings were used to assess energy savings due to the retrofits. Analysis showed significant energy reductions in these building categories. The models will allow evaluation of these retrofits at other locations.

Data for the dining halls and for cooling electricity use in the other buildings did not allow model development, and no conclusion was reached. Evaluation of energy savings for these cases is not statistically supportable.

Energy Savings Credited to the Retrofits

Table 18 shows the energy savings credited to the implemented retrofits. The savings results from regression analysis were used for the L-shaped barracks, the rolling-pin barracks, and the motor vehicle repair shop. Here, significant savings were identified for heating only. Energy results were adjusted for differences in operational conditions between the test and reference buildings. Direct comparison data were used for the dining hall, for which statistical models could not be developed. Again, heating energy savings were the only energy differences assumed to be nonrandom. Direct comparison energy savings were used for the improved operations at the L-shaped barracks, for which statistical compensation was inappropriate. Here, DHW consumption and weather-adjusted heating consumption were compared before and after the retrofit at Bldg 811. "Baseline consumption" refers to the average consumption of the reference buildings for the component energy that was saved. Energy savings are expressed in terms of natural gas consumption.

Table 19 shows the original savings expectations for each building category and the measured savings as a percentage of the expected target. Expected savings from the original retrofits are from the BLAST runs presented in USACERL TR E-183 and include expected savings from all building component energies (heating, cooling, electricity). Expected savings due to improved operations were derived from simplified engineering calculations. The measured savings used for the percentage of expected savings column is the energy reduction credited to the retrofits as discussed above.

Table 18

Energy Savings From the Retrofits

Building	Energy Saved (MBtu)	Percent of Baseline
633(MP)	744	41
811(LS)	1973	27
811op(LSop)	1741	28
1361(DH)	64	24
1363(RP)	1777	41

Key: MP = Motor Vehicle Repair Shop
LS = L-Shaped Barracks
LSop = L-Shaped Barracks w/improved operations
DH = Enlisted Personnel Dining Hall
RP = Rolling-Pin-Shaped Barracks

Table 19

Expected Savings From Retrofits and Percentage Achieved

Building	Savings Expected (MBtu)	Percent of Expected Achieved
633(MP)	1040	72
811(LS)	3339	59
811op(LSop)	2003	87
1361(DH)	3620	1.8
1363(RP)	3343	53

Key: MP = Motor Vehicle Repair Shop
LS = L-Shaped Barracks
LSop = L-Shaped Barracks w/improved operations
DH = Enlisted Personnel Dining Hall
RP = Rolling-Pin Shaped Barracks

3 ECONOMIC ANALYSIS

Overview

Energy analysis of the original retrofits (presented in Chapter 2) indicated lower energy savings than expected. In addition, the actual cost of implementing the retrofits was, in many cases, significantly higher than had been projected.* Further, changes in the construction and energy market since the project year might have been observed if current year costs were considered. As a result, it was decided to update the economic calculations of these retrofits in terms of the Energy Conservation Investment Program (ECIP) criteria[6] based on the actual savings and construction costs, and new estimates of the project year and current year construction costs. Economics on the improved operations retrofit were included for completeness.

Purpose of Economic Analysis

The purpose of the economic analysis was to evaluate the cost-effectiveness of five standard energy conservation retrofit packages based on actual savings and construction costs; actual energy savings and project year estimated construction costs; and actual energy savings and estimated current year construction costs. Also, market scenarios were examined for which the retrofits would meet ECIP criteria.

Procedure

Actual measured energy savings for each of the five retrofit packages were developed as discussed in Chapter 2. Energy savings determined by statistical analysis were used for the L-shaped and rolling-pin barracks and the motor pool. Direct comparison data were used for (1) the dining hall, for which statistical models could not be developed, and (2) the improved operations at the L-shaped barracks, for which statistical compensation was inappropriate.

Actual construction costs were determined from U.S. Army Corps of Engineers (USACE) contract records (Appendix J). Construction cost estimates for the project and current year were developed using the appropriate USACE and Dodge system unit price data based on actual contractor submittals and as-built drawings. In addition, when necessary, material suppliers and retrofit subcontractors were contacted for more detailed information. The USACE Life-Cycle Cost in Design (LCCID) computer program was used to calculate the savings-to-investment ratio (SIR) and simple payback based on ECIP criteria.

Market scenarios were developed based on the ECIP criteria and energy/nonenergy discount factors from the LCCID program. Graphic representations were produced to show combinations of energy savings, fuel costs, maintenance and repair savings, and construction costs for which the ECIP criteria were satisfied.

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* In some cases, the proposed retrofits were modified to accommodate site constraints, resulting in higher costs than originally planned. In other cases, market conditions were different than anticipated for a specified material.

6 "Energy Conservation Investment Program (ECIP) Guidance," multiple-address letter from U.S. Army Engineering and Housing Support Center (25 April 1988).

Construction Cost Estimates

Tables

Construction cost estimates were developed based on actual contractor submittals and as-built drawings using USACE and Dodge system unit cost data. Detailed line item estimates are provided in Appendix I for current year estimates and in Appendix J for project year estimates. These line item estimates are summarized in Tables 20 and Table 21.

Discussion of Cost Estimates

The line titled "Basic" in Tables 20 and 21 includes all line items of the retrofit other than mechanical. The line titled "Mechanical" includes all line items related to electrical work, HVAC work, and controls. A 25 percent mark-up is applied to the mechanical cost estimate since it was assumed (as was the actual case) that these items would generally be subcontracted. The percentage rates for indirect costs, profit, and contingency are based on review of TM 5-800-2.[7]

Table 20

Project Year Cost Estimates
Cost Estimate by Building/Project Year ($)

Cost Item	633/1984	811/1984	811op/1987*	1361/1984	1363/1984
1. Basic	22,139	171,773		34,059	86,447
2. Mechanical	4268	11,321		37,742	10,420
3. 25% OH on Mechanical	1067	2830		9436	2605
4. Subtotal	24,474	185,924		81,237	99,472
5. Indirect Costs, 20% of Line 4	5495	37,185		16,247	19,894
6. Profit, 5% of lines 4+5	1648	11,155		4874	5968
7. Contingency, 10% of lines 4+5+6	3462	23,426		10,236	12,533
8. Total Estimate	38,079	257,690		112,594	137,867
9. Actual Cost	91,310	356,049	19,150	113,207	113,903

*Building 811 operations package was not reestimated; actual cost is given for completeness.

[7]TM 5-800-2, *Cost Estimates - Military Construction* (HQDA, June 1985).

Table 21

Current Year Cost Estimates

	Cost Estimate by Building ($)			
Cost Item	**633**	**811**	**1361**	**1363**
1. Basic	32,078	199,921	23,189	102,150
2. Mechanical	4769	12,409	38,895	11,020
3. 25% OH on Mechanical	1192	3102	29,724	2755
4. Subtotal	38,039	215,432	71,808	115,925
5. Indirect Costs, 20% of Line 4	7608	43,086	14,362	23,185
6. Profit, 5% of Lines 4+5	2282	12,926	4308	6956
7. Contingency, 10% of Lines 4+5+6	4793	27,144	9048	14,607
8. Total Estimate	52,722	298,588	99,526	160,673

The project year estimates in some cases show significant deviation from the actual construction costs. The meaning of these differences should not be misconstrued. There are many factors affecting the accuracy of the estimates as well as the construction cost. In particular, in most cases, the estimator has the opportunity to visit the site for a first-hand inspection, which was not possible in this reestimation effort. Also, since the actual subcontractor mark-ups and prime contractor overhead and profit data were not available, there is some latitude for variation from these factors. Finally, since the actual construction cost resulted from open competition in the free market, the actual cost is the true "best estimate" of what these retrofits would cost under similar market conditions.

With these caveats, and assuming no gross errors occurred in the estimating process, the buildings for which significant differences where observed may indicate the potential for cost reductions by clarifying the bid package specification and by improving the structure of the bidding process itself. For example, the bid package requested itemized bids for buildings 633, 811, 1361, and 1363, but specified that the contract award would be made as a whole to one bidder for all items. This type of estimate may have required a wider range of skills than available to an individual contractor and resulted in increased costs due to large contingencies.

Cost-Effectiveness of the Retrofits

The cost-effectiveness of the retrofits, using ECIP criteria, was evaluated by calculating the SIR and simple payback using the LCCID program. Cost-effectiveness was evaluated for project year with actual construction costs, project year with estimated costs, and current year with estimated costs. The LCCID 1985 energy escalation rates were used for the project year estimates and the 1987 escalation rates were used for the current year estimates due to availability. Energy savings were the actual savings in natural gas consumption measured in MBtu/year. Gas costs were based on the weighted average cost of firm and interruptible gas at Fort Carson. Based on evaluation of the retrofits and current Army maintenance policies, it was determined that no credit (or debit) would be taken for maintenance and repair (M&R) costs. In other words, it was assumed that no changes in M&R costs would occur due to the retrofits. Finally, because the ECIP criteria specify a life of 15 years for HVAC retrofits and a 25-year life for weatherization, calculations were performed for both lifetimes for buildings 633, 811, 1361, and 1363. Tables 22 through 24 list the results of the LCCID calculations. LCCID printouts are included as Appendix M.

Development of Market Scenarios

Market scenarios were developed to examine under what conditions the four retrofit packages would meet the ECIP criterion of SIR $\geq$ 1.0. Parameters examined were construction cost, annual energy savings, fuel cost, and annual nonenergy (e.g., M&R) savings. The scenarios were examined by developing an equation expressing the relationship between the parameters when the ECIP criterion is satisfied. This equation was developed as follows:

Let Cc = Construction cost

From LCCID:

Supervision and Inspection Overhead (SIOH) = 0.055 Cc

and Design Cost = 0.06 Cc

Table 22

Cost-Effectiveness of Retrofits: Actual Construction Costs

Building	Building Life (Years)	Energy Savings (MBtu/yr)	Energy Cost ($/MBtu)	SIR*	Simple Payback (Years)
633	25	744	4.03	0.59	30.5
811	25	1973	4.03	0.4	44.9
811op	25	1741	4.08	8.27	2.7
1361	25	64	4.03	0.04	440.0
1363	25	1777	4.03	1.12	15.9
633	15	744	4.03	0.39	30.5
811	15	1973	4.03	0.26	44.9
811op	15	1741	4.08	5.14	2.7
1361	15	64	4.03	0.03	440.0
1363	15	1777	4.03	0.74	15.9

*Savings-to-Investment ratio.

Table 23

Cost-Effectiveness of Retrofits:
Project Year Estimated Costs

Building	Building Life (Years)	Energy Savings (MBtu/yr)	Energy Cost ($/MBtu)	SIR*	Simple Payback (Years)
633	25	744	4.03	1.4	12.7
811	25	1973	4.03	0.55	32.5
1361	25	64	4.03	0.04	438.0
1363	25	1777	4.03	0.93	19.3
633	15	744	4.03	0.83	12.7
811	15	1973	4.03	0.36	32.5
1361	15	64	4.03	0.03	438.0
1363	15	1777	4.03	0.61	19.3

*Savings-to-investment ratio.

Table 24

Cost-Effectiveness of Retrofits:
Current Year Estimated Costs

Building	Building Life (Years)	Energy Savings (MBtu/yr)	Energy Cost ($/MBtu)	SIR*	Simple Payback (Years)
633	25	744	3.11	0.99	22.9
811	25	1973	3.11	0.46	48.8
1361	25	64	3.11	0.04	502.0
1363	25	1777	3.11	0.78	29.2
633	15	744	3.11	0.62	22.9
811	15	1973	3.11	0.29	48.8
1361	15	64	3.11	0.02	502.0
1363	15	1777	3.11	0.49	29.2

*Savings-to-investment ratio.

Therefore, the total investment:

$$It = Cc + 0.055\ Cc + 0.06\ Cc = 1.115\ Cc$$

In the ECIP calculation, this total investment is given a 10 percent credit, so that the final total investment, for ECIP purposes is:

$$It = 0.9(1.115)\ Cc = 1.0035\ Cc \qquad \text{[Eq 1]}$$

Now introduce:

De = electrical energy cost discount factor

Dg = gas energy cost discount factor

Se = annual electrical energy cost savings

Sg = annual gas energy cost savings

De and Dg are discount factors which together include the time effects of the appropriate discount rate and energy cost escalation rate. Actual values can be found under item 2, column 4, in the LCCID printouts (Appendix M).

The total discounted energy savings can then be expressed as:

$$Et = DeSe + DgSg \qquad \text{[Eq 2]}$$

Nonenergy savings, in this case M&R savings, can be represented using:

Dn = nonenergy cost discount factor

Sn = annual nonenergy savings

Thus, the total discounted nonenergy savings is:

$$Nt = DnSn \qquad \text{[Eq 3]}$$

In the case of nonenergy savings, an additional ECIP criterion comes into play. The ECIP criteria state that only 25 percent of the total discounted savings, i.e., the sum of Et and Nt, can consist of nonenergy savings. In equation form, this is:

$$\text{Total discounted savings} = Et + Nt \qquad \text{[Eq 4]}$$

Where:

$$Nt/Et = 0.25/0.75 \text{ or } Nt = 1/3\ Et \qquad \text{[Eq 5]}$$

Finally, the SIR can be expressed as:

$$\mathrm{SIR} = \frac{\text{Total Discounted Savings}}{\text{Total Investment}} = \frac{\mathrm{Et} + \mathrm{Nt}}{\mathrm{It}} \qquad \text{[Eq 6]}$$

$$= \frac{\mathrm{DeSe} + \mathrm{DgSg} + \mathrm{DnSn}}{1.0035\ \mathrm{Cc}} \qquad \text{[Eq 7]}$$

This satisfies the ECIP criterion SIR $\geq$ 1. Setting SIR = 1, the final equations describing the market scenario are:

$$\mathrm{Cc} = \frac{\mathrm{DeSe} + \mathrm{DgSg} + \mathrm{DnSn}}{1.0035} \qquad \text{[Eq 8]}$$

and:

$$\mathrm{Sn} \leq 1/3\ \frac{(\mathrm{DeSe} + \mathrm{DgSg})}{\mathrm{Dn}} \qquad \text{[Eq 9]}$$

In the energy analysis of Chapter 2, energy savings credited to the retrofits are expressed in terms of natural gas Btu, so Equations 8 and 9 can be simplified further. The values of Dg and Dn are 22.69 and 11.65, respectively, for a 25-year life, and 14.17 and 9.11 for 15-year life. These values contain energy cost escalation effects for Colorado, which is in Census Region 4,[8] and are therefore strictly applicable only for states within the same region. Also, these values are based on the 1987 energy escalation rates and cannot be applied to the project year estimates.

Substituting these values into Equations 8 and 9 for a 25-year life results in:

$$\mathrm{Cc} = \frac{22.69\ \mathrm{Sg} + 11.65\ \mathrm{Sn}}{1.0035} \qquad \text{[Eq 10]}$$

and:

$$\mathrm{Sn} \leq 0.649\ \mathrm{Sg} \qquad \text{[Eq 11]}$$

It should be noted that the limitation on Sn is an ECIP criterion. Cases for which Sn exceeds 0.649 Sg may be very cost-effective, but must be funded under programs other than ECIP.

Figures 6 through 14 are graphical representations of Equations 8 and 9 for 25-year and 15-year life cycles. These graphs show acceptable construction and fuel costs that allow the retrofits to meet the ECIP criterion with the measured annual energy savings and specified retrofit life for various annual nonenergy

[8] Lippiatt, B.C. and R.T. Ruegg, *Energy Prices and Discount Factors for Life-Cycle Cost Analysis 1990*, NISTIR-85/3273-4 (National Institute of Standards and Technology, Gaithersburg, MD, May 1990).

parameters, such as fuel costs and annual M&R savings, it is possible to read from the graphs the construction cost required to meet the ECIP criterion of SIR $\geq$ 1.0.

As an example, the market scenario for Bldg 633 with a 25-year project life shows that if fuel costs are $4/MBtu, and no nonenergy (M&R) savings are realized, a construction cost of $68,000 will result in an SIR=1 for the measured energy savings. In addition, if the cost of construction is $135,000, and no nonenergy savings are realized, fuel costs would need to rise to $8/MBtu before the retrofit would be cost-effective. However, if nonenergy savings of $1000/year were realized, the $135,000 retrofit could pay for itself if fuel costs were $7.20/MBtu.

Many factors were involved in the economic analysis. Graphs of market scenarios were produced, fixing the energy savings of a retrofit package to that observed at Fort Carson and fixing the SIR to 1 for 15- and 25-year life cycles. Appendix N lists the BASIC computer program used to develop the acceptable market scenarios from the ECIP criterion of Equations 10 and 11. This program could be used for different energy savings, locations, and life cycles. If more than one form of energy were saved (e.g., if savings in electricity were observed in addition to savings in natural gas), or greater SIRs were desired, Equations 8 and 9 should be used as the basis for market scenario development.

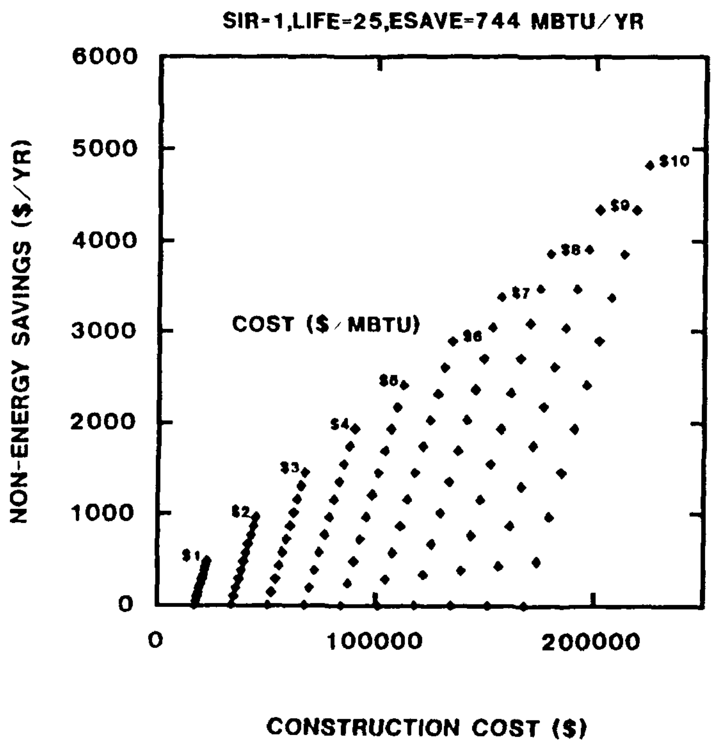

Figure 6. Market scenario, motor vehicle repair shop, Bldg 633.

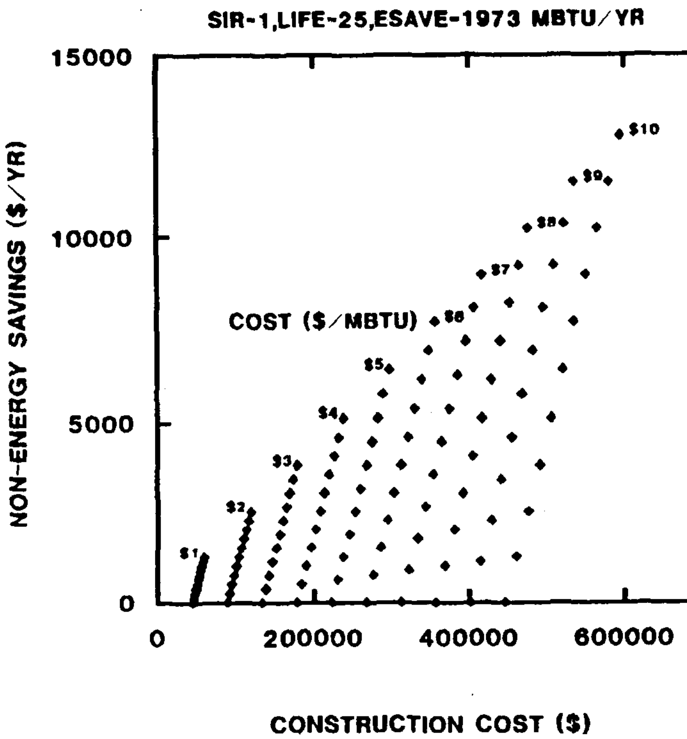

Figure 7. Market scenario, L-shaped barracks, Bldg 811.

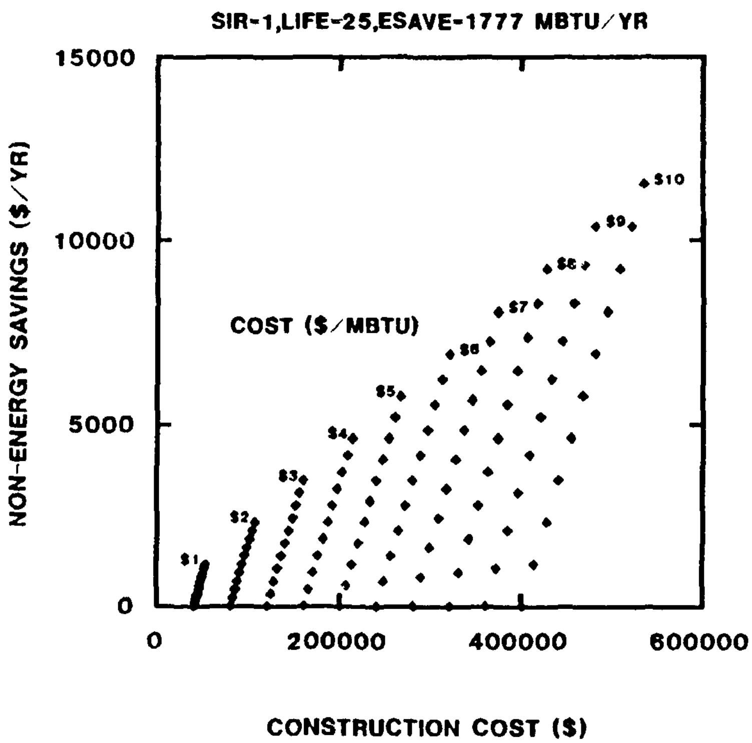

Figure 8. Market scenario, rolling-pin barracks, Bldg 1363.

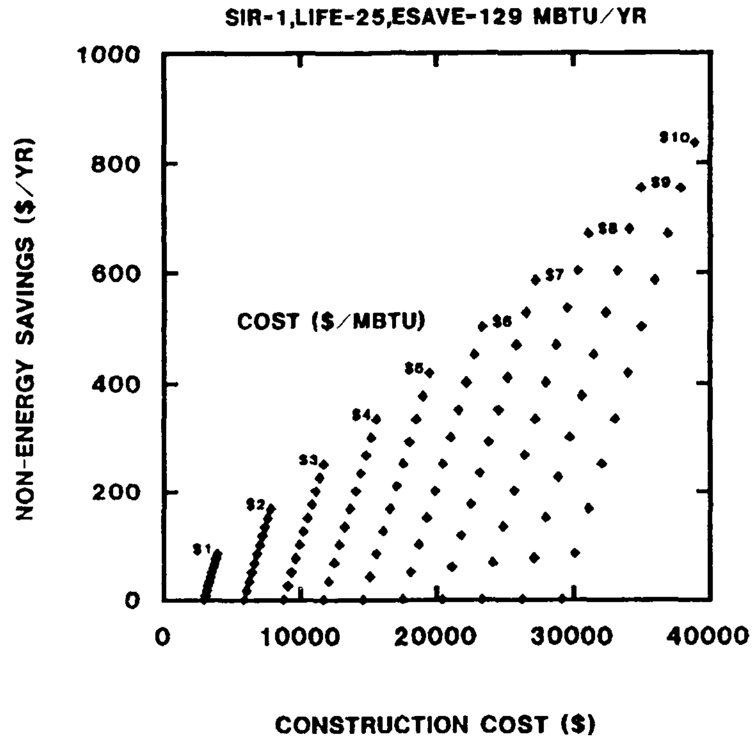

Figure 9. Market scenario, dining facility, Bldg 1363.

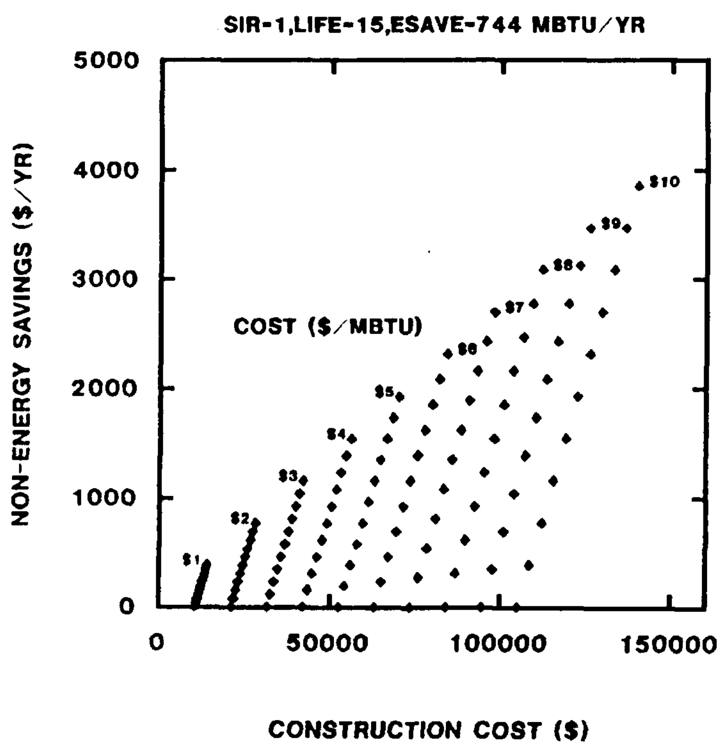

Figure 10. Market scenario, motor vehicle repair shop, Bldg 633.

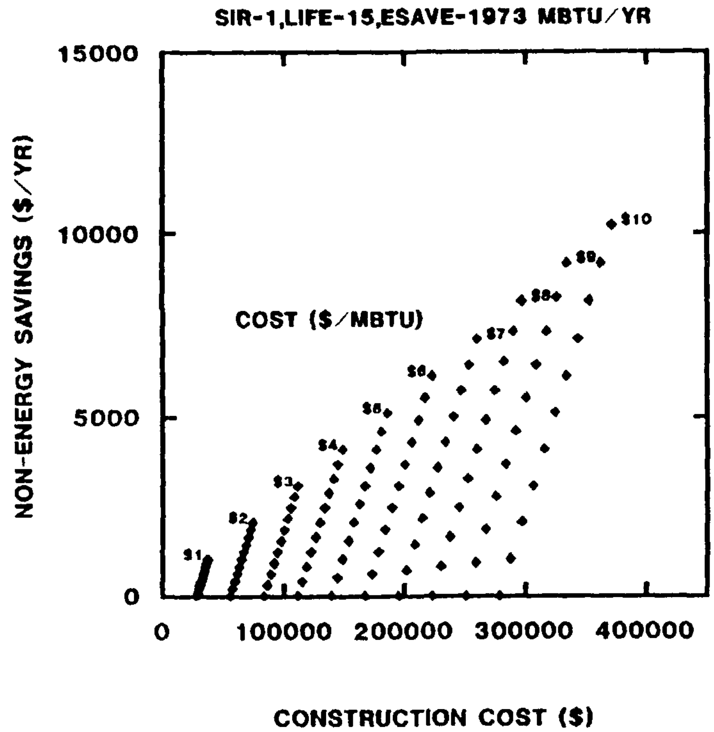

Figure 11. Market scenario, L-shaped barracks, Bldg 811.

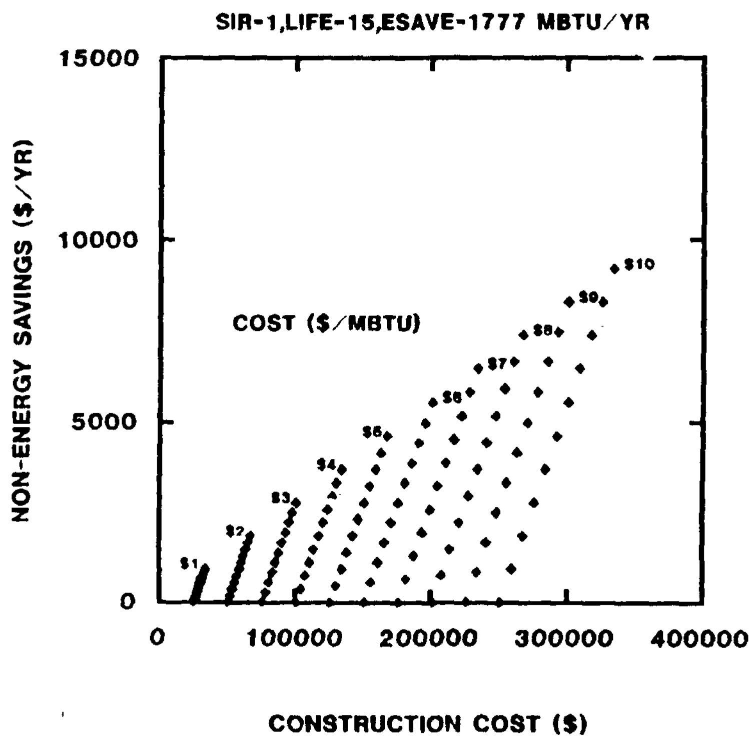

Figure 12. Market scenario, rollin-pin barracks, Bldg 1363.

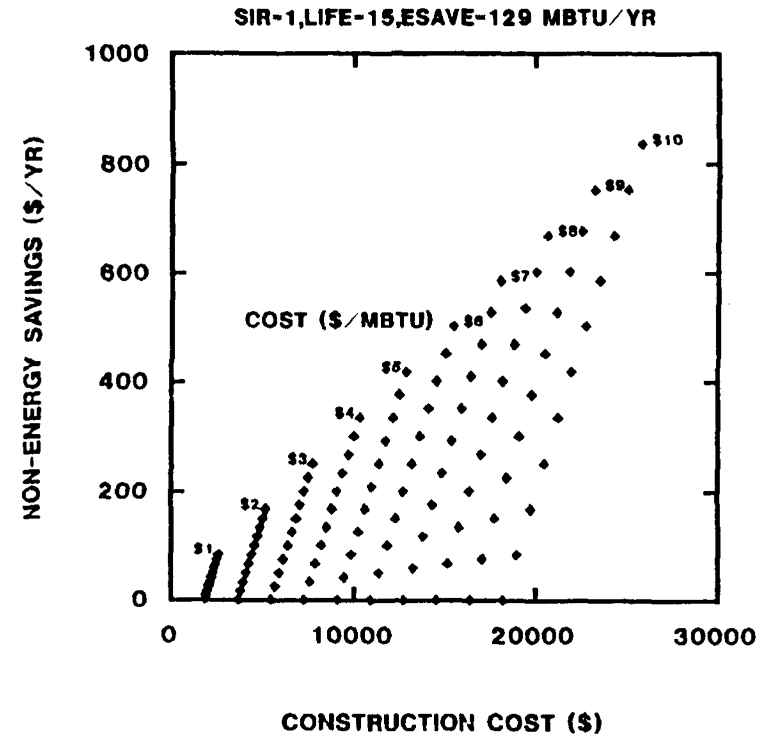

Figure 13. Market scenario, dining facility, Bldg 1361.

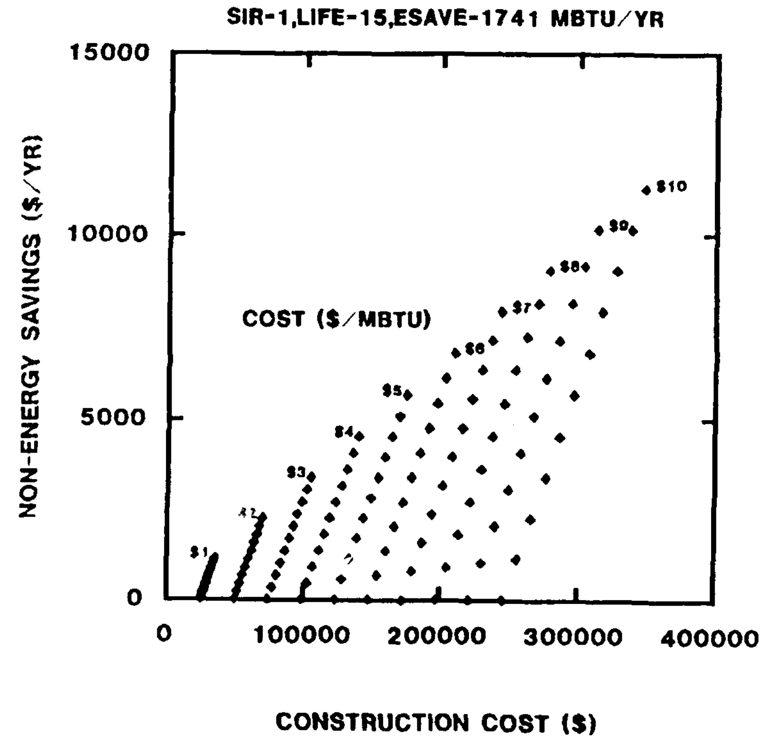

Figure 14. Market scenario, L-shaped barracks, Bldg 811.

Summary of Findings

Review of the data presented in Tables 22 through 24 indicated that, based on actual construction costs, only the retrofit at the rolling-pin barracks and the L-shaped barracks improved operations retrofit met the ECIP criterion of SIR $\geq$ 1. Using project year estimated costs, the motor pool retrofit meets this criterion. With current year estimated costs and current fuel prices, none of the original retrofits met the ECIP criterion.

While these conclusions are less optimistic than expected, the market scenarios indicate that even with the low energy savings achieved, the original retrofits may still have some merit. Examination of the 25-year life scenarios allowed USACERL to calculate, for the current year cost estimates, what natural gas prices would have to be (in Census Region 4) for the retrofits to have an SIR = 1. These prices are shown in Table 25. (Information for the improved operations retrofit with a 15-year life scenario is also included.)

Except for the retrofit at the dining hall, all of the original retrofits could possibly become cost-effective in the near future. This projection assumes, of course, that contract solicitation could result in contract costs no higher than the current cost estimates.

Results from the improved operations period were quite encouraging. The initial investment for these improvements yielded a simple payback period of 3.1 years with an SIR of 4.4.

Table 25

Gas Energy Prices for SIR = 1.0
With 1988 Estimated Retrofit Costs ($/MBtu)

Building	Building Life (Years)	Natural Gas Cost
633	25	3.13
811	25	6.69
811op	15	0.70
1361	25	87.18
1363	25	3.99

4 BUILDING AND RETROFIT PERFORMANCE

Meetings, informal visits with site personnel, building walk-throughs, and data review provided insight on building operational conditions and retrofit functioning and acceptability. This insight may be helpful in interpreting energy results, identifying areas for improvement, and planning future work efforts.

Several graphs of the data are presented. Specific data selections are identified with a 5-digit alphanumeric code signifying the building designator,* year, and week** of collection.

Motor Shops

Electricity Use

Despite the fact that there are many lights in the motor repair shops, they seem to be seldom used. The bulbs themselves are often dirty and thus add little light above the level of daylighting. Few electric tools were observed during building walk-throughs, and typically, the only electrical appliances were radios. Thus, the major electricity consumers appear to be the fans for the heating system (when they are working--occupants report that they often do not function).

Thermostats

The programmable thermostats allow comfort conditions in two areas that have different heating requirements. However, night setback options were disabled by base personnel after installation (possibly due to unanticipated night work and/or confusion about programming procedures). The installed thermostats are difficult to program. Thus, if occupants try to reset the thermostat, they may or may not change the current temperature, but they probably will change the overall setback schedule. It may be appropriate to choose simpler thermostats, post sample thermostat programs on the wall, or prevent access to unauthorized personnel by using lock boxes or positioning controls in mechanical rooms with remote temperature sensing. (Security of mechanical rooms would need to be increased over existing conditions.)

The thermostats need to be more rugged than the installed model, or perhaps caged for protection. Further, their positioning might be optimized. In one case, it appears that the thermostat has been used as a step to climb over an interior partition. In another case, a metal cabinet is placed in front of the thermostat, throwing off sensing capabilities. In yet another, an unprotected thermostat placed on a pillar in the middle of the service bay was damaged severely.

Boiler Controller

The remote-temperature boiler controller shuts off the boiler when the outside air temperature rises above a setpoint. If set correctly, this eliminates the need to turn off the boiler for the summer and restart it in the fall, and it ensures that heat is produced during the winter only when conditions are appropriate. Although not observed at the motor shops, in other buildings, similar controllers were often set to have

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*Building designators are: I = 633, J = 634, K = 635, L = 636, M = 811, N = 812, O = 813, P = 1361, Q = 1363, R = 1369, S = 1666, T = 1667, and V = 1669.

**The week of the year begins on the Saturday before 1 January and is numbered Week 0.

heat turn on at a very high outdoor temperature; thus, the labor-saving potential was not exploited and a building service call was required to disable heat for the summer.

Office Partition

An office area partition has met with great enthusiasm by the occupants who can now work at their desks under warmer conditions than can be maintained in the bay area. This partition also provides bay area workers with a warm refuge after extended work periods. These comfort considerations have prompted the occupants of nearby shops to employ this or similar modifications to their buildings, even before energy savings had been verified.

Overhead Doors

One of the seven doors installed has had a problem with the spring mechanism that eases the lowering of the door; it has needed repeated attention. However, most of the spring mechanisms work quite satisfactorily. Some metal panels that cover the interior door insulation have come loose from their guides after apparent vehicle impacts. Perhaps riveting these panels in place would prevent this situation.

In addition to the increased insulative value of the retrofit overhead doors, the fact that they are new is a further benefit because all the panels are intact (in contrast to the numerous holes and makeshift repairs in the existing doors) and the doors open and close easily, which makes the workers more likely to close them in cooler weather.

Windows and Walls

The comfort level in the shop area has increased greatly with the modifications to the doors, windows, and walls. Now workers can work for longer stretches without requiring a warming break and can work without gloves on jobs that benefit from increased manual dexterity.

Open Windows and Doors

The lower-than-anticipated savings in heating may be due to the observed compromise to the building envelope, in particular, open overhead doors and broken windows in the vehicle stations. It has been observed that overhead doors are often raised during the heating season to allow unrestricted entrance and exit to the building and to vent vehicle exhaust from the building. Also, due to the lack of cranes inside the shop, heavy parts are removed/replaced from outside by a mobile crane with its boom sticking inside through an open door.

To reduce (not eliminate) the occurrence of open doors, it may be necessary to provide easier building access. Motorized door openers, air curtains, or swinging entrance doors may all be reasonable options. Further, it may be appropriate to disable heater operation when overhead doors are open. This measure may provide the appropriate incentive for occupants to make use of exhaust sleeves that allow venting of vehicle exhaust without opening doors.

Numerous broken windows challenge the effectiveness of retrofit measures. Prompt repair and breakage prevention will improve the energy efficiency of the building.

Domestic Hot Water

DHW heating was disabled as an installation energy conservation measure apart from and before the studied retrofit package was installed. The lack of warm water in the lavatory may reduce troop morale and explain some of the observed property vandalism.

Gas and Temperature Profiles

Figures 15 through 29 show sample gas use and interior temperature profiles for the motor pool. The graphs show a general lack of environmental control, with largely varying interior temperatures (from day to day and week to week) that are sometimes quite cold (40 °F) and sometimes quite hot (90 °F), nonintuitive and shifting control setpoints at which heating begins (between 45 and 60 °F), and lack of night and weekend setback in the retrofit building. Further, the graphs show solar gain effects in early morning and late afternoon as interior temperatures rise while heating gas is off; gas peaks at the beginning of each heating cycle as the boilers ramp up to operating steam pressure.

Electrical Profiles

Figures 30 through 33 show sample electrical profiles for the motor repair shops. Electricity use is inconsistent within and across buildings from day to day and week to week in its baseline and peak. Shifting baselines indicate differences in round-the-clock power consumers. Differences in consumption within and between buildings may indicate differences in workload and type of work performed as well as general operational practices.

L-Shaped Barracks

Walls

The appearance of one barracks building that had a new stucco finish installed has been improved dramatically over the painted concrete blocks of the existing units, prompting inhabitants of the other barracks to request the same facelift. In addition, the maintenance requirements should be lessened as exterior painting will be limited to trim work.

Ventilation

The reduction of ventilation in the old mess hall area was part of the retrofit package. Since a kitchen is no longer operated in this area, it is reasonable that less ventilation is needed for fresh air requirements and it is assumed that natural air infiltration will meet this need.

The ventilation servicing the barracks wing was disconnected apart from and before the studied retrofit package. The ventilation system had been designed for an open-bay barracks and had not been modified when the building was converted to semiprivate rooms. The addition of interior walls resulted in fresh air being supplied to the hallways only. It may be that this arrangement did little to meet the ventilation requirements of the individual sleeping rooms and so was disconnected, or disconnection may have been part of an energy conservation effort. Whatever the reason for disconnection, the resultant air quality is sometimes poor and requires the opening of windows for comfortable breathing conditions.

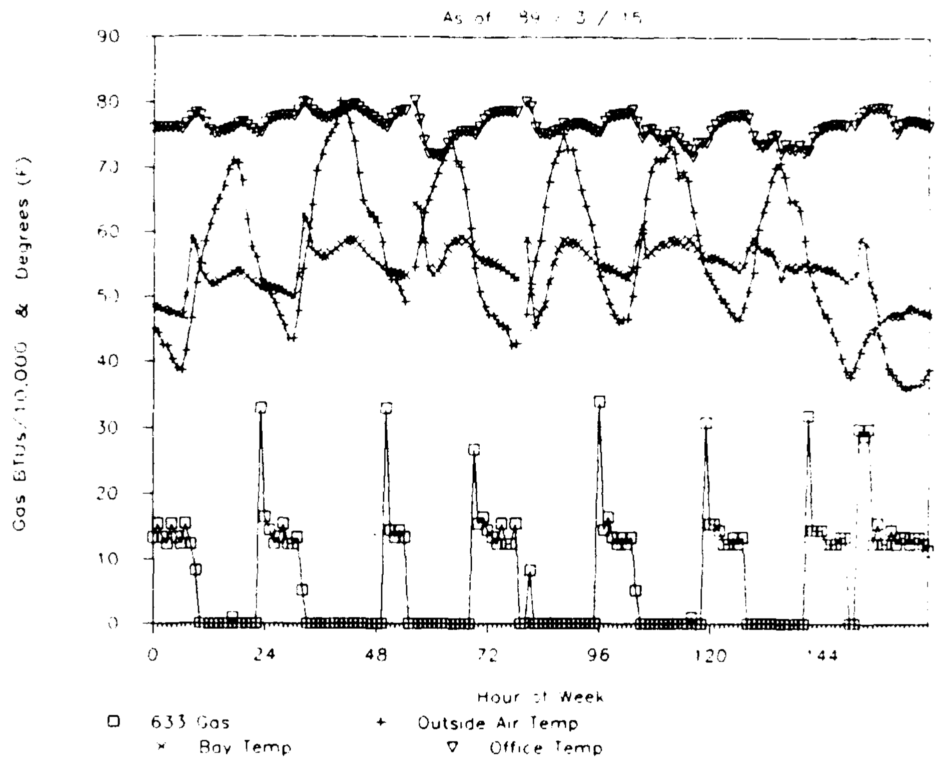

Figure 15. Gas use and temperature, Bldg 633 (I8618).

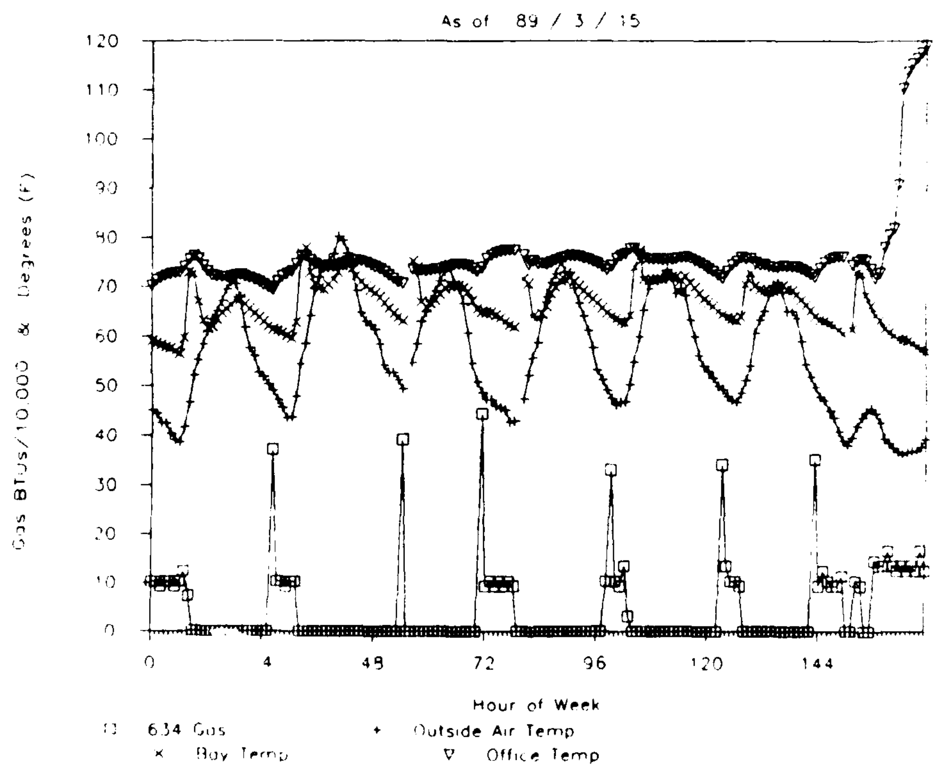

Figure 16. Gas use and temperature, Bldg 634 (J8618).

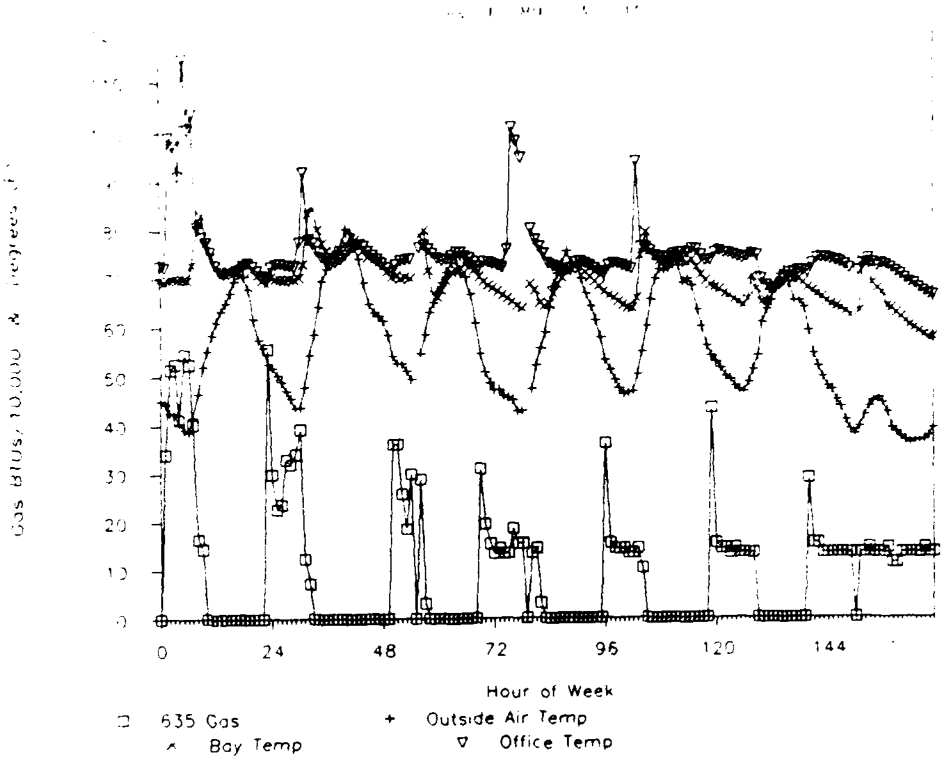

Figure 17. Gas use and temperature, Bldg 635 (K8618).

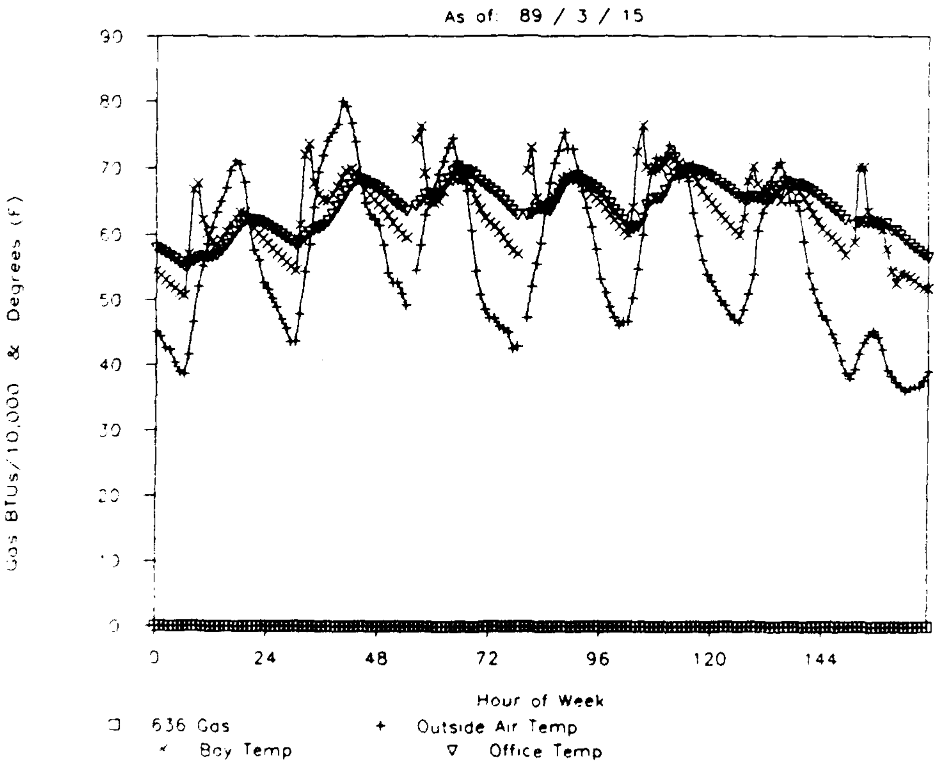

Figure 18. Gas use and temperature, Bldg 636 (L8618).

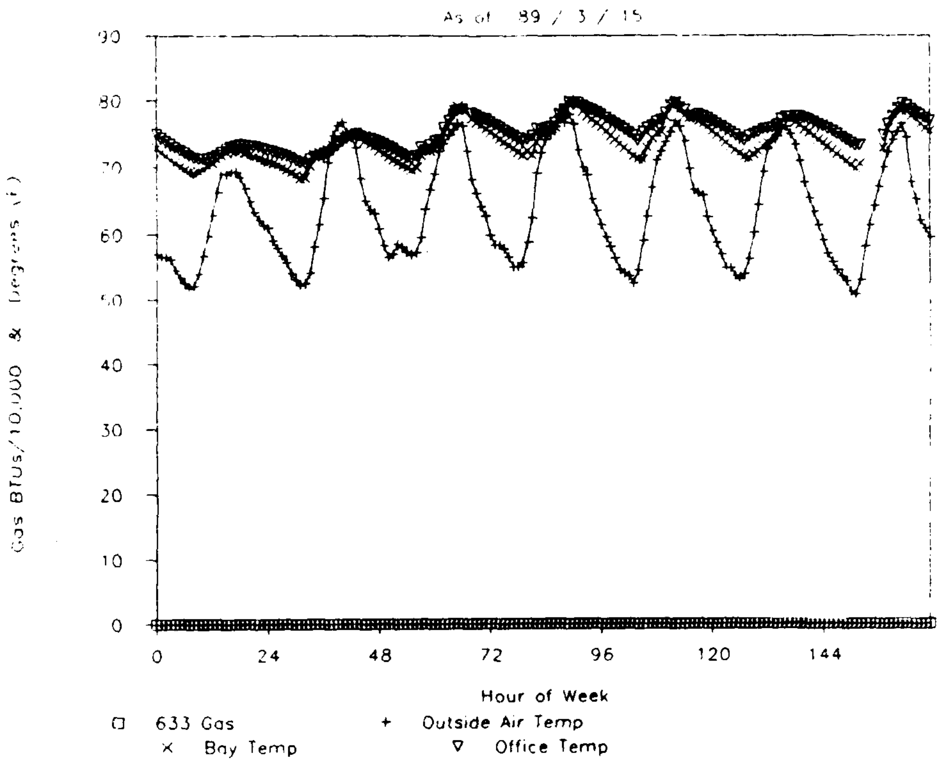

Figure 19. Gas use and temperature, Bldg 633 (I8636).

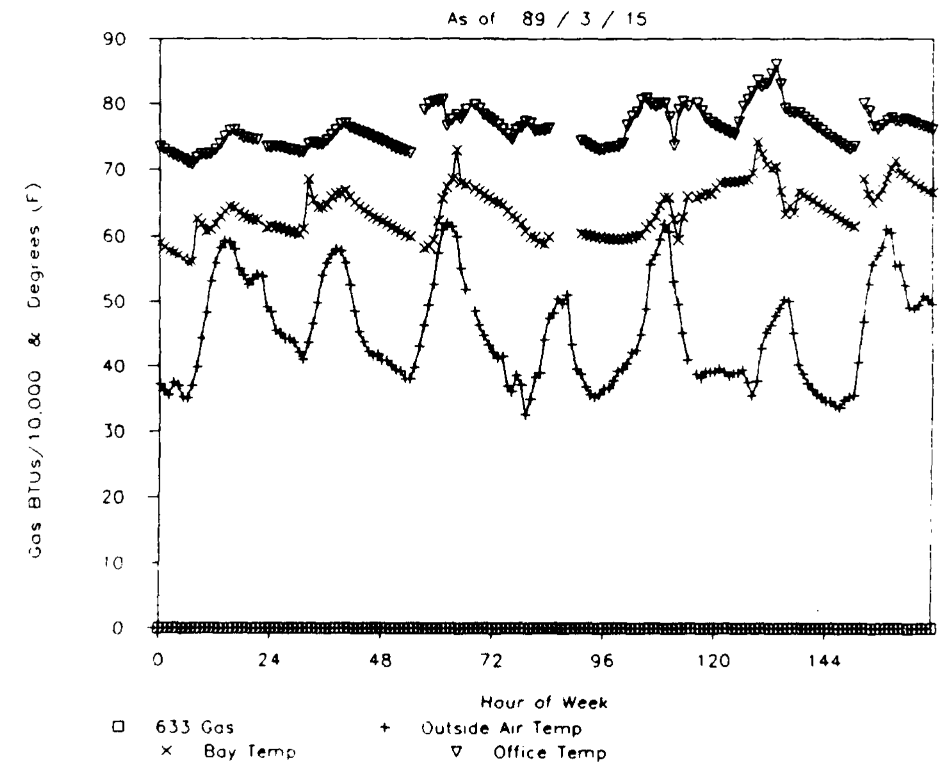

Figure 20. Gas use and temperature, Bldg 633 (I8645).

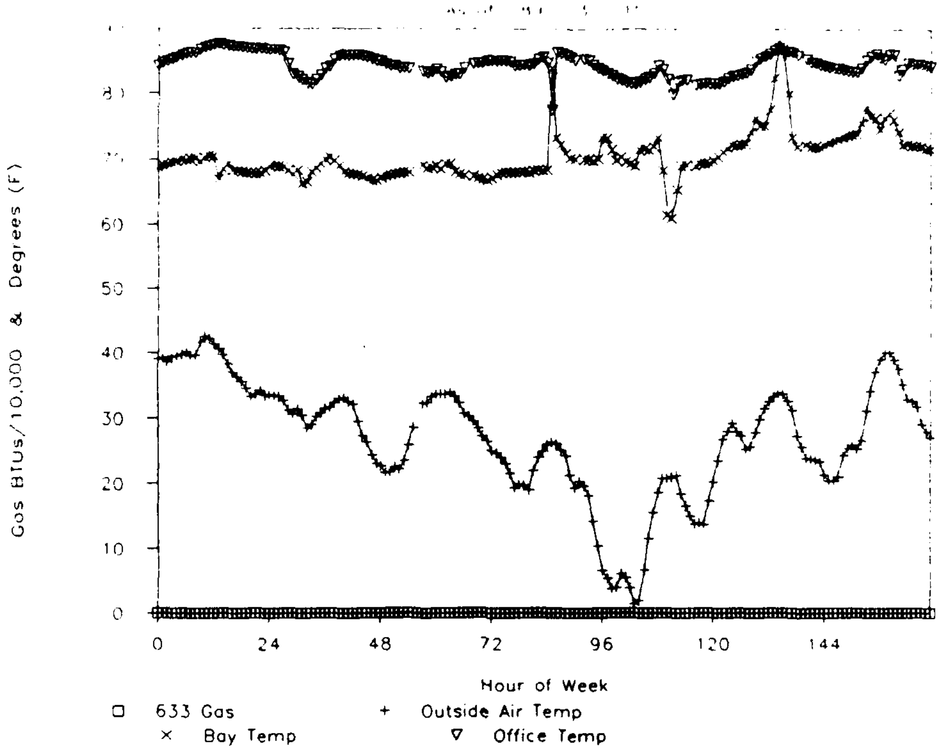

Figure 21. Gas use and temperature, Bldg 633 (I8648).

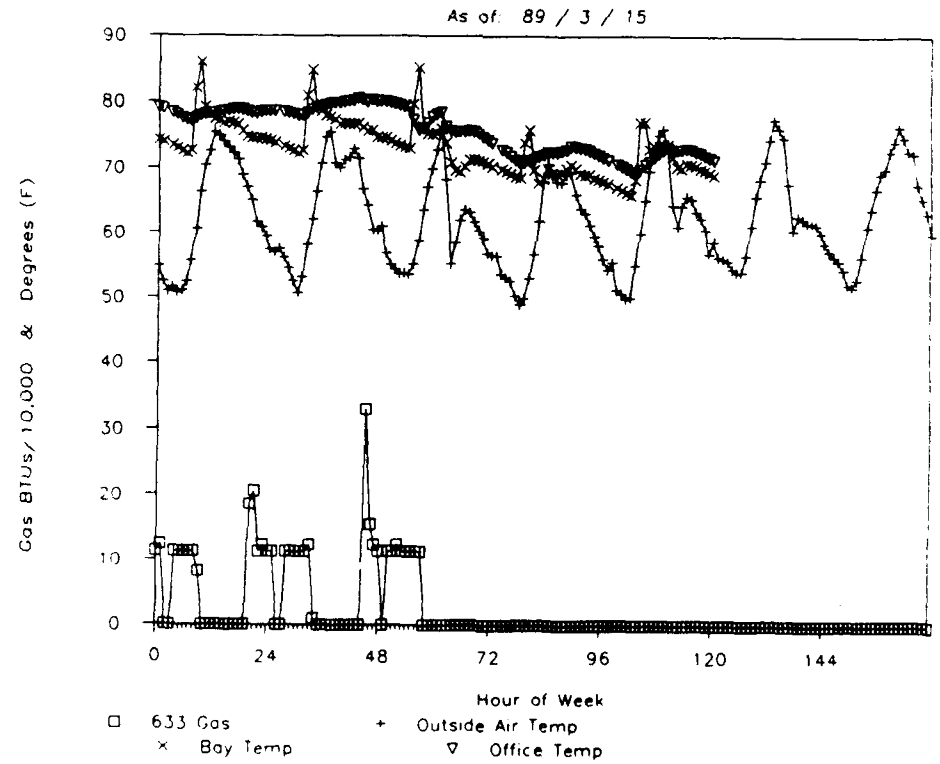

Figure 22. Gas use and temperature, Bldg 633 (I8718).

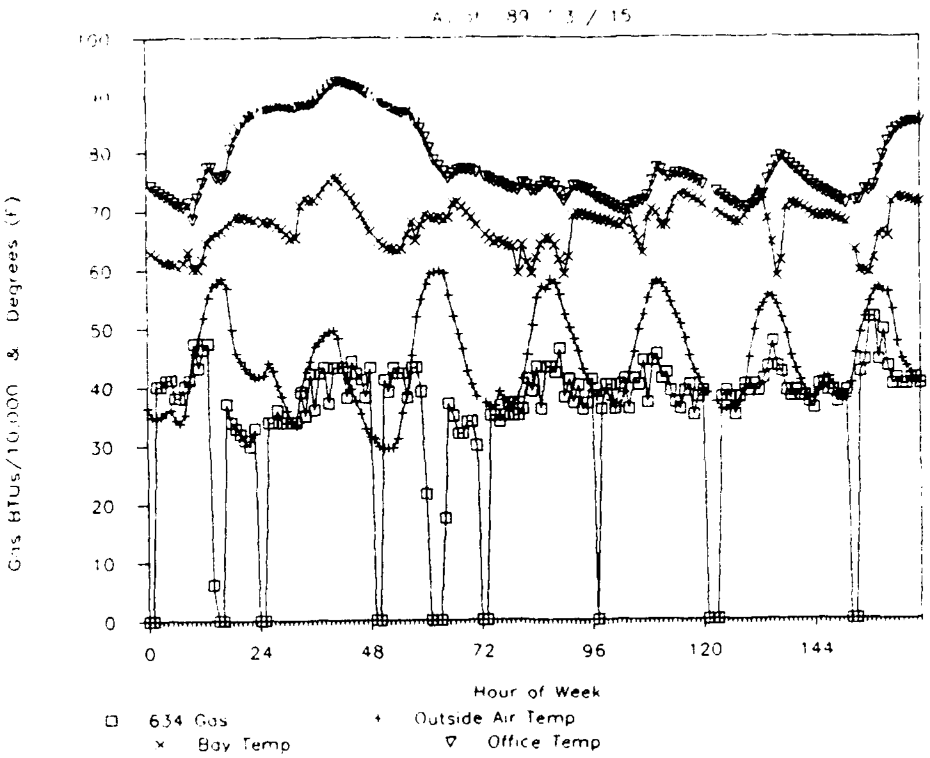

Figure 23. Gas use and temperature, Bldg 634 (J8705).

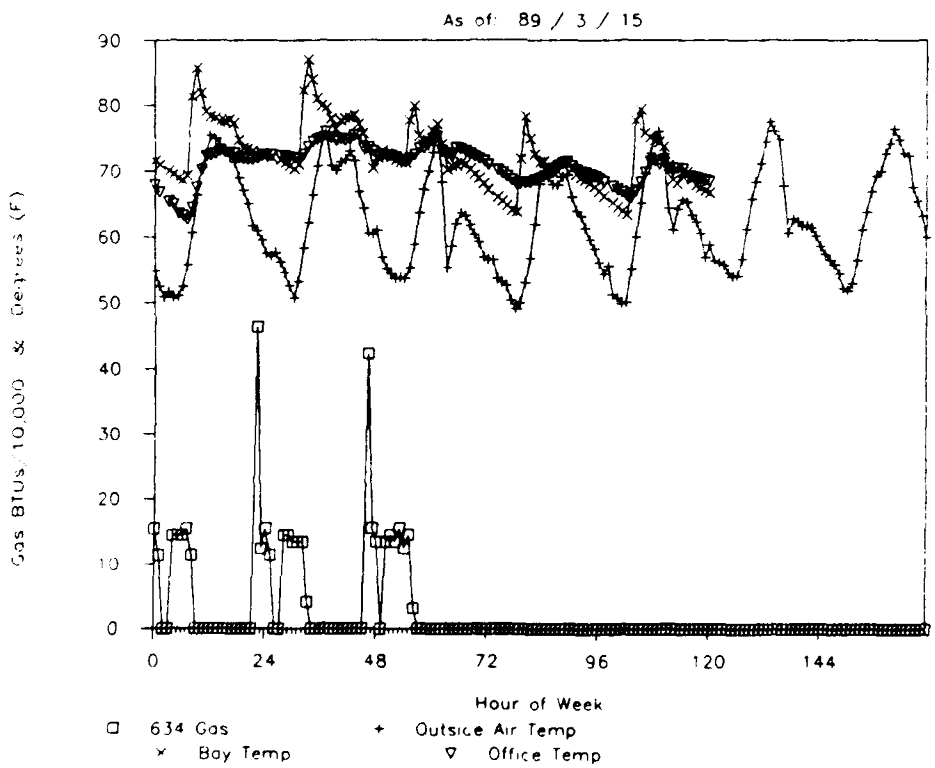

Figure 24. Gas use and temperature, Bldg 634 (J8718).

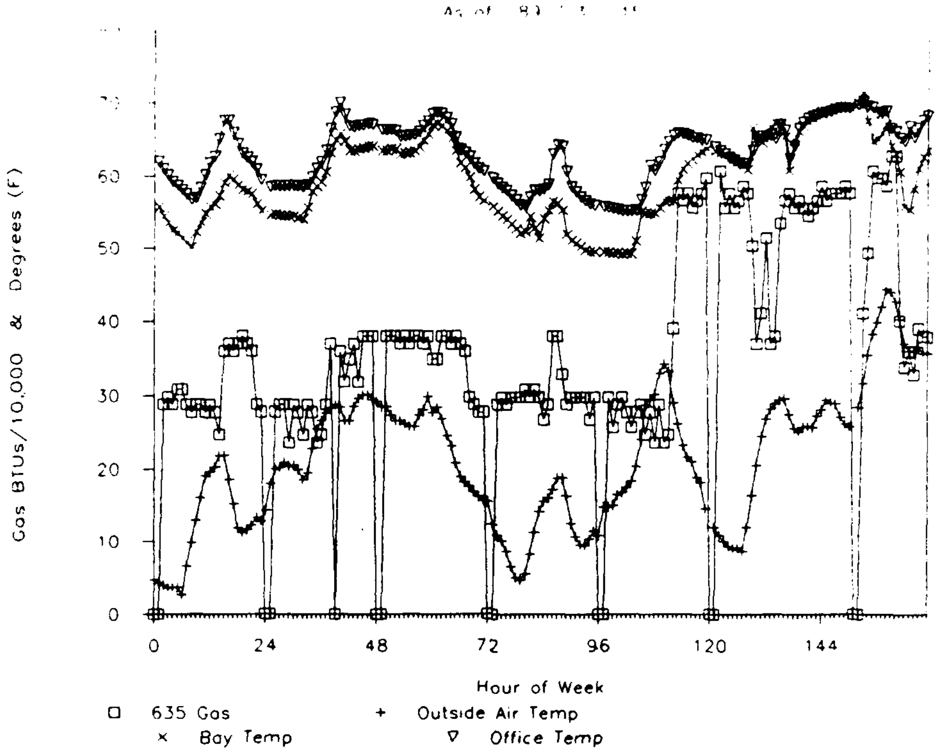

Figure 25. Gas use and temperature, Bldg 635 (K8702).

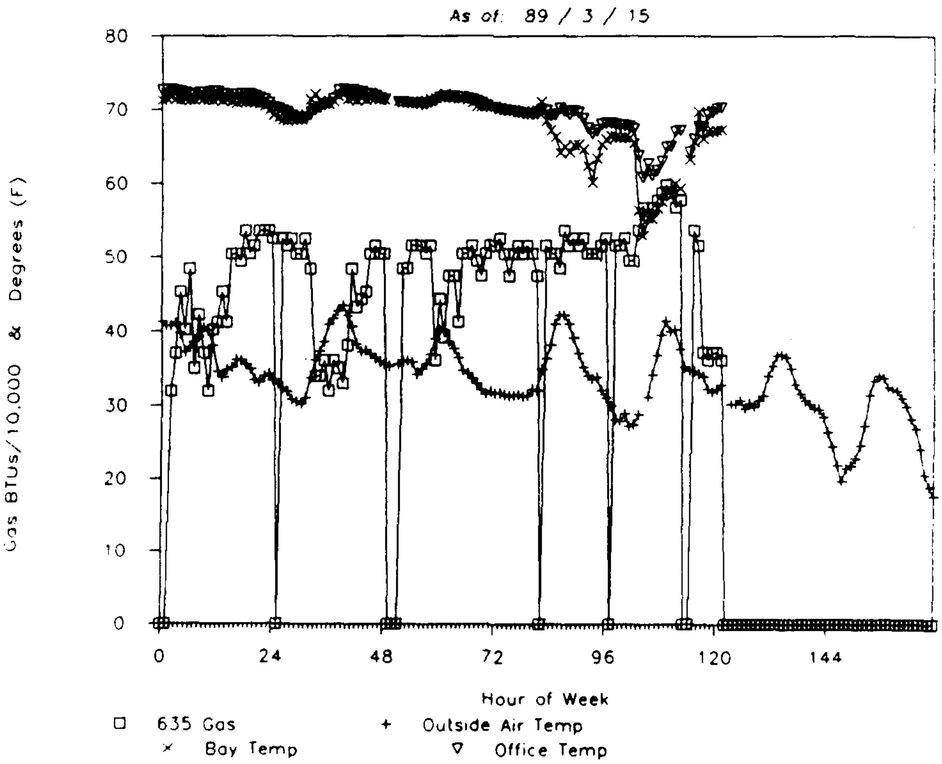

Figure 26. Gas use and temperature, Bldg 635 (K8706).

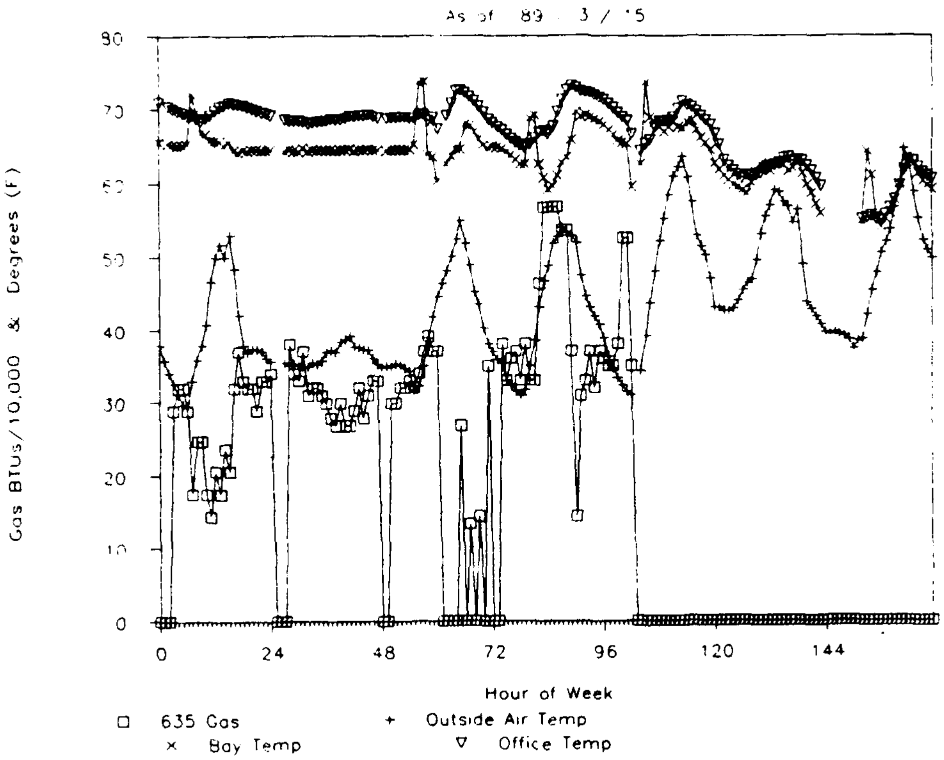

Figure 27. Gas use and temperature, Bldg 635 (K8713).

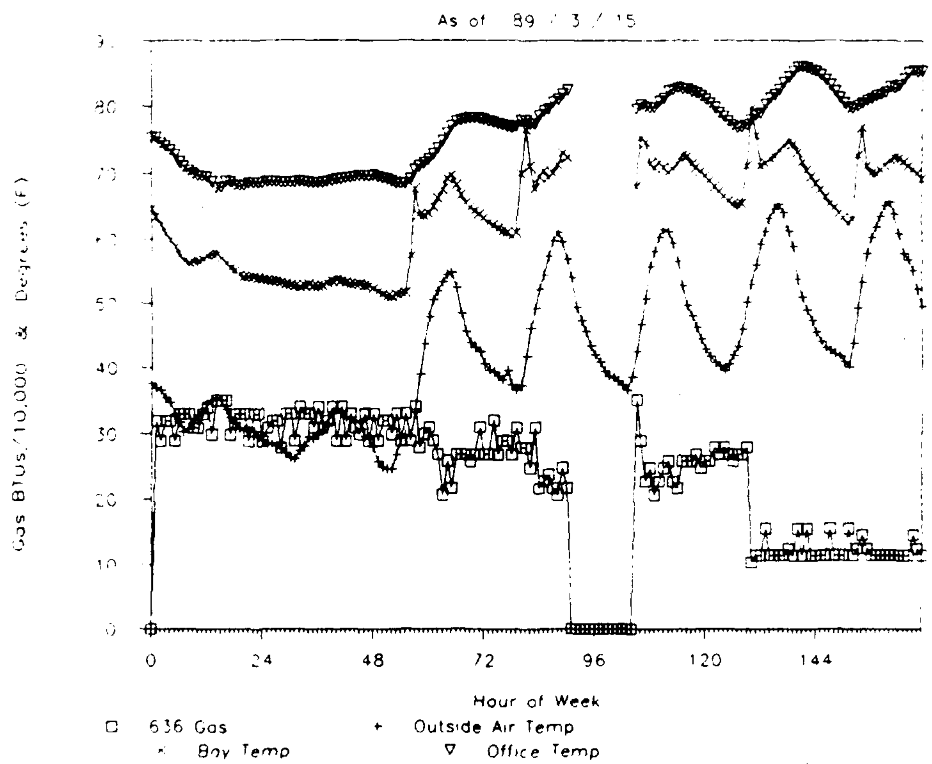

Figure 28. Gas use and temperature, Bldg 636 (L8640).

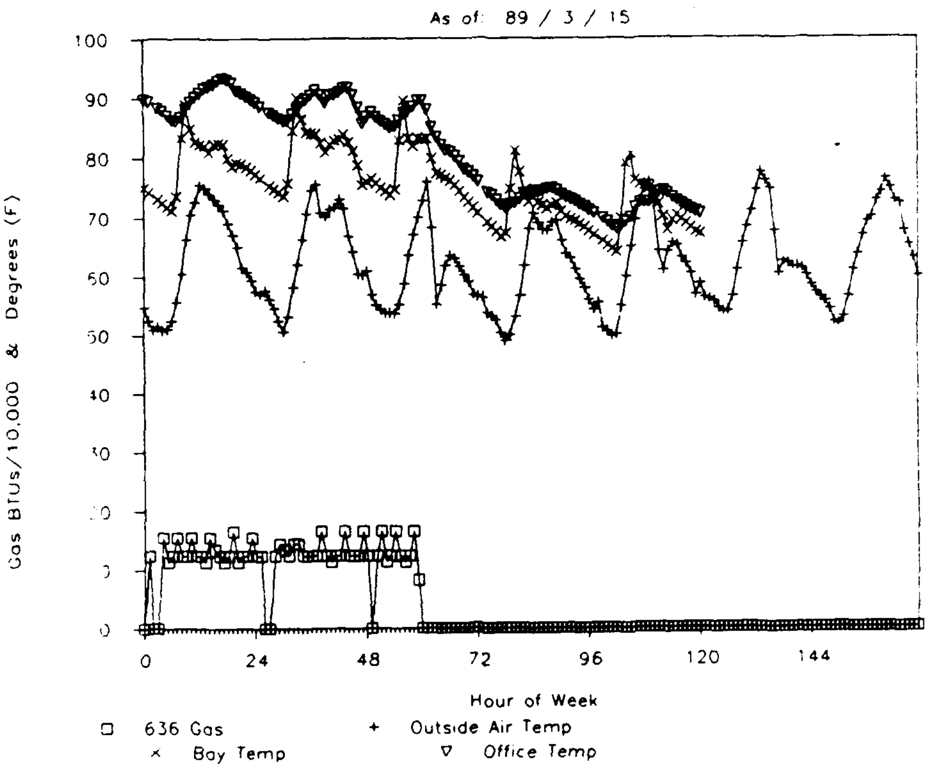

Figure 29. Gas use and temperature, Bldg 636 (L8718).

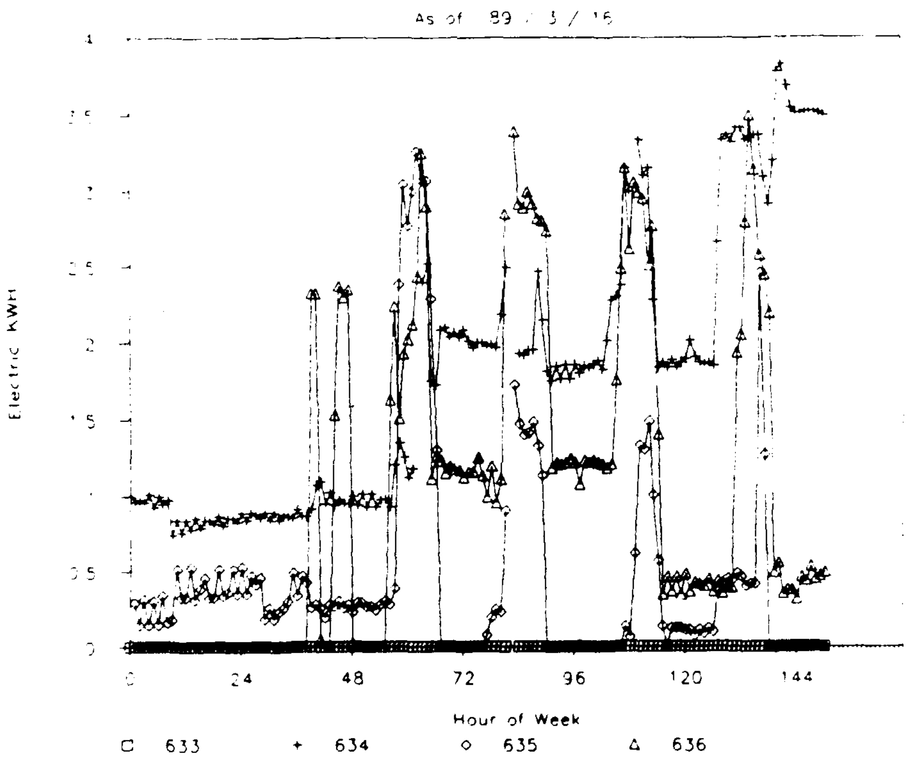

Figure 30. Motor shop electricity use (K8609).

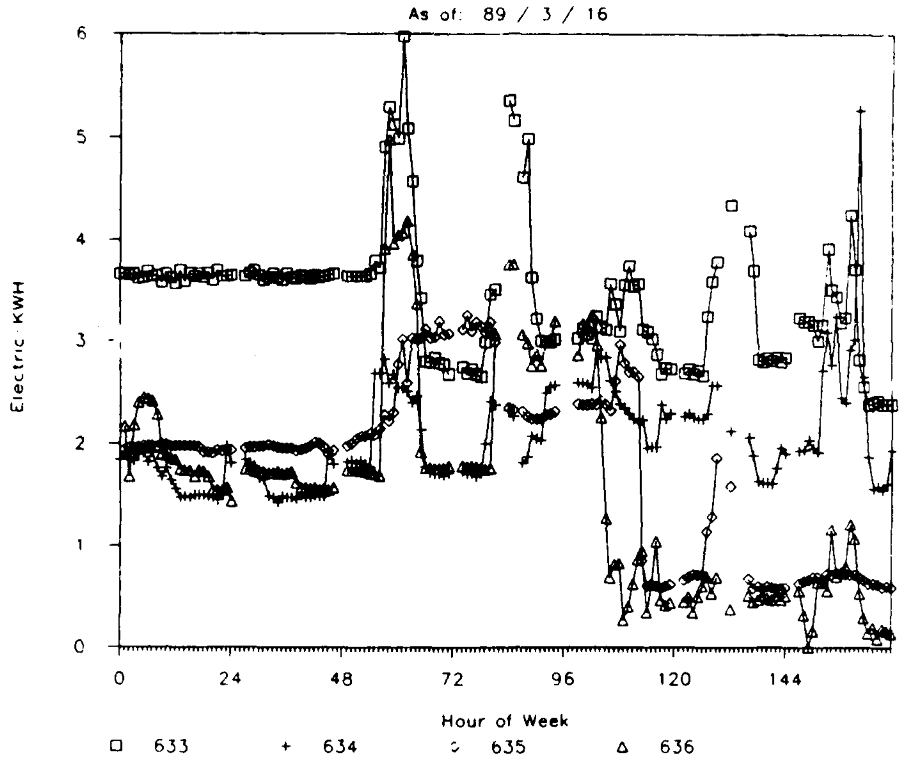

Figure 31. Motor shop electricity use (K8715).

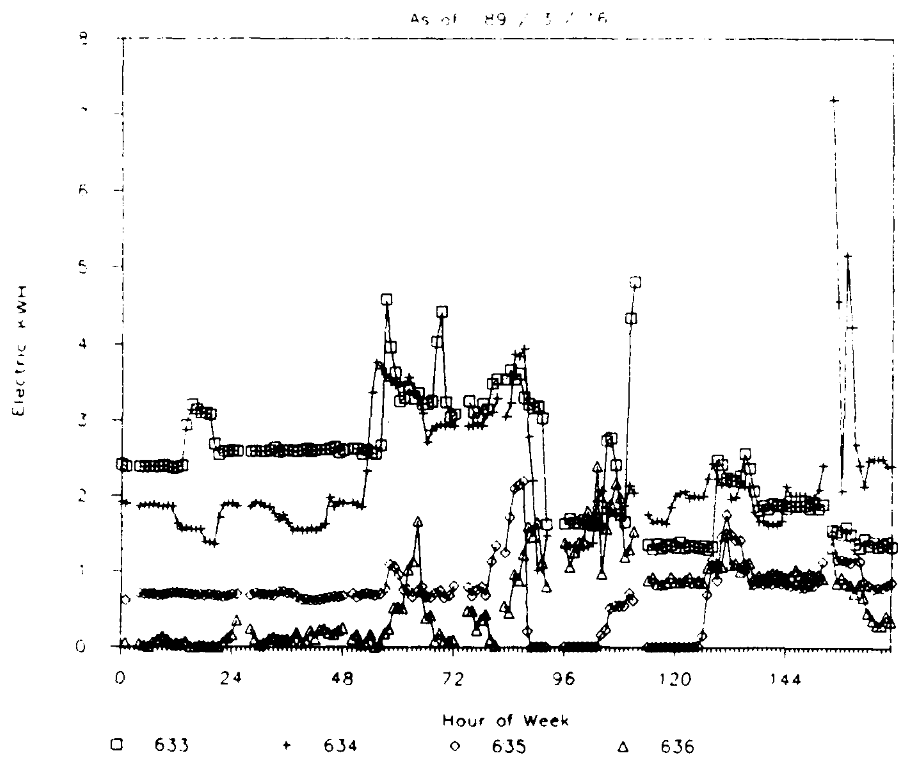

Figure 32. Motor shop electricity use (K8716).

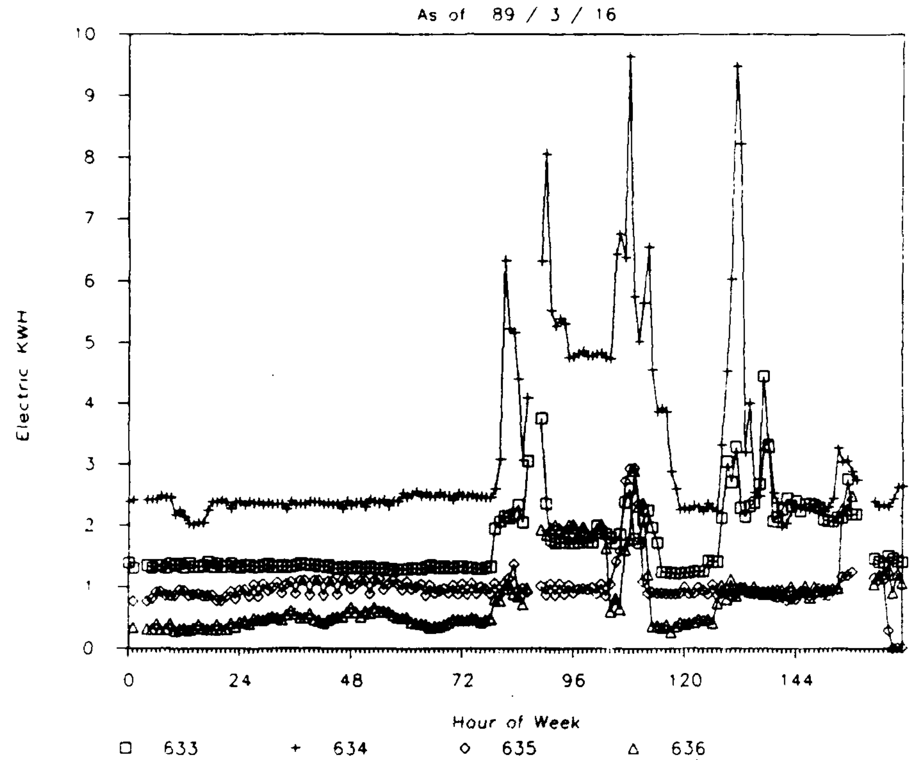

Figure 33. Motor shop electricity use (K8717).

Interior Temperatures

Gathered data indicate that interior spaces are consistently overheated in winter, prompting inhabitants to open windows to maintain interior comfort. This compromising of the building envelope during heating seasons (other than for needed ventilation) resulted in substantial energy loss.

The cooling system does not maintain comfort conditions in summer. Reasons for this include warmer than needed water temperatures and lower than required flow rates. The buildings are frequently warm in the summer and windows are opened to circulate building air.

System Efficiencies

An additional consideration that the data illuminate is the low heating system efficiencies. The data show annual system efficiencies of 29 to 37 percent in 1986-87 as opposed to the original assumed efficiency for heating of 60 percent from the BLAST analysis.

Improved Operations

Before the 1987-88 heating season, a careful evaluation of sources of the system inefficiencies and inadequate temperature control were followed by tune-up, repair and (where necessary) replacement or enhancement of insufficiently functioning equipment. Substantial savings were realized. These modifications and their implications are discussed in Chapter 5.

Dining Halls

Heating and Interior Temperatures

Review of the data indicated that there was little connection between heat provided and building use, and that comfortable interior temperatures rarely prevailed. Heating was not provided to two of the dining halls (buildings 1361 and 1669) in the fall of 1986, although records on meals served indicate building use. Interior temperature profiles float with outdoor air temperatures and often experience 20-degree swings. One of these same buildings (1669) was not heated during February; however, it experienced fairly comfortable conditions as interior or solar loads presumably provided enough heat. Another building (1369) was not used during fall 1986, but was provided with steady heat--albeit uncontrolled, resulting in interior conditions that ranged from hot to cold. This same building was open for business in the summer but was heated until August, which left the building quite warm. Some examples of the lack of interior temperature control are shown in Figures 34 through 36 (P8641, R8715, V8714).

Controls

Although 7-day timeclocks were installed as part of the retrofit effort, they were disabled by base personnel after installation. Figure 37 (P8617) shows a daily heating setback for building 1361 during the last half of the 1985-86 heating season. However, the heating was shut off during the first half of the 1986-87 heating season and the setback was disabled entirely when heating was turned on in January 1987 (Figure 38, P8700). The reference buildings had no such setback, but rather a fluctuation probably related to air temperature (Figures 39 and 40, R8617 and V8617).

The retrofit dining hall showed a heating hot water reset schedule for a few weeks in spring 1986 (Figures 41 through 44). Although week 8606 (Figure 42) shows that heating water is being reset based on outdoor temperature, the reset control was disabled by week 8610 (Figure 44). The reference dining halls showed a constant temperature hot water heating (Figures 45 and 46, R8608 and V8608).

Ventilation

The ventilation systems have been disabled in many of the dining halls, presumably without regard for fresh air requirements.

Building Use

There was wide variation in energy consumption between buildings. Much of this finding may well be due to the inconsistent operation of the dining halls. Information gathered on number of meals served in these facilities indicates that the buildings were used well below capacity (usually 30 to 50 percent) and were frequently closed. This variation in building use is evident in data gathered on steam, cooking gas, DHW, and electricity. Figures 47 through 49 show electrical profiles for week 8640. In this example, the retrofit building is showing periodic daily use, while the others show no pattern.

Building Closure

Ironically, the retrofit building was closed as a cost-cutting measure in June 1987.

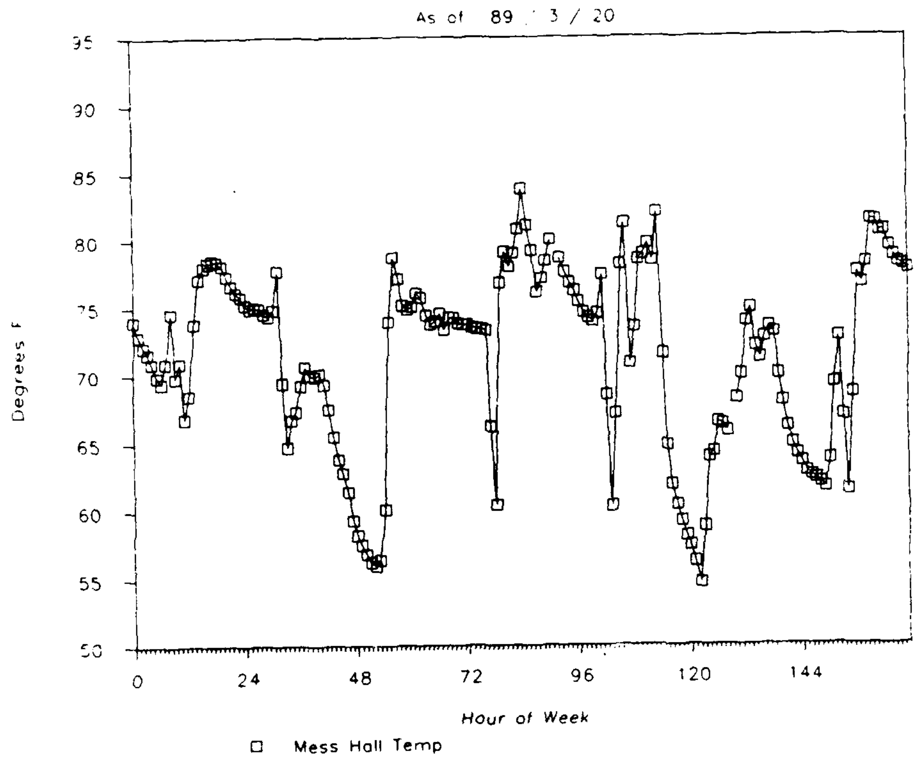

Figure 34. Dining hall temperatures (P8641).

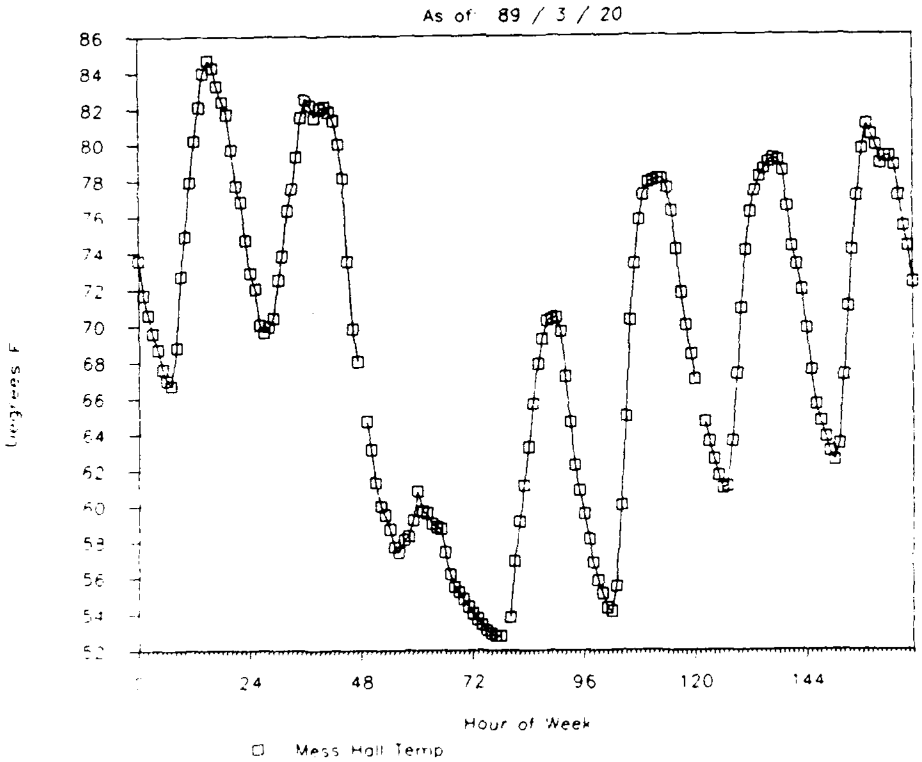

Figure 35. Dining hall temperatures (R8715).

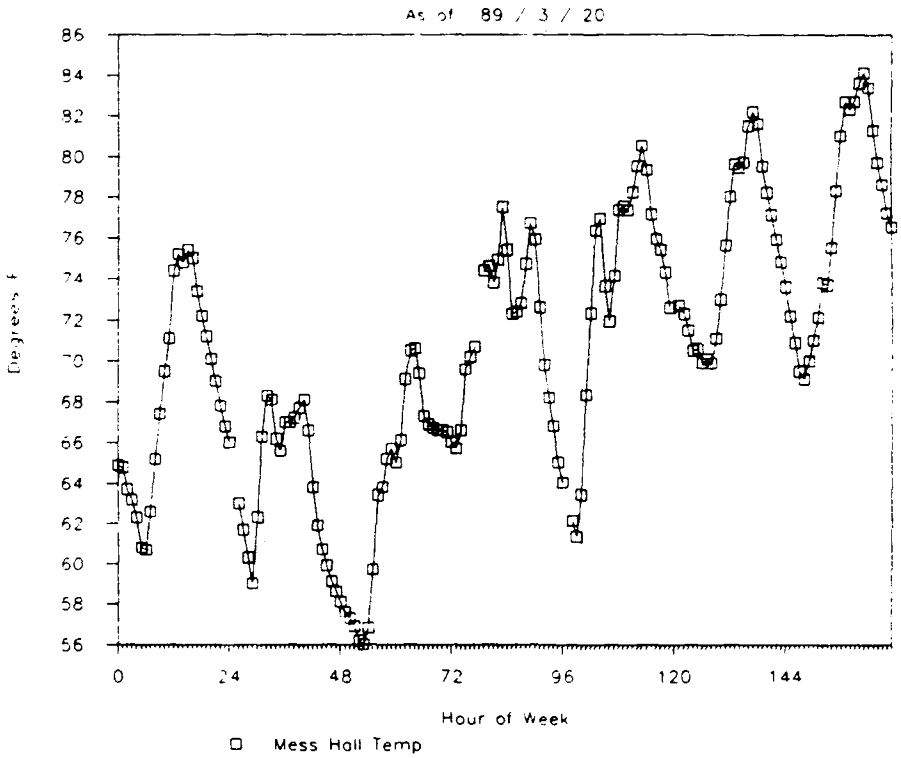

Figure 36. Dining hall temperatures (V8714).

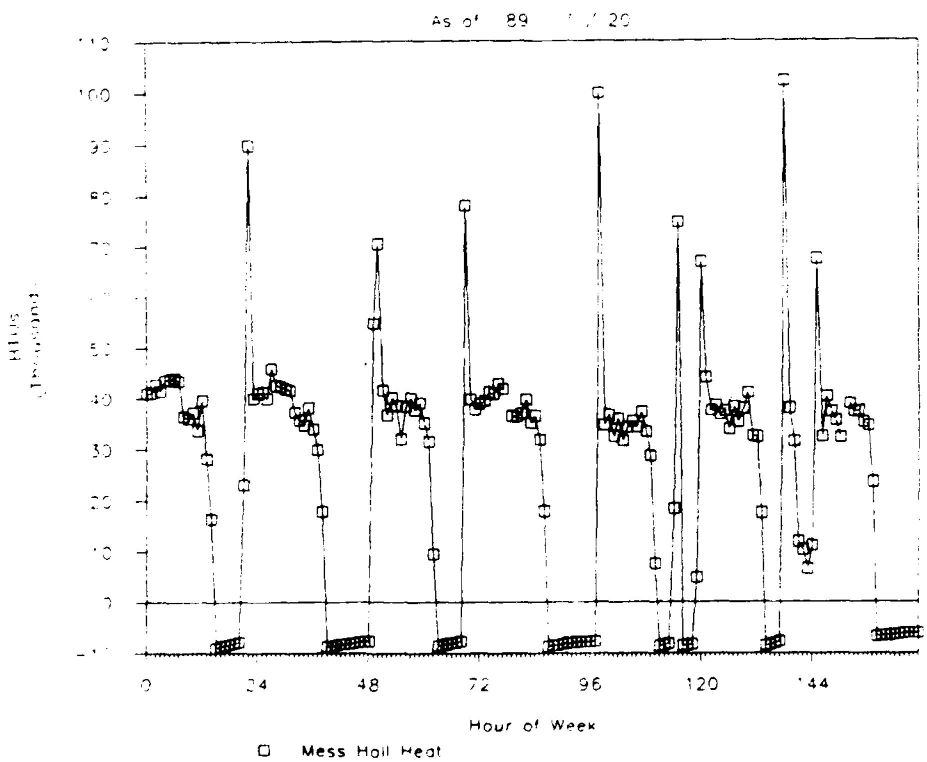

Figure 37. Dining hall heating (P8617).

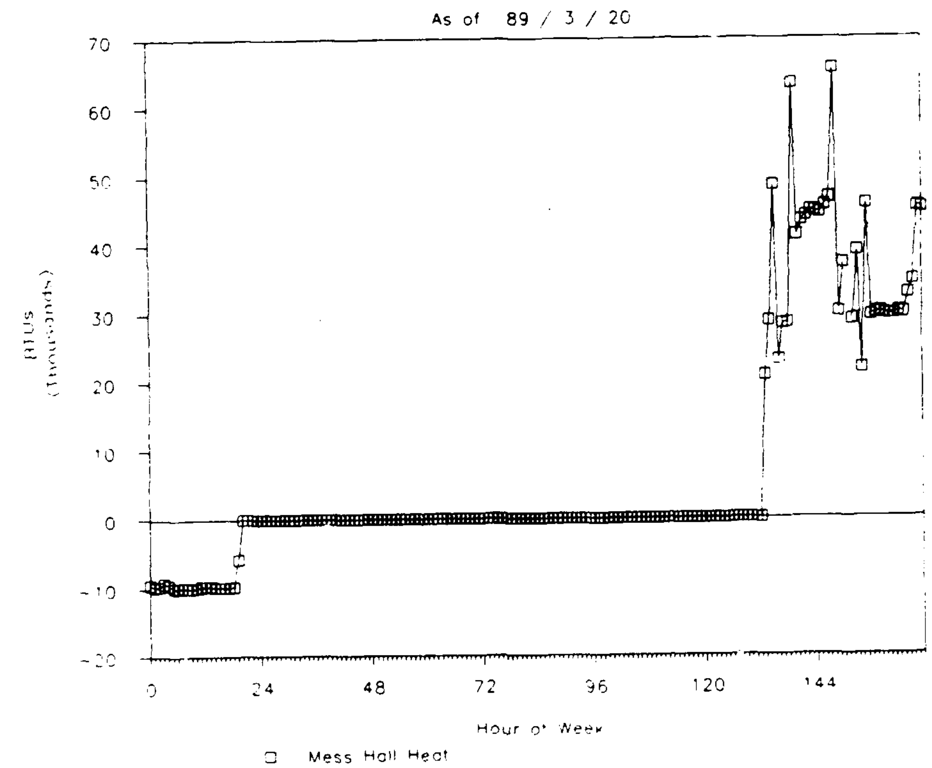

Figure 38. Dining hall heating (P8700).

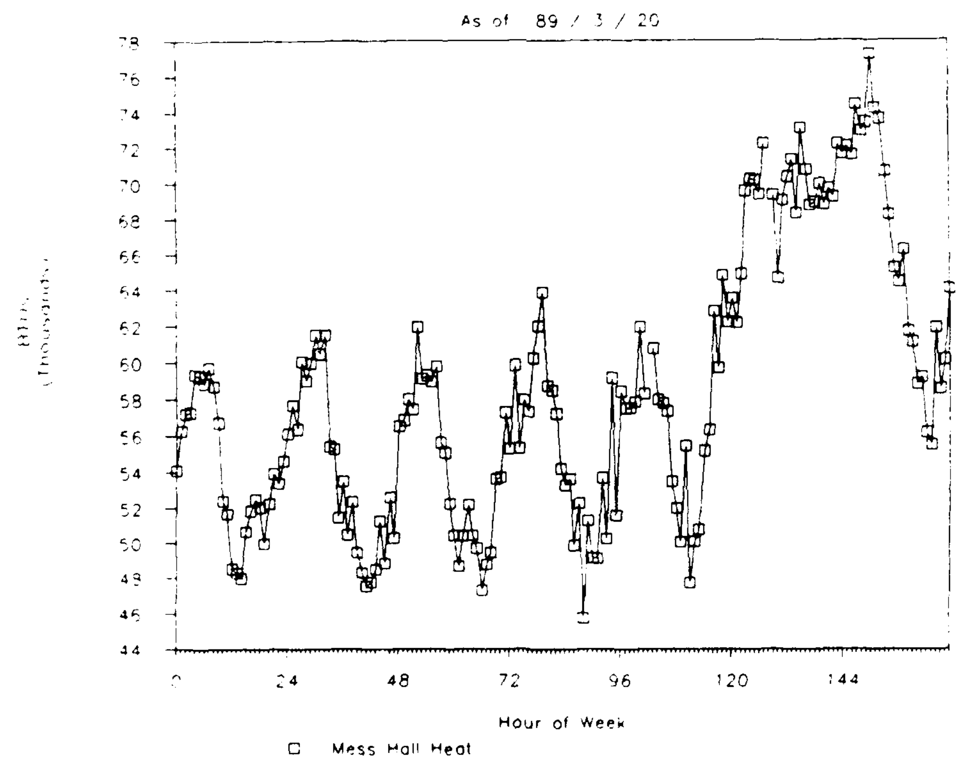

Figure 39. Dining hall heating (R8617).

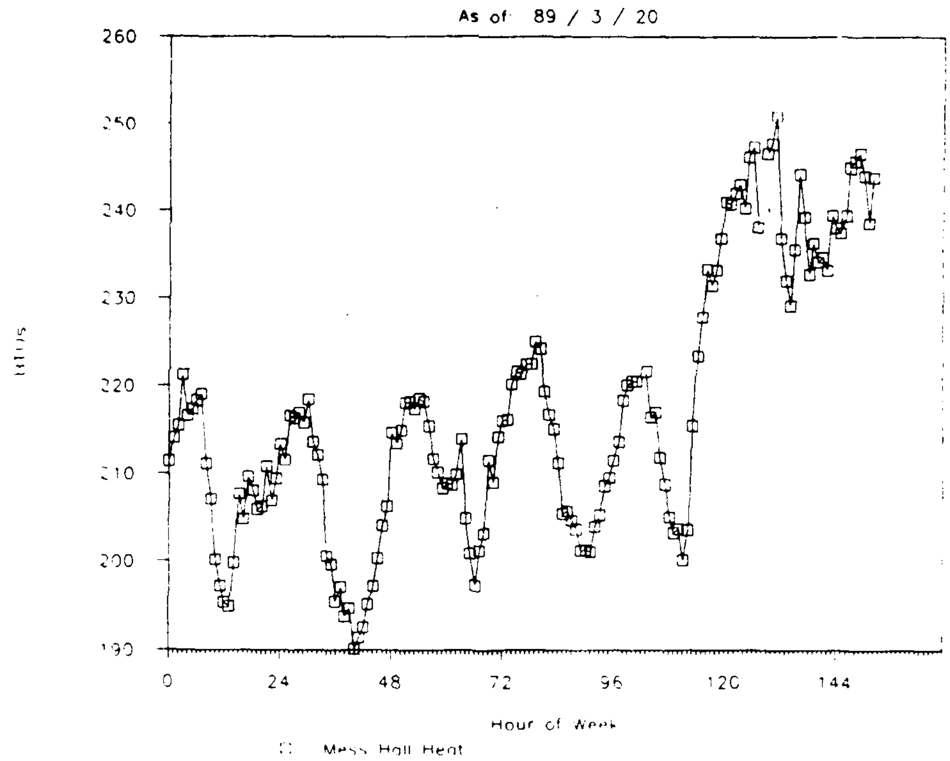

Figure 40. Dining hall heating (V8617).

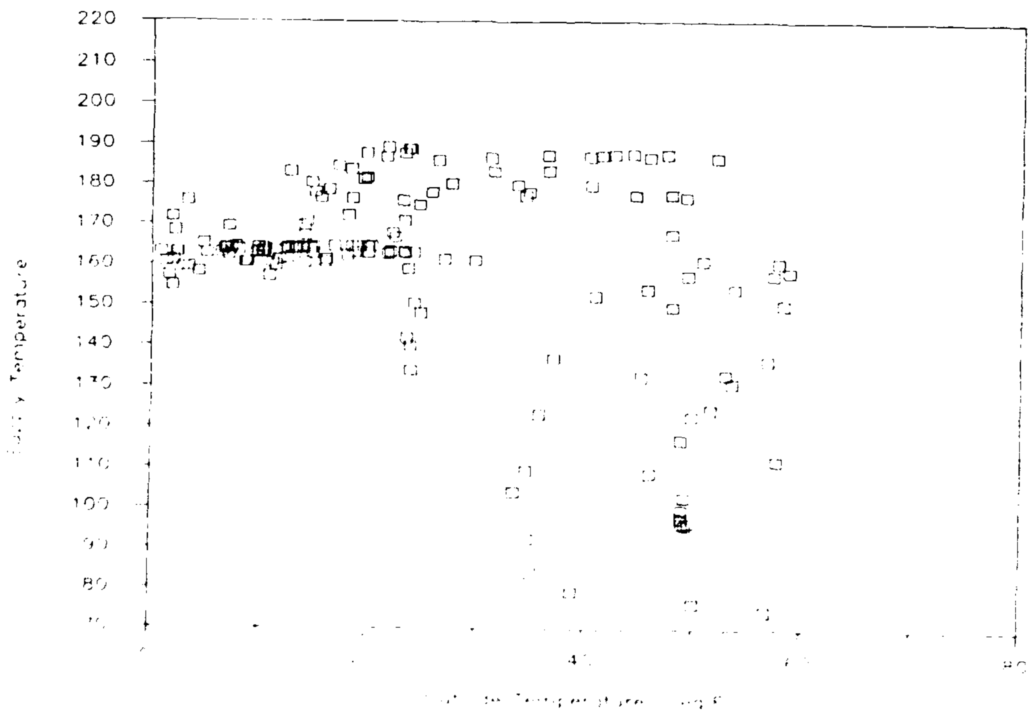

Figure 41. Dining hall reset schedule (P8605).

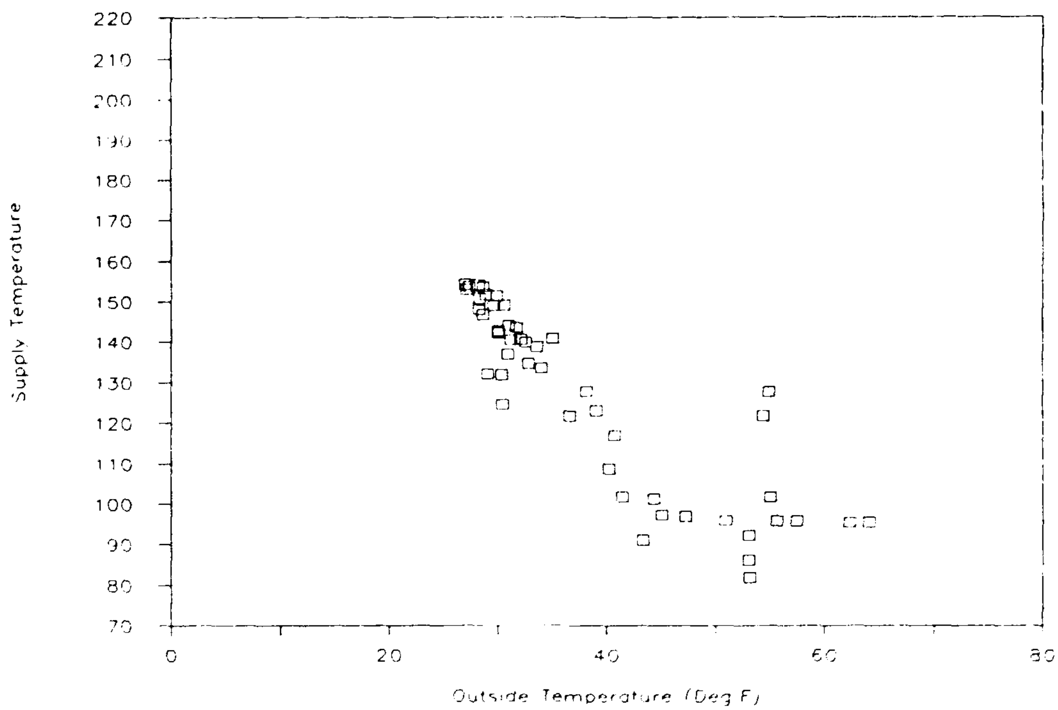

Figure 42. Dining hall reset schedule (P8606).

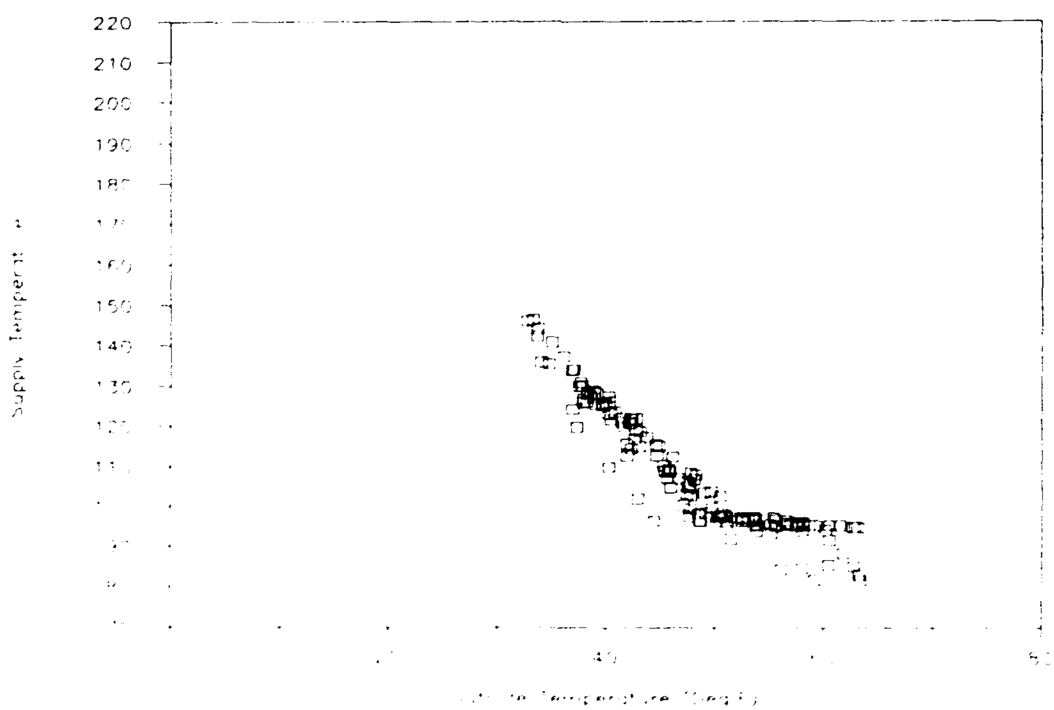

Figure 43. Dining hall reset schedule (P8608).

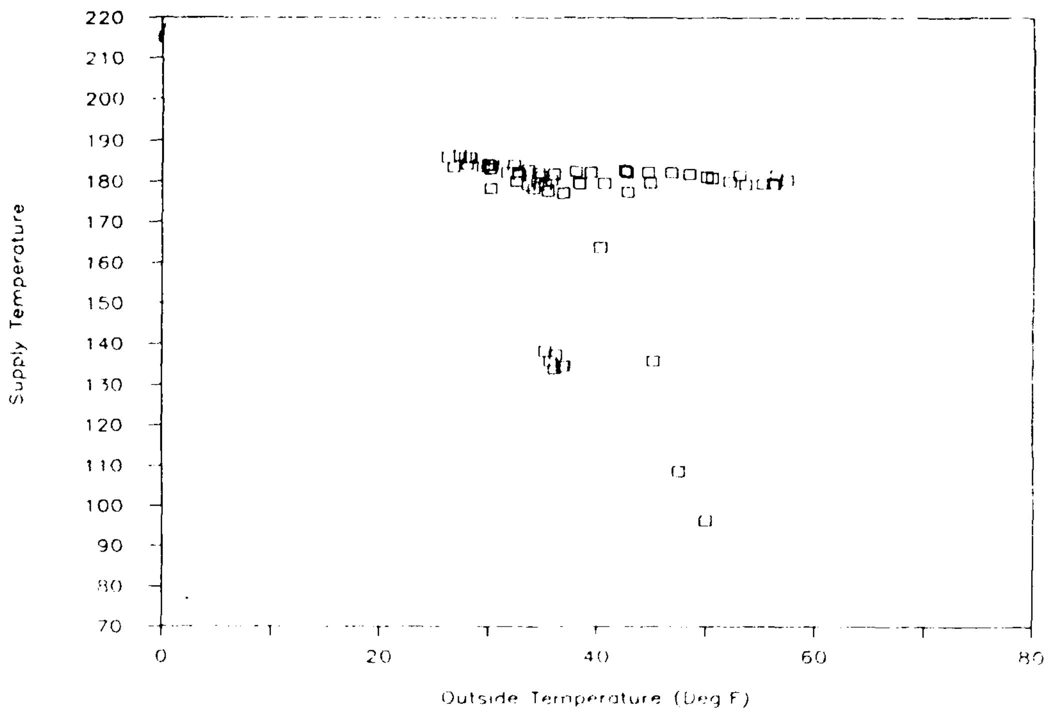

Figure 44. Dining hall reset schedule (P8610).

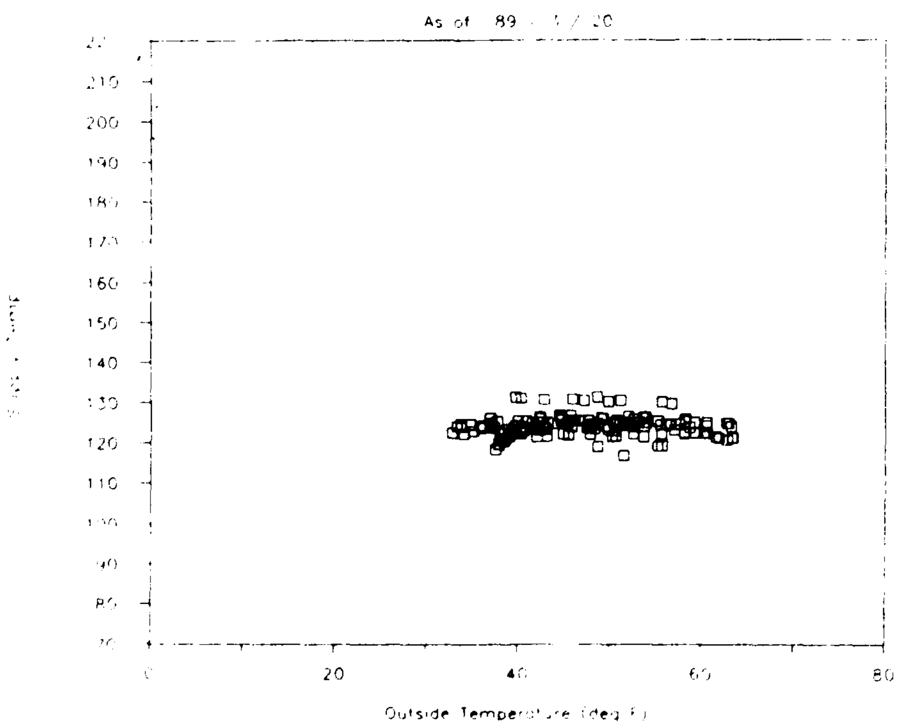

Figure 45. Dining hall reset schedule (R8608).

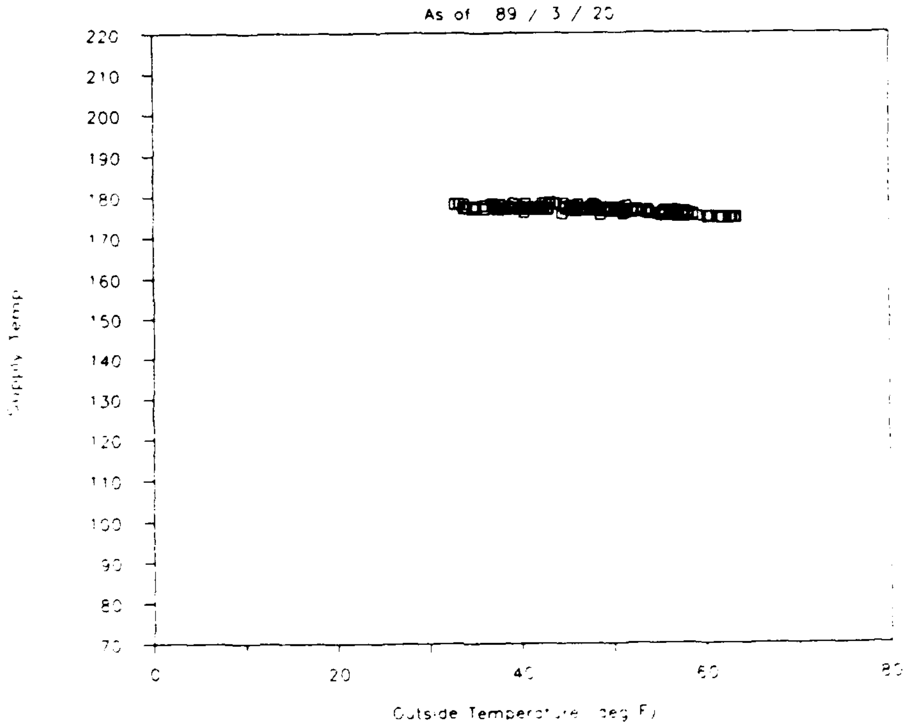

Figure 46. Dining hall reset schedule (V8608).

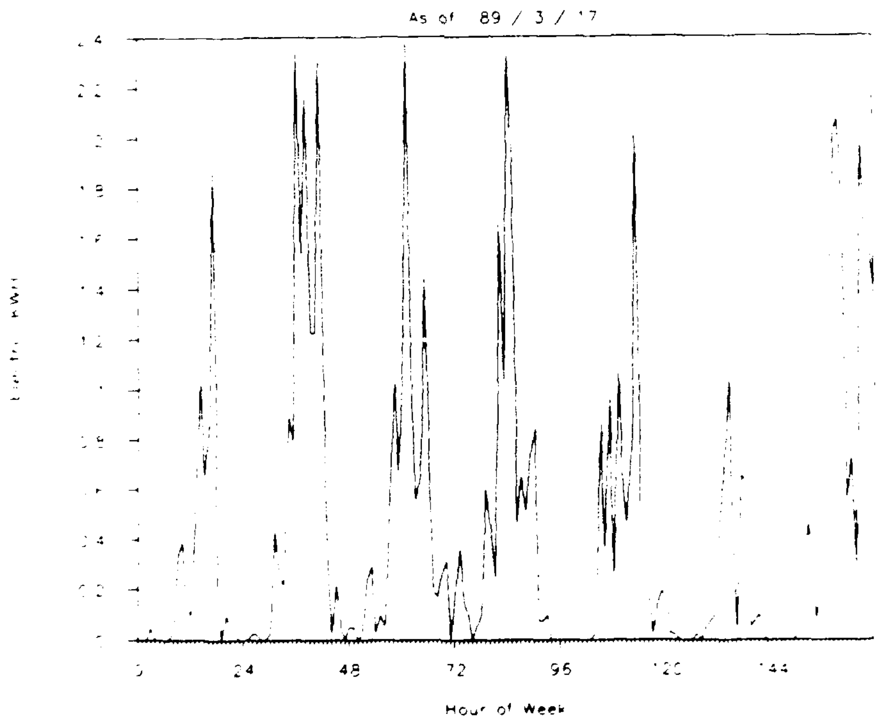

Figure 47. Dining hall electricity (P8640).

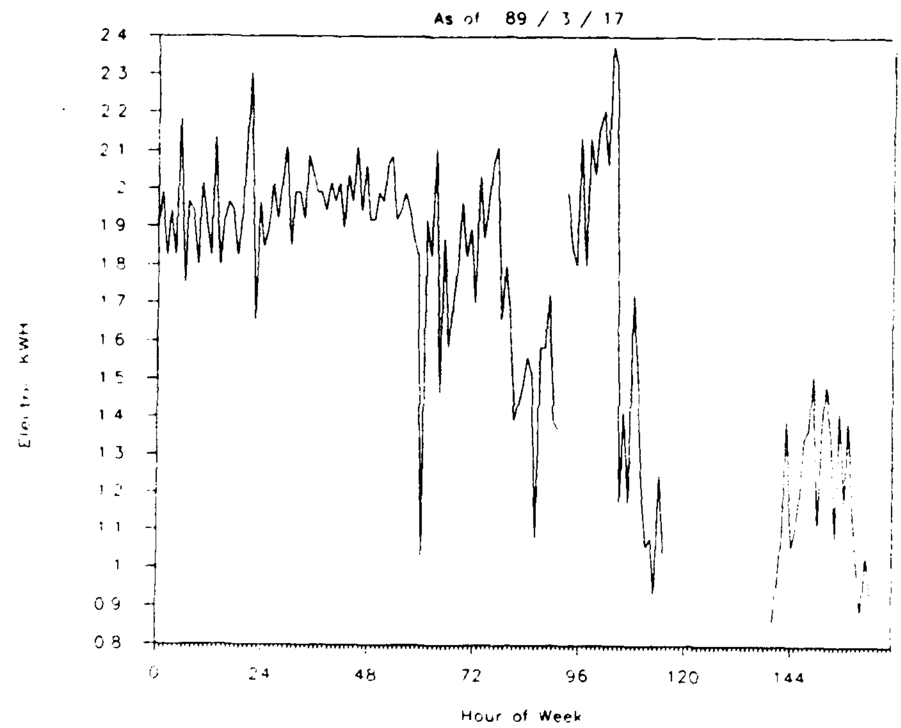

Figure 48. Dining hall electricity (R8640).

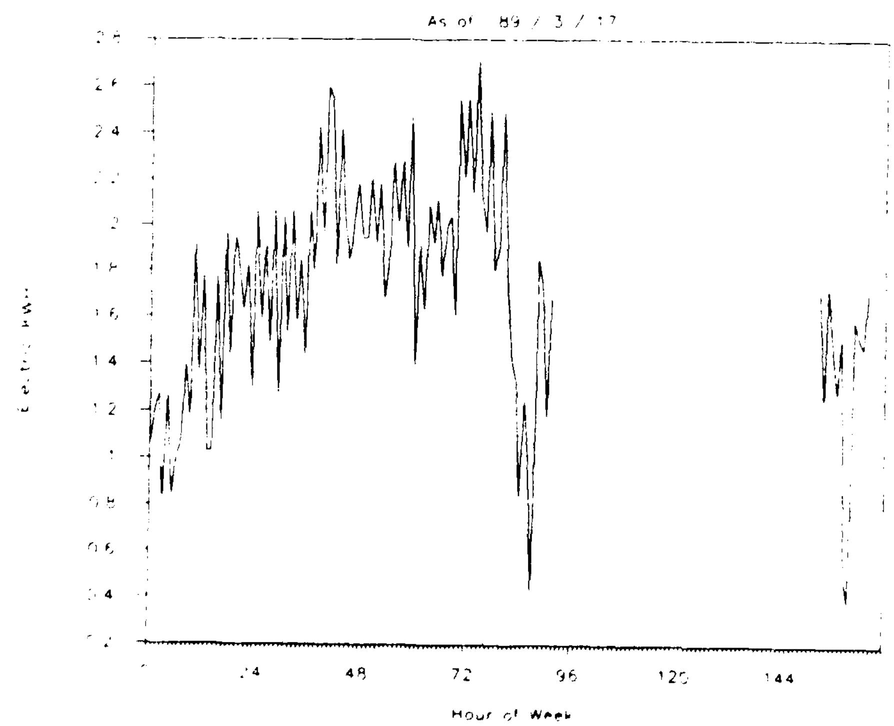

Figure 49. Dining hall electricity (V8640).

Rolling-Pin Barracks

Heating

The lower than expected heating savings must be attributed to the decision not to install wall insulation* in this building category. In addition, the building control system is suspect for compromising the effectiveness of the retrofits. Here, as in other buildings, open windows have been observed repeatedly during the heating season due to overheated interior spaces. Figures 50 through 53 show sample interior temperature profiles for the barracks buildings.

Cooling

Here, as in other buildings, the cooling system does not maintain comfort conditions in summer. The reasons include warmer than required water temperatures and lower than required flow rates. In some buildings, no cooling took place during the entire test period. When cooling did occur, water flow was erratic and often far below pump capacities. It is speculated that much of the observed flow was pitch-, pressure-, or convective-induced rather than pumped. Since interior temperatures are warm, windows are opened to provide comfortable conditions.

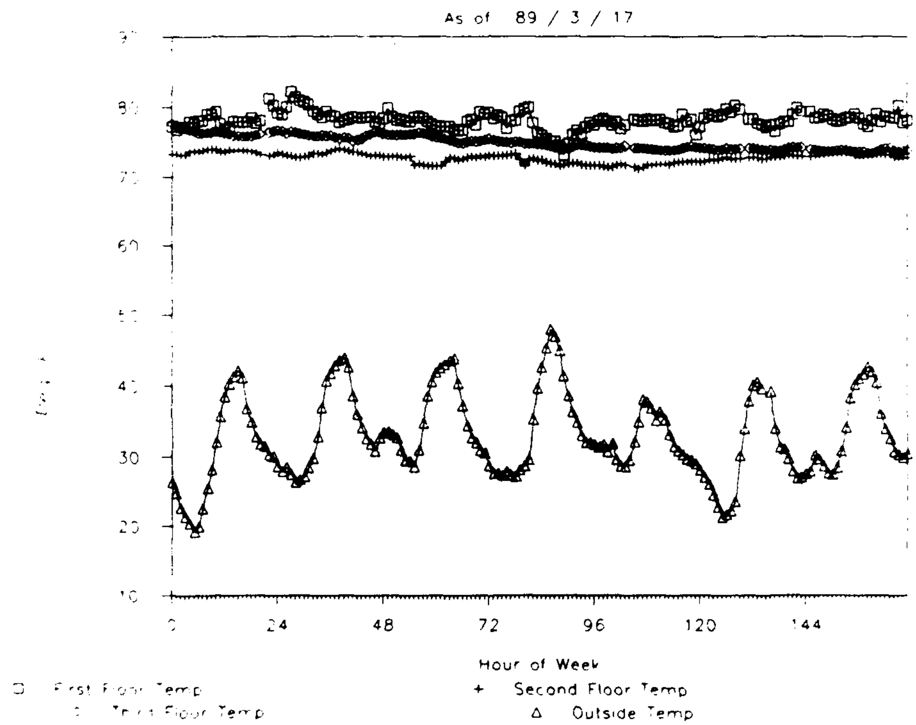

Figure 50. Rolling-pin barracks temperatures (Q8649).

*Wall insulation was originally planned as part of the rolling-pin barracks retrofit package. Reasons for dismissing this retrofit are discussed in Interim Report E-88/08.

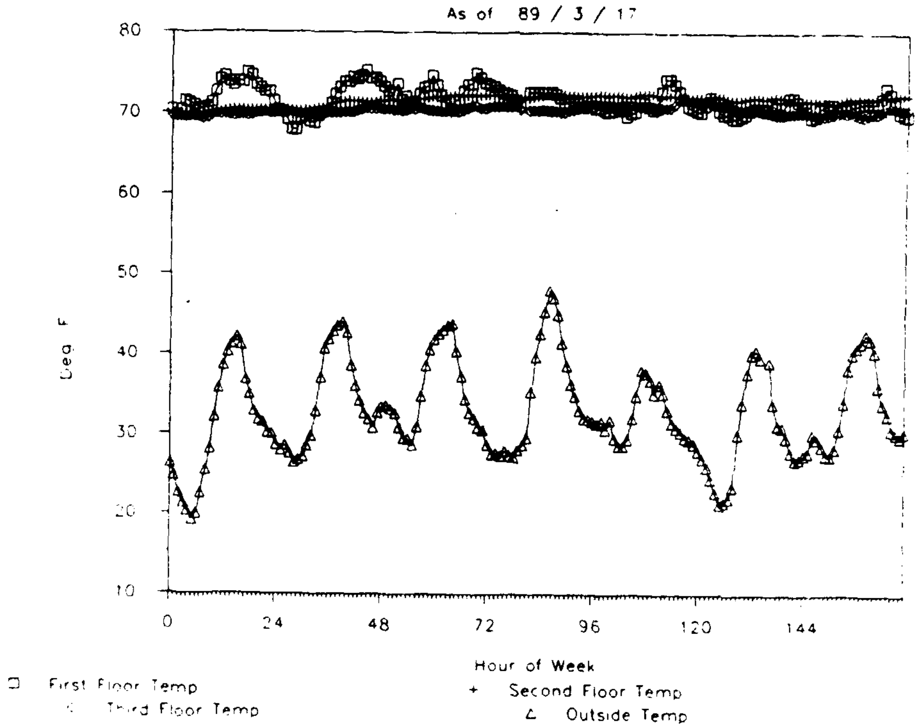

Figure 51. Rolling-pin barracks temperatures (S8649).

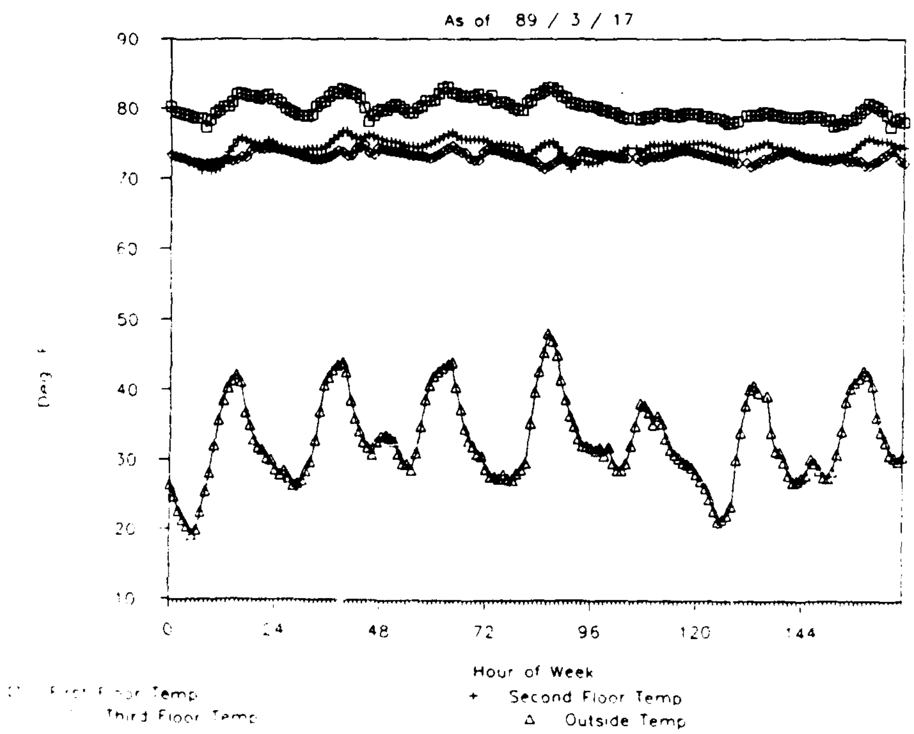

Figure 52. Rolling-pin barracks temperatues (T8649).

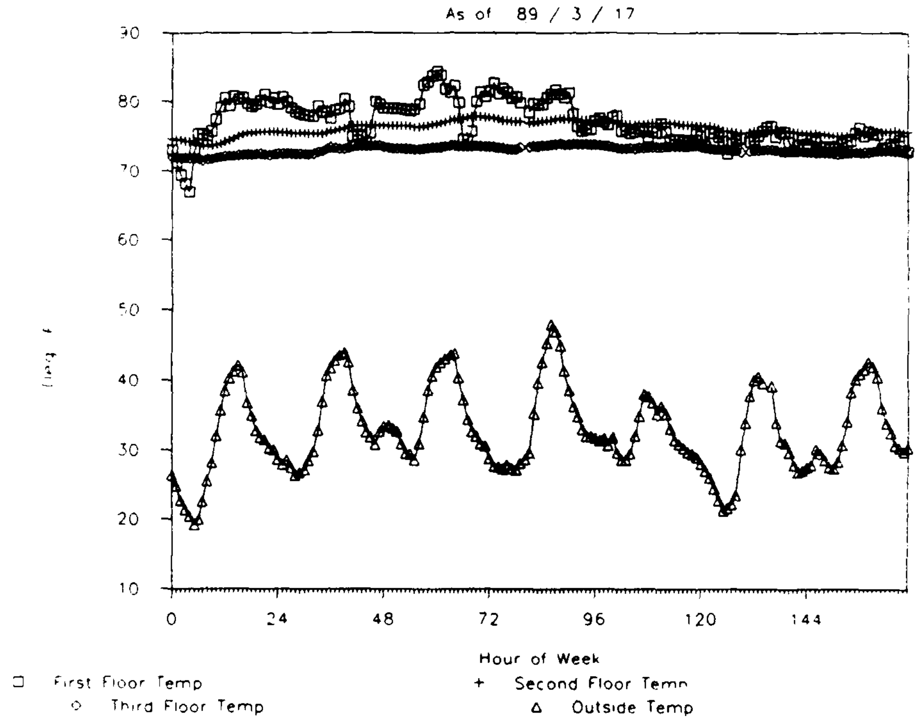

Figure 53. Rolling-pin barracks temperatures (U8649).

Heating Reset Schedules

Figures 54 through 57 show sample heating hot water reset schedules for the rolling-pin barracks. The retrofit building's reset was operating during the test period. The schedule is somewhat steeper than expected, but still more than meets interior heating loads. The nonretrofit buildings showed approximate constant temperature heating water with a slight slope.

Electricity Use

Figures 58 through 61 show sample electrical profiles for the rolling-pin barracks. The buildings show periodic use, with peaks typically observed in late evening. Electrical consumption varies widely between buildings. Data from building 1666 are significantly different from the other reference buildings. Occupancy information does not explain the observed differences.

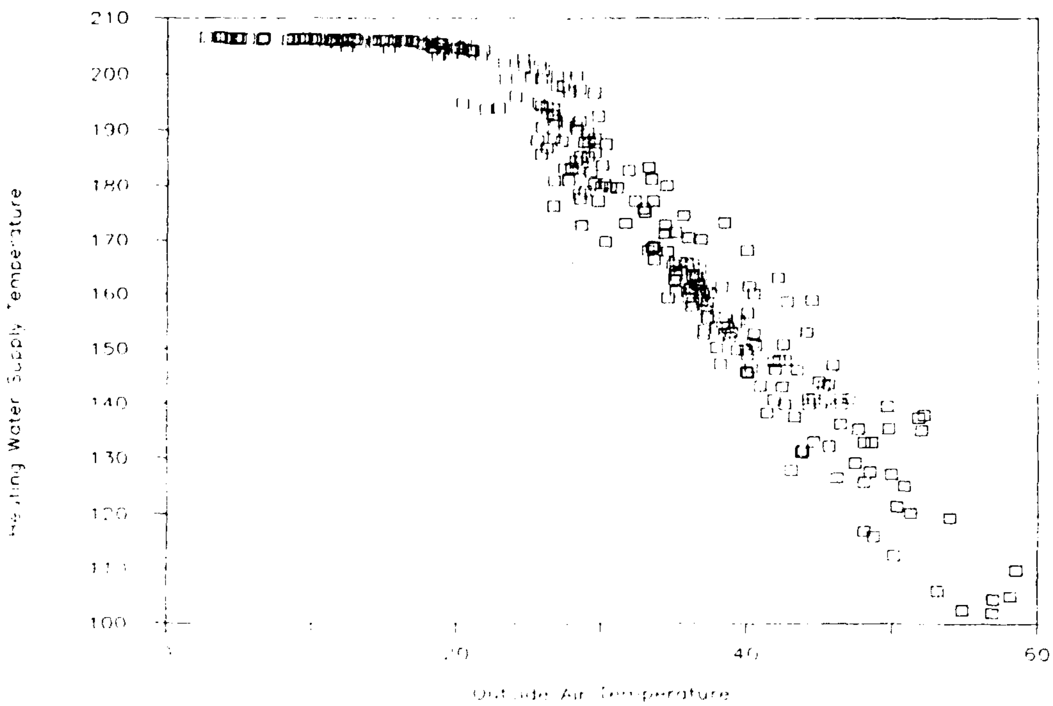

Figure 54. Reset schedule--Bldg 1363.

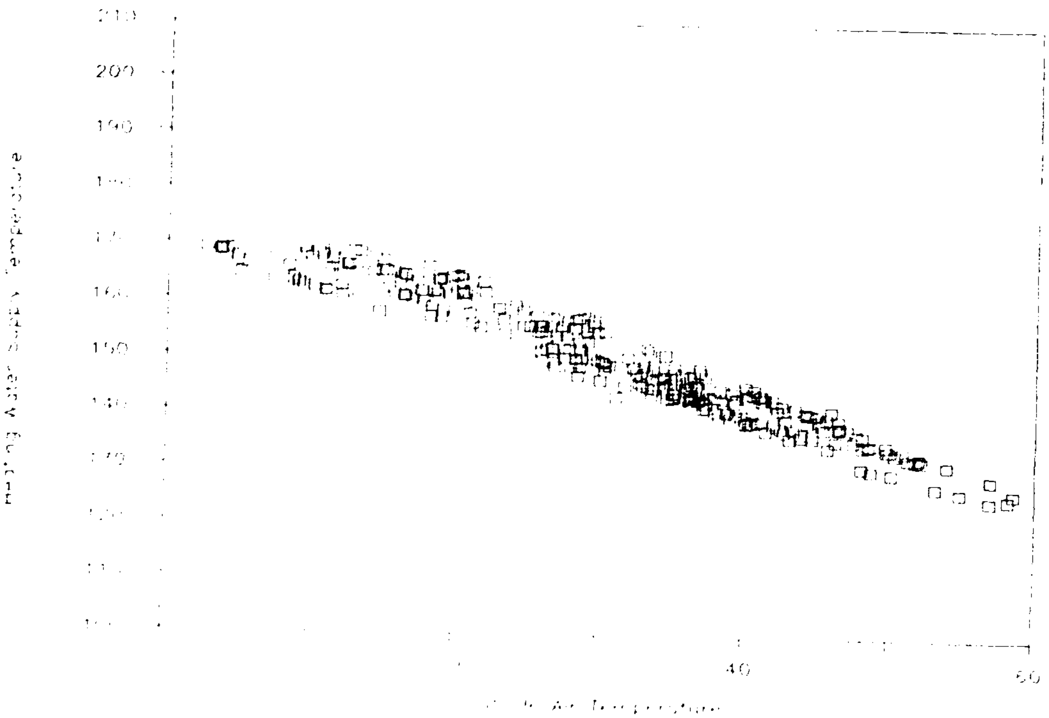

Figure 55. Reset schedule--Bldg 1663.

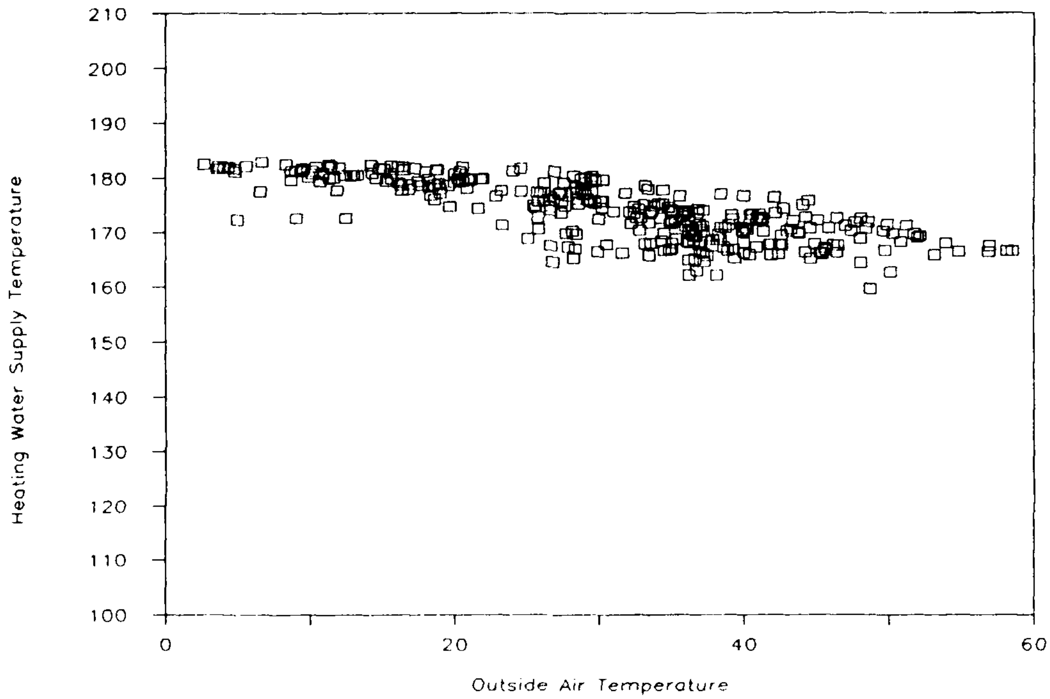

Figure 56. Reset schedule--Bldg 1666.

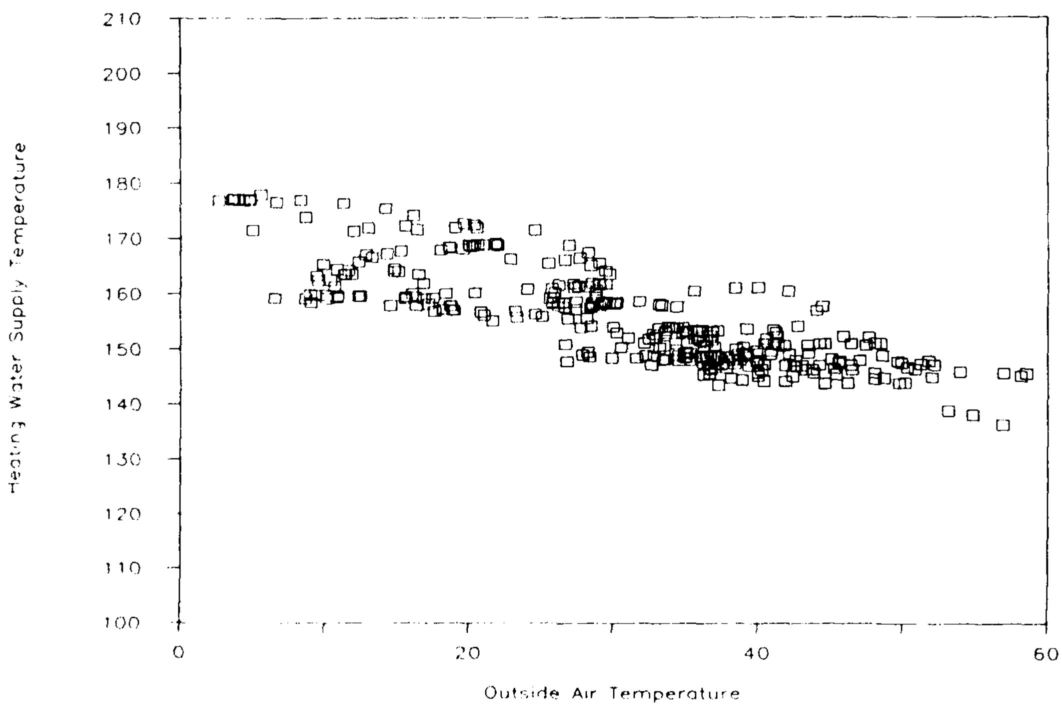

Figure 57. Reset schedule--Bldg 1667.

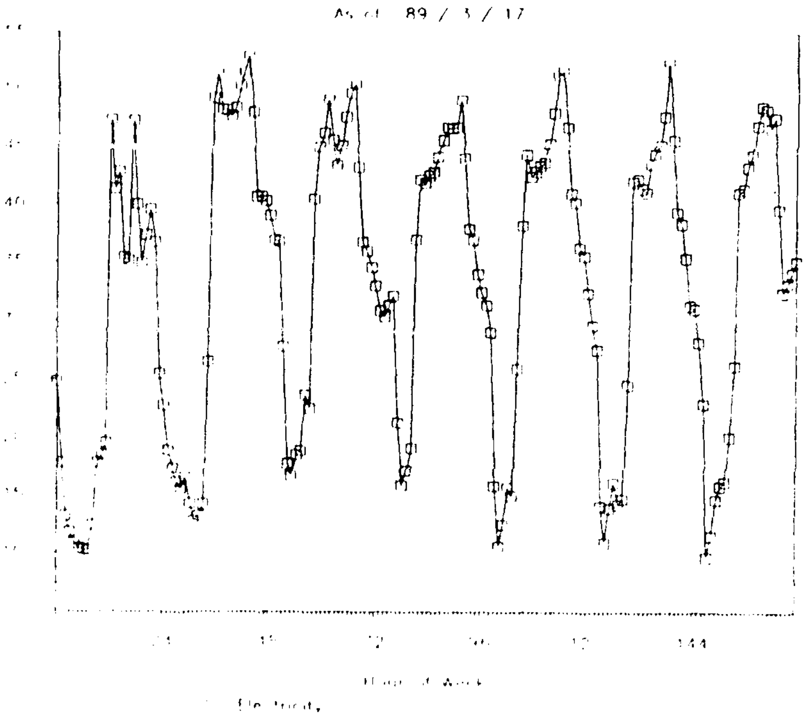

Figure 58. Rolling-pin barracks electricity use (Q8636).

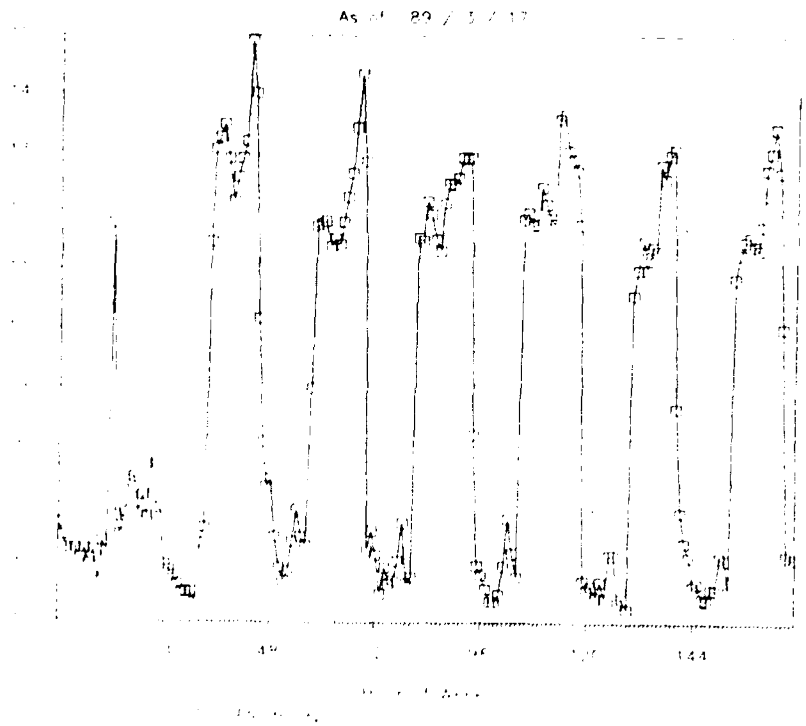

Figure 59. Rolling-pin barracks electricity use (S8636).

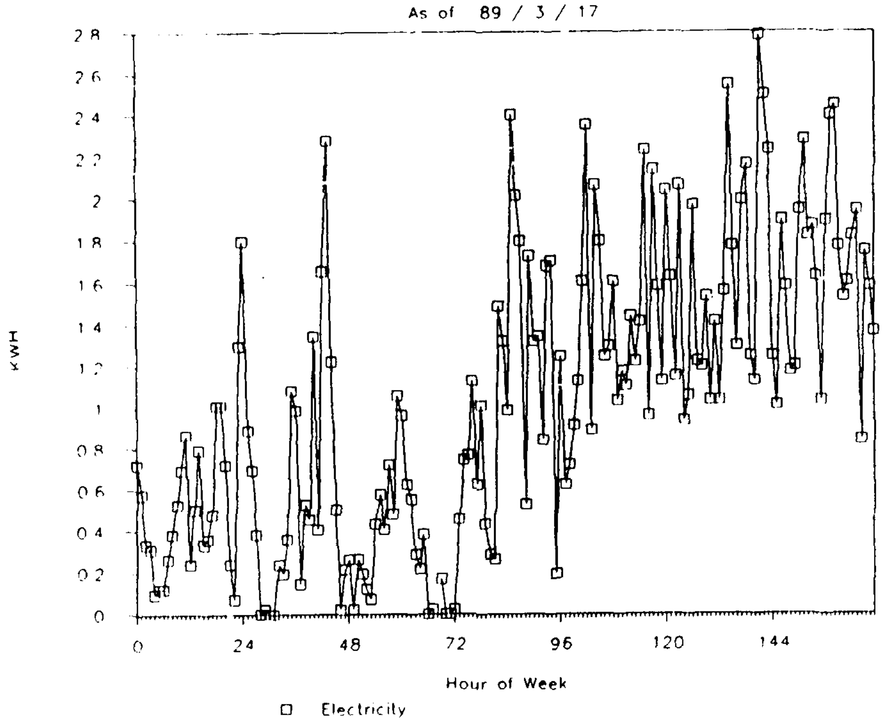

Figure 60. Rolling-pin barracks electricity use (T8636).

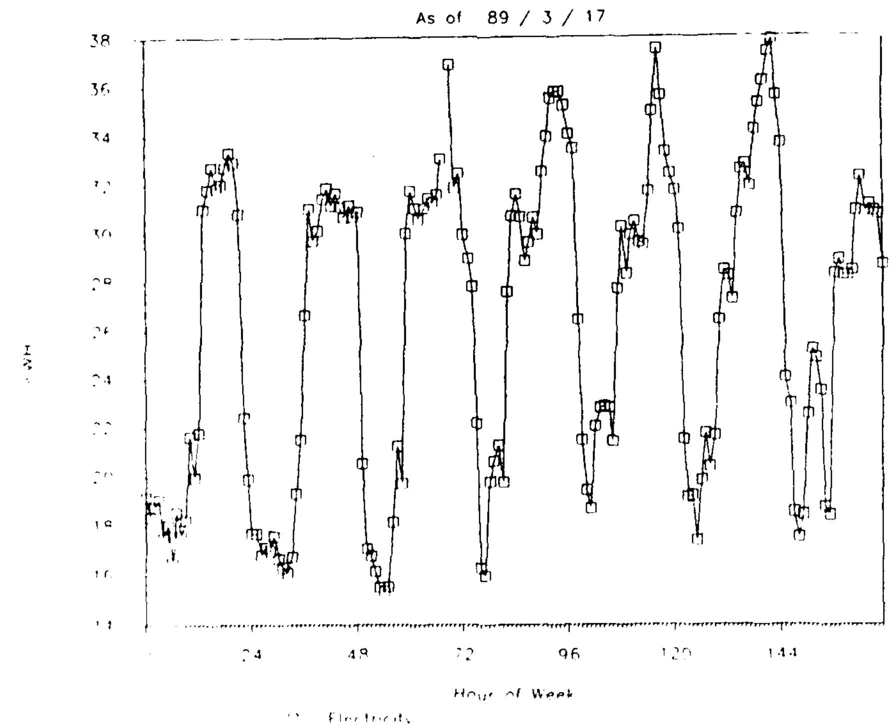

Figure 61. Rolling-pin barracks electricity use (U8636).

5 OPERATIONAL IMPROVEMENTS AT THE L-SHAPED BARRACKS

Overview

Interim results from the monitored buildings showed energy savings that were lower than anticipated. Review of the data indicated that conservation measures were compromised due to existing building operation. Further, opportunities for large energy savings were not being exploited. Of particular concern were the heat production and distribution systems, which lacked efficiency and control. Therefore, followup work was conducted at one of the test buildings, the L-shaped barracks.

Bldg 811 was targeted to receive improved-operation retrofits. A detailed building inspection was conducted to assess operational conditions and document areas for improvement. An overhaul plan and cost analysis were prepared. Selected improvements were implemented and monitored periodically over the 1987-88 heating season. A 4-week detailed onsite monitoring effort was performed during February and March 1988. Energy data were collected and analyzed to assess the energy and cost impact of the improved operations.

Operational Findings: General

The building was substantially overheated, causing occupants to open windows for comfort. The overheated condition was caused by a combination of inadequate equipment, improperly set equipment, and inappropriate actions of occupants and operators. The part-load efficiencies of the space heating and DHW heating systems were low due to various standby losses and control strategies.

Operational Findings: Specific

The building's thermal control was inadequate for three major reasons: (1) steam valves on the heating hot water converters were too large and the resultant control was on/off rather than modulating, (2) the existing hot water controllers were not set for existing conditions and were difficult to set and maintain, and (3) some control wiring was broken.

Two space heating problems were observed: (1) the boiler was controlled to maintain steam pressure 24 hr per day, whether or not there was a need for heat during mid-September through mid-May, and (2) the heat developed in the boiler was vented through the flue during the off-cycle. These factors caused significant standby losses in an area with a lengthy swing season. Other problems with the heating equipment included a leak in the boiler, a need for boiler tune-up and repair, a failed steam trap, inappropriate heating water valving, and excessive vibrations in a circulating pump.

The DHW service posed both energy and comfort concerns. The plumbing for the DHW was valved so that most of the need was serviced by the steam boiler rather than the more efficient direct-fired gas water heater. Further, the direct-fired water heater was underfiring and could not meet the DHW need. The existing shower heads were huge or nonexistent, causing a DHW demand that was heavier than necessary. The absence of mixing valves created scalding conditions if someone flushed the toilet while others were in the shower. The setting for the circulating DHW temperature was higher than necessary, causing undue standby losses.

Although some building operators are highly skilled, many are not aware of how the building systems operate and what the appropriate response is for a particular problem. Operators do not log or coordinate service responses with the different people sent to respond to heating complaints and therefore can easily undo each others' fixes and over-adjust delicate instruments. Repairs are often makeshift, focusing on symptoms rather than causes and leaving systems only semioperative. Further, operators trust that occupant complaints are valid and rarely verify the need for system attention.

The need for energy education among building occupants is also apparent. Some occupants were uncomfortable in rooms heated to 75 °F due to inappropriate clothing for winter conditions or indignation about using a blanket on their beds. Other occupants had cold rooms because they barricaded their radiators with furniture. Rarely were occupants found to be aware of existing opportunities for comfort such as thermostats or radiator dampers. This lack of knowledge leads to numerous unnecessary service calls.

Improvements Implemented

Various operational and housekeeping improvements were implemented:

- The boiler control was modified so that the boiler would fire only when the circulator pumps called for heat to the building.
- A damper motor was installed on the boiler to close the flue damper during the off-cycle.
- The boiler leak was repaired.
- The boiler was tuned up.
- The failed steam trap was replaced.
- The heating water was valved appropriately.
- The vibrating circulation pump was serviced.
- Smaller sized steam valves and actuators were installed in the hot water converters.
- New pneumatic heating reset controllers were installed and adjusted for the barracks wings.
- Broken control wires were repaired.
- Existing controls were cleaned. Controls that operated nothing and wires that ran nowhere were removed. Existing controls were labeled.
- The valving for the DHW was changed so that the steam boiler was isolated from the water heating function.
- The direct fired gas water heater was adjusted to increase its firing rate.

- Antiscald, flow-restricting shower heads were installed in the 15 showers in the building.

- The DHW temperature setting was turned down.

Data Analysis

Collected data were reviewed to assess if operations had improved. The results were quite encouraging. Improvements in interior temperature trends, control capabilities, system part-load efficiencies, and heating and DHW loads resulted in substantial fuel savings.

Enhanced Controls/Improved Interior Temperature Trends

The standard L-shaped barracks design at Fort Carson provides heating with hot water at a fixed setpoint, usually near 200 °F, regardless of the thermal load (differential indoor/outdoor temperature) on the building. The resultant overheating requires occupants to open windows for comfort in all but the coldest weather conditions. Initial retrofit efforts with the L-shaped barracks included reset control on the heating hot water, but with limited success. Factors hampering the control included: the oversized steam valves on the hot water converters (causing on/off rather than modulating control); the complexity of the controllers (making adjustments difficult); and the coordination and education of the service staff.

During the improved operations period, interior temperatures in the test building, no. 811, were brought into the comfort range. This condition was accomplished through (1) new, properly adjusted heating controls that reset heating water temperatures as outdoor temperatures change; (2) appropriately sized steam valves on the hot water converters which allow modulating steam control, yielding fewer temperature excursions on heating hot water and room temperatures; and (3) diligent data monitoring and collaboration with site service staff.

Figure 62 is a dramatic example of the enhanced control capabilities during the improved operations period. Here, the hot water reset schedule (heating hot water supply temperature vs. outside air temperature) with the new set of reset controllers and new steam valves is significantly lower in temperature, shallower in slope, and tighter in throttling range than the previous year's attempt at reset control. (This example is not representative of the entire heating season, however, since insufficient coordination between USACERL and base personnel before the onsite monitoring period lead to inappropriate, too frequent adjustment of control settings.) In spite of these difficulties, reset control during the improved operations period was generally lower in temperature and tighter in throttling range throughout the year than the previous year's attempt.

Figure 63 is an example of the temperature improvements obtained in the building. Here, the improved operations period, May 1987 through May 1988, shows temperatures averaging about 7 degrees cooler in the heating season (September through May) than the existing operations during May 1986 and May 1987. Temperature reductions for the entire building averaged about 5 degrees during this period.

Part-Load Efficiency

Heating system efficiency changes based on the system load. At 100 percent load, it is operating at maximum efficiency. At less loaded conditions, the efficiency decreases until it reaches 0 percent efficiency at no load. To determine an improvement in efficiency, a system needs to be evaluated over its operating range or part-load conditions.

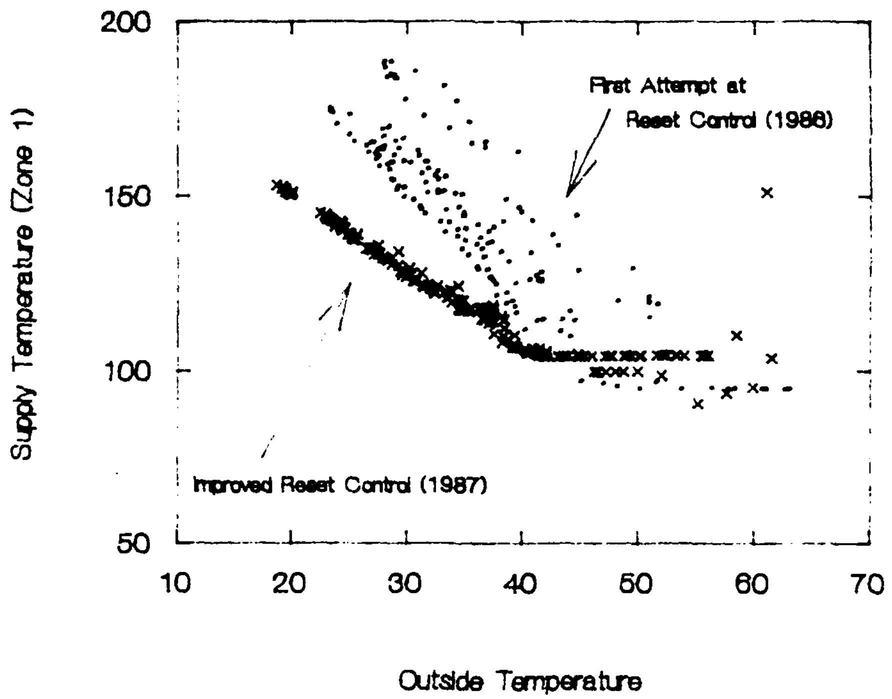

Figure 62. Reset control.

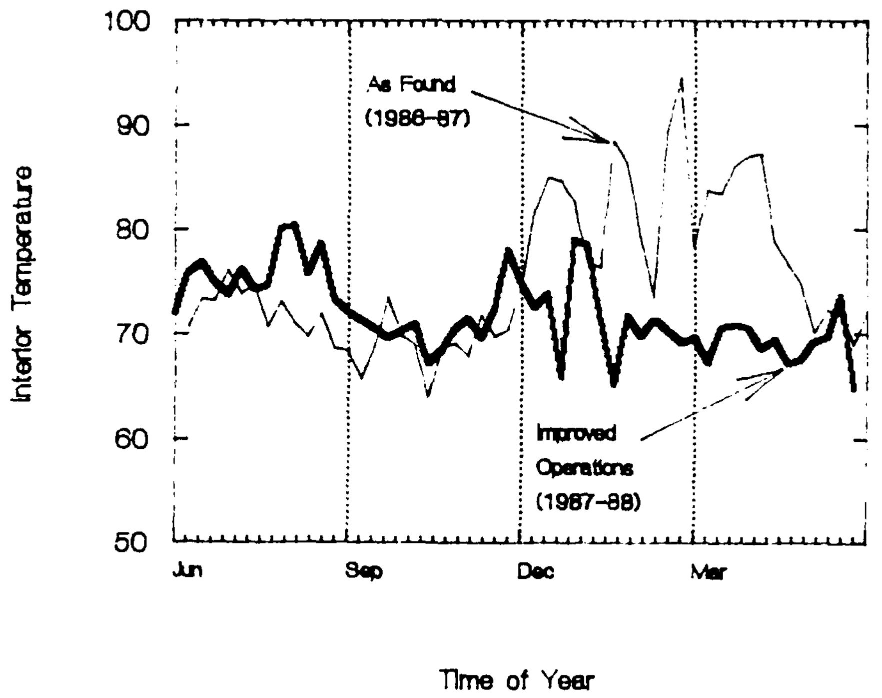

Figure 63. Interior temperature profiles.

Several system modifications during the improved operations period led to increased part-load efficiencies of the combined space heating and DHW heating system. These modifications included: (1) installation of a flue damper on the boiler to minimize off-cycle losses; (2) revalving of the DHW heating system to isolate this heating function to the direct-fired gas unit; (3) rewiring of the boiler controls such that steam was produced for heating only during heating conditions; (4) tune-up of the boiler, including adjustment of its fuel/air ratio to maximize steady-state efficiency; (5) repair of the leaks in the boiler; and (6) repair of failed steam traps to reduce venting of live steam.

Figure 64 shows the part-load data for the existing and improved operations. The comparison of part-load data was challenging since the existing operations of the heating/DHW system did not clearly show efficiency as a function of system load. The reason for this outcome is not known. Improved operations did show a strong, classical relationship of increased efficiency with increased load. For comparison, the classical form of the part-load curve was superimposed on the existing data, although the curve fit was extremely poor.

With the above qualification, the following conclusions were drawn. The improved operations curve is both higher and less scattered than the existing curve, yielding more consistent and, on average, more efficient operation over the system's operating range.

Heating Load Reductions

Heating load reductions occurred due to reduced interior temperatures which caused occupants to close the windows. The heating load reduction during the improved operations period was 1033 MBtu/yr or 50 percent of the previous year's load, corrected for weather differences. (Complete data are included in Tables 9 through 11.)

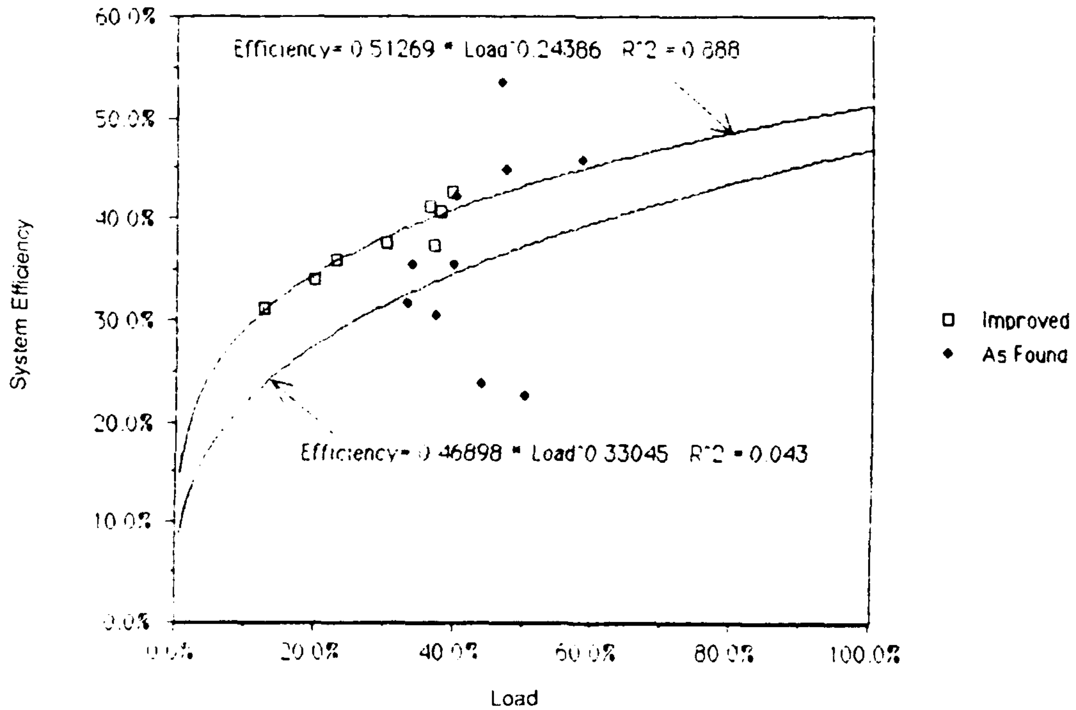

Figure 64. Part-load efficiency curves.

Domestic Hot Water Energy Savings

Savings in energy for DHW production occurred due to: (1) the installation of restricted flow shower heads, which reduced the thermal load and (2) reduced water temperature settings (from 180 °F to 160 °F), which decreased the standby losses. The DHW load reduction during the improved operations period was 86 MBtu/yr or 11.7 percent of the previous year's load. This estimate is conservative since the reduced flow shower heads were only installed during 6.5 months of the 12-month comparison period.

System Efficiency

Overall annual system efficiency decreased a nominal 2 percent, from 40.6 percent to 38.5 percent.* This 2 percent is the net effect of decreasing system loads by 34 percent and increasing part-load efficiencies by 5 to 7 percent. Anticipated system efficiency reductions due to decreased load only are on the order of 10 percent (see Figure 64), which further substantiates the part-load improvements.

Fuel Savings

Fuel savings during the improved operations period were significant. Gas consumption was reduced by 1741 MBtu/yr or 28 percent of the previous year's consumption, adjusted for weather conditions (Figure 65).

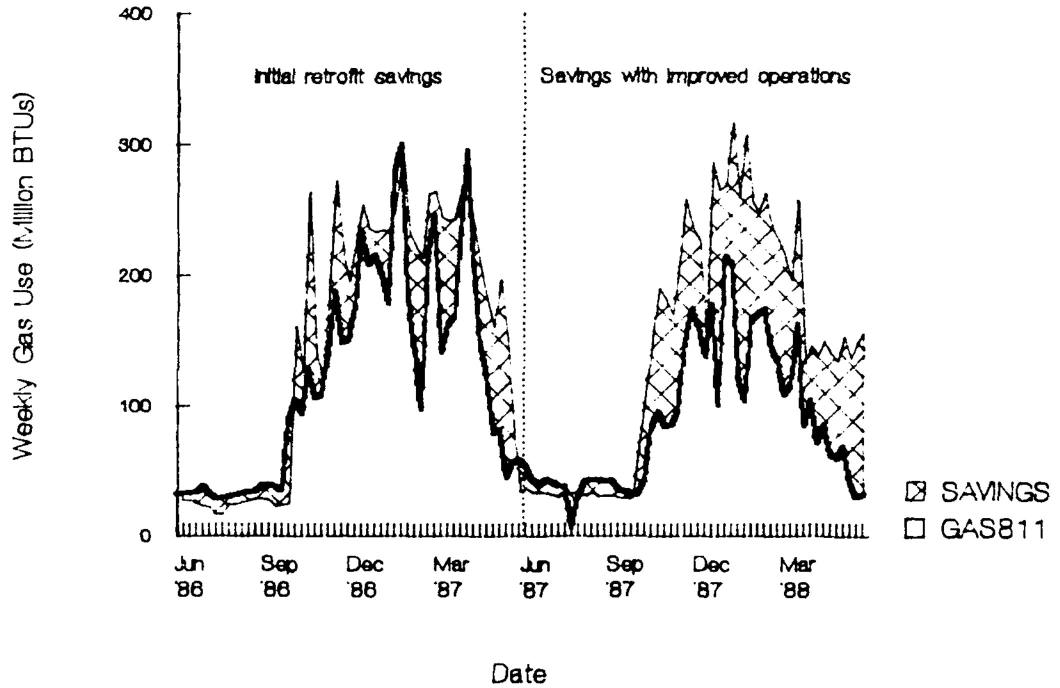

Figure 65. Gas use comparison between buildings.

*Efficiencies are calculated by [(Heating total) + (DHW total)]/(Gas total).

Other Improvements

Numerous other improvements were made to Bldgs 811, 812, and 813 during this project. These included: elimination of the scalding problem in the showers in Bldg 811, select replacement of pumps and steam traps, actuator improvements, compressor servicing, pressure regulator and air bleed valve replacement, investigation of the heating response methods, controls adjustment, repeated bleeding of the air valves, cleanup and labeling of controls, investigation of heating problems, and instruction of service staff and occupants.

Recommended Action for Improved Operation

Guidance was prepared for Fort Carson describing the improvements made to Bldg 811. It is hoped that these or similar changes will be used to advantage in other L-shaped barracks buildings or those with similar heating/DHW systems.

Much of the opportunity for savings due to improved building operations depends on adequate occupant and operator education and coordination. The possibility of increasing job-specific training programs for operators to include guidelines for troubleshooting a building heating complaint should be investigated. In addition, an in-house log book of service calls, including problems reported and responses taken, and a designated controls staff that exclusively makes adjustments to building controls will improve building functioning.

Occupant education programs should be expanded. Simple occupant modifications such as clothing and bedding adjustments, strategic furniture positioning, and passive humidification can greatly enhance occupant comfort. Making select occupants aware of heating control capabilities that do exist in these buildings, e.g., thermostats in the South zone, radiator dampers that could be made operable, fan controls on cooling coils, and air bleed valves on hydronic heating loops, could increase interior comfort and decrease service calls.

Further, the air needs to be eliminated from the hydronic heating systems permanently. This condition might be achieved by increasing the system pressure. If air entrainment continues to be a problem, the installation of automatic air bleed valves on hydronic heating loops should be investigated. Also, repairing radiator damper chains should reduce service calls.

Summary of Findings

Potential savings from improving building operations are large. In this test, fuel savings from improved operations nearly equaled the savings due to the original retrofit which was primarily envelope changes (1741 MBtu/year saved with improved operations vs. 2046 MBtu/year saved on the initial retrofit on an as-operated building). The cost of improved operations is significantly lower than the cost of envelope improvements and operational improvements are essential for allowing envelope improvements to demonstrate their full savings potential.

Continued return on investment will require some upkeep of the mechanical equipment, including periodic boiler tune-up, elimination of air from the hydronic heating system, servicing of the air compressor that supports the controls (bleeding out excess water, supplying oil when needed), informed responses to heating calls which do not unnecessarily change current valving and control settings, repair of equipment as it fails (especially steam traps), and lack of vandalism to any of the installed equipment.

The insights gained during this project were valuable and stressed the need for a comprehensive energy program. That is, several factors--building envelope, building controls, mechanical operations, and the actions of operators and occupants--together bring about the total building energy consumption. The entire building system needs to be assessed and remedied appropriately to bring buildings to their full potential energy effectiveness.

The lessons learned in the L-shaped barracks are not unique, nor is the level of building operations found at this test installation. There is a vast opportunity for fuel and dollar savings throughout the Army environment by recognizing the cost-effectiveness of routine mechanical upkeep and enhancements to outdated methods of heating control.

6 REVISED BLAST ANALYSIS OF BUILDING RETROFITS

Overview

The original retrofit packages were developed with the BLAST computer program. However, when actually implemented, the packages were modified to accommodate site constraints.* Further, assumptions concerning building operation were not representative of the conditions found.** To conclude the project, a new series of building simulations was produced. The twofold purpose of these simulations was: to (1) attempt to calibrate the actual consumptions with building operations and (2) obtain building models that would be indicative of the existing and retrofitted buildings. Purpose 1 was a necessary step in knowing that purpose 2 had been reached. Purpose 2 will allow others to gauge whether similar (or other) retrofit packages might be effective at their installations on similar building types.

The first step in simulating any building is to describe the conditions that comprise the building's physical structure, operations, and conditioning equipment. Information available from the building design plans was used as much as possible to develop the BLAST model of each retrofitted building. The construction materials, lighting fixture power, occupancy levels, and baseboard capacities were used when available. Daily schedules required by lighting, occupancy, and DHW were deduced using daily profiles plotted from the measured data. Thus, differences between weekend and weekday energy uses were established. Building walk-throughs were conducted to verify some existing conditions.

For calibration, the developed building model was compared with the measured data. Because the monitoring was not done specifically for this purpose, the calibration was necessarily limited to comparisons such as overall fuel or electric use for a period of several months. After an initial comparison, major discrepancies were identified. Corrections were made only for specifications that could be shown to differ from the original assumption or that could reasonably be assumed to be different.

For modeling, an analysis was conducted by modifying the calibrated model (for the retrofit condition) to remove the retrofits, establishing a preretrofit model and the energy consumption associated with it. Within this model, individual retrofit measures were reintroduced to determine the impact of each one. Finally, these models were run for each of five different climates representing Department of Defense (DOD) housing sites.

Results were gathered for the calibration process, the simulation of retrofits in the local (Colorado Springs) climate, and the effects of introducing the same retrofits to the same buildings in other climates. The BLAST descriptions were run using the 1986/87 Colorado Springs weather and the typical meteorological year (TMY) weather data for Washington, DC, Raleigh, NC, El Paso, TX, and San Antonio, TX.

An L-shaped barracks, Building 811, was used to test the method of calibration to be used on the other buildings and thus is reported in greatest detail. Existing conditions in the real buildings were chaotic, as described elsewhere in this document. While these conditions, if understood, might be

* For example, inoperable storm windows were unacceptable to base personnel, so double-pane windows were installed; worn-out doors that were scheduled for weatherstripping were replaced; and similar modifications.

** Buildings were overheated, undercooled, and operating inefficiently. Further, some conditioning systems were different than assumed and some building spaces were ignored in initial models.

described in great detail, to describe all of these details with an end to producing an annual consumption figure would overwhelm an energy analysis simulation. At the same time, energy analysis simulations cannot easily describe less than optimal conditions (e.g., the efficiency loss due to dirty filters). Thus, the BLAST models more closely reflect operating buildings rather than the actual operations found. However, the new BLAST models do establish usable models of these building types. Further, they identify ballpark estimates of savings which can be expected for the modeled changes.

L-Shaped Barracks

Building Description

The L-shaped barracks shown in Figure 66 is made of two parts: the one-story former mess hall which is now used as an office and the three-story barracks. The total conditioned floor area of the L-shaped barracks is 39,543 sq ft--5184 sq ft for the office and 34,359 sq ft for the barracks.

In the preretrofit building, external walls had 8 in. of concrete masonry units (CMU) and 5/8 in. of gypboard for a total U value of 0.46 Btu/hr·sq ft·°F. In the retrofitted building, 2 in. of foam and stucco were added to the external wall, giving a total U value of 0.06 Btu/hr·sq ft·°F. For the retrofitted building as well as the preretrofit, the roof is a 4 in. slab concrete covered by 2 in. of insulation and slag for a total U value of 0.12 Btu/hr·sq ft·°F. The building floor is a 6 in. slab concrete over crawl space for a total U value of 1.4 Btu/hr·sq ft·°F. Windows had single-pane glazing in the preretrofit building and double-pane glazing in the retrofitted building. The total window area has been reduced from 7990 sq ft or 36 percent of the external wall area in the preretrofit building to 3755 sq ft or 17 percent of the external wall area in the retrofitted building.

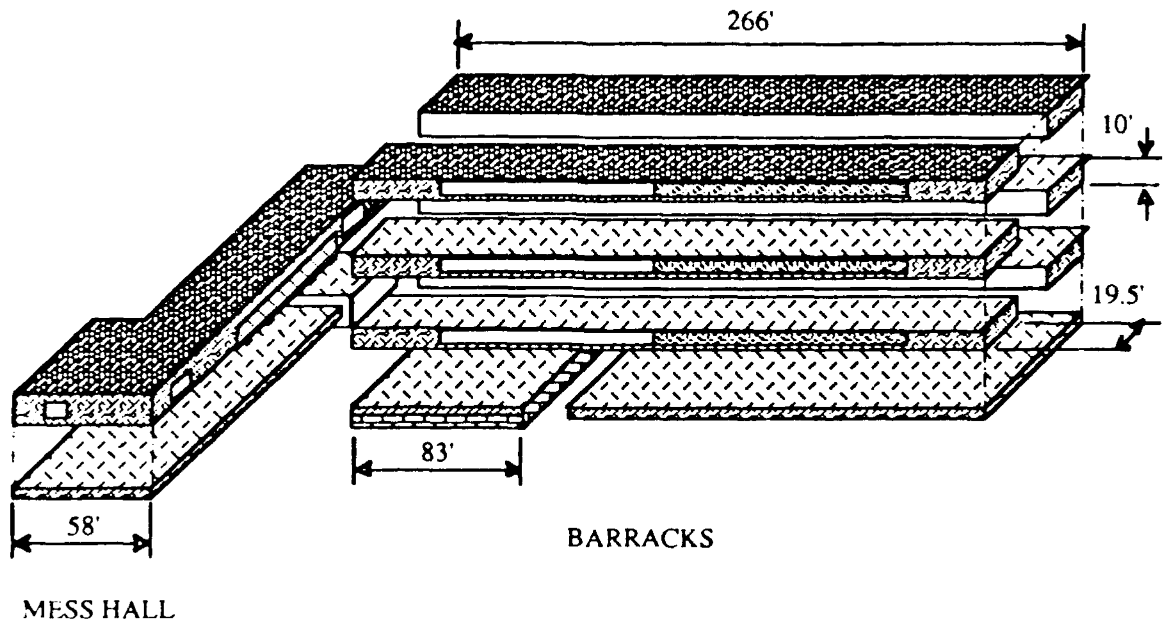

Figure 66. BLAST model description of the retrofitted L-shaped barracks (separate volumes represent separate BLAST zones).

An average of 128 persons lived in the barracks in 1986. The average number of people working in the office was assumed to be about 10. The installed lighting power is 1.0 W/sq ft in the barracks and 1.5 W/sq ft in the office. The installed equipment power is 0.5 W/sq ft in the barracks and 0.75 W/sq ft in the office. In the preretrofit building, the infiltration rate was assumed to be 1.0 air change per hour (ACH) and in the retrofitted building, which has better windows, it was assumed to be 0.5 ACH.*

The building is heated through the use of fin tube radiators (modeled as baseboards in BLAST) and cooled by a two-pipe fan coil system. Heating in Colorado Springs is usually needed from October 15 through May 15. The heating system is not controlled by the indoor temperature. However, a reset system decreases the hot water temperature circulating inside the baseboards when the outdoor temperature increases. This hot water temperature reset schedule was modeled in BLAST so that baseboard capacities were at their maximum for an outside air temperature of 0 °F and at zero for an outside air temperature of 65 °F. Maximum baseboard capacities were derived from the building design plans and were given for an average water temperature of 190 °F. The cooling system operates such that the indoor temperature stays below 75 °F at all times. This system has been retrofitted so that outside air is used only to provide fresh air to the toilets.** Steam boilers produce the hot water used in the heating system. Chilled water is serviced by a central plant.

Model Calibration

Calibration Method. An effort was made to establish a BLAST model of the 811 L-shaped retrofitted barracks that would reflect the real building energy behavior. The goal was to have the BLAST model predict seasonal energy consumption variations as well as total yearly energy consumptions as close as possible to the measured consumptions available from the real building. Because of the way measured data had been compiled, more detailed comparisons were not realistic. The measured data were subtotaled into three typical seasons:

- Spring: April to May
- Summer: June to September
- Winter: October to March

The 811 L-shaped building model was simulated with BLAST version 3.0 using weather data for Colorado Springs in 1986 and 1987. Energy consumption predicted by the BLAST model for these three seasons would then be compared with the measured data from the existing building.

Calibration Results. The first results obtained by the BLAST simulation for the hot water and the electricity consumption were within 5 percent of the measured data. The chilled water and gas

* Chapter 22 of the *1985 ASHRAE Fundamentals* (American Society for Heating, Refrigeration, and Air-Conditioning Engineers) gives a current value of infiltration for new construction that is biased toward energy efficiency at 0.5 ACH and a current value of infiltration for older construction at 0.9 ACH.

** The amount of outside air provided by the system represents the minimum amount required to provide fresh air inside the bathrooms: 3960 CFM. In practice, this ventilation is achieved by opening windows.

consumption were farther away from the measured data. Adjustments were made to bring the chilled water and gas consumption in line with the measured data. The following special conditions were incorporated into the building description:

1. The seasonal boiler efficiency was reduced from the 60 percent, used as a default in BLAST, to 41 percent as derived from the average results provided by the season/week model data and obtained by dividing the total heating load by the total gas consumption for the heating season.

2. The cold deck temperature was raised from 55 °F, used as a default in BLAST, to 61 °F which matched the measured cold water temperature.

3. The cooling system operation was limited to late afternoon and evening hours, since occupancy is limited during the day. In the first stage of the calibration process, some simulations were done with the windows open from 7 a.m. to 11 p.m. in the summer to reduce the cooling load on the system. However, the chilled water consumption was still much higher than that measured on site. Another concern was that the assumptions on the number of open windows could not be based on reliable information. The building was then modeled as having windows closed at all times and the chilled water consumption was reduced by assuming cooling system operation in the evening only.

Table 26 shows the site energy consumption comparisons between the BLAST model and the 811 building measured data. It shows that the BLAST model of the 811 retrofitted barracks is representative of the real building and thus can be used as a baseline for a retrofit impact study.

Table 26

Results of the L-Shaped Barracks Calibration*

Time Period	Electricity (MBtu)	Cooling (MBtu)	Heat 1 East	Heat 2 West	Heat 3 Mess	Total Heat (MBtu)	DHW** (MBtu)	Gas (MBtu)
Summer 86	231 *271*	192 *217*	8.4 *1.2*	8.3 *1.2*	0.0 *0.4*	16.7 *2.8*	186 *233*	653 *687*
Winter 86/87	347 *322*	0 *2*	763 *699*	685 *699*	82 *201*	1530 *1600*	392 *357*	4535 *4485*
Spring 87	112 *110*	0 *0*	160 *130*	135 *130*	13 *37*	308 *297*	152 *124*	931 *1038*
Year [Summer 86, Spring 87]	690 *703* *+2%*	192 *219* *+14%*	931 *830*	828 *830*	95 *238*	1855 *1899* *+3%*	730 *714* *-2%*	6119 *6210* *+2%*

*BLAST model energy consumptions are shown in italics.
**Domestic hot water.

Retrofit Impact Study

A preretrofit building 811 description was developed from the retrofitted building 811 used in the calibration process by removing every component of the retrofit package. To study the impact of each retrofit measure, additional BLAST descriptions were prepared by adding individual components of the retrofit package to the preretrofit building. Table 27 lists components of the retrofit package.

Results are presented in Tables 28 through 32. The "Total Energy" column is the sum of the electricity, chilled water, and gas consumptions. These are site results and not source results; the electricity consumed would tend to be more expensive, per Btu, than chilled water or gas. In each table, the energy consumptions of the preretrofit building are presented first, followed by the results obtained by adding each individual component of the retrofit package to the preretrofit building, and finally the energy consumption of the retrofitted building resulting from applying the whole retrofit package to the preretrofit building. Percentages in italics represent the improvement over the preretrofit building.

Note that in Colorado Springs, an additional possible retrofit was simulated—a heating system controlled by internal temperature rather than the radiating baseboards controlled by the outside temperature. This heating system uses the same two-pipe fan coil system used for cooling during the summer.

Discussion

Notes on Model Interpretation. The L shaped barracks was modeled with a heating system that is set irrespective of envelope changes from maximum to minimum capacity as the OAT changes from 0 to 65 °F, or at a constant 190 °F. Since there is no feedback from the conditioned space, envelope changes have no effect on heating. Because cooling does have a temperature control, it is affected by envelope changes. Since no changes are made to the building's heating controls after the envelope changes are made, all savings in heating are credited to the reset on hot water which may reduce overheating or even lead to cold conditions.

The mess hall wing was modeled with a reset control on heating. Actual conditions have no reset on this small zone but a thermostat that cycles the circulation pumps.

Given the above assumptions, energy consumption tracked well with measured data. Operational conditions were not verified.

It appears that the model overpredicts the potential savings since the measured data are assumed to represent a building that is constantly reset. Since this is not the case, the energy total is a high baseline and the model of a constant temperature system is even higher. It was estimated that baseline consumption is near 11,000 MBtu/year. However, the "before" data and side-by-side data show a baseline nearer 8000 MBtu/year.

The modeled savings from reset (4857 MBtu/year) are higher than the original BLAST estimate of envelope improvements (3339 MBtu/year). This result further suggests controls to be prime targets for retrofits. Actual and predicted savings are summarized as follows:

Original BLAST savings for whole bldg: 3339 MBtu

Table 27

Retrofit Package Component Description: L-Shaped Barracks

Retrofit	811 Retrofit	811 Preretrofit
Insulation building 811	2 in. Foam insulation Stucco finish No insulation on pilaster	No insulation paint finish
Windows	Double-pane glazing Reduced window area	Single-pane windows
No outside air	No outside air except for toilets	Outside air
Hot water temperature reset	Hot water temperature decreases from 190 °F to 100 °F as the outside air temperature increases from 0 °F to 65 °F.	Hot water temperature stay constant at 180 °F

Table 28

Retrofit Impact Study in Colorado Springs: Site Energy Consumption, L-Shaped Barracks

Colorado Springs, L-Shaped Barracks (1986)	Electricity* (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Gas (MBtu)	Total Energy (MBtu)
Preretrofit	697	295	4446	714	10,733	11,725
Insulation 811	696 *0%*	303 *3%*	4446 *0%*	714 *0%*	10,733 *0%*	11,732 *0%*
Windows	690 *-1%*	235 *-20%*	4446 *0%*	714 *0%*	10,733 *0%*	11,658 *-1%*
No outside air	721 *3%*	282 *-4%*	4446 *0%*	714 *0%*	10,733 *0%*	11,736 *0%*
Fan coil heating system**	1003 *44%*	292 *-1%*	2633 *-41%*	714 *0%*	7704 *-28%*	8999 *-23%*
Hot water temperature reset	696 *0%*	292 *-1%*	1725 *-61%*	714 *0%*	5876 *45%*	6869 *-41%*
Retrofitted	705 *1%*	220 *-25%*	1724 *-61%*	714 *0%*	5876 *-45%*	6801 *-42%*

*Domestic hot water.

**Simulated in Colorado Springs only.

Table 29

Retrofit Impact Study in Washington: Site Energy Consumption, L-Shaped Barracks

Washington TMY L-shaped Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Gas (MBtu)	Total Energy (MBtu)
Preretrofit	707	499	4158	714	10,210	11,416
Insulation 811	706 *0%*	494 *-1%*	4158 *0%*	714 *0%*	10,210 *0%*	11,410 *0%*
Windows	699 *-1%*	412 *-17%*	4158 *0%*	714 *0%*	10,210 *0%*	11,321 *-1%*
No outside air	726 *3%*	466 *-7%*	4158 *0%*	714 *0%*	5360 *-48%*	6566 *-42%*
Hot water temperature reset	708 *0%*	498 *0%*	1469 *-65%*	714 *0%*	5360 *-48%*	6566 *-42%*
Retrofitted	705 *0%*	356 *-29%*	1469 *-65%*	714 *0%*	5360 *-48%*	6421 *-44%*

*Domestic Hot Water.

Table 30

Retrofit Impact Study in Raleigh: Site Energy Consumption, L-Shaped Barracks

Raleigh TMY L-Shaped Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Gas (MBtu)	Total Energy (MBtu)
Preretrofit	708	566	3846	714	9570	10,844
Insulation 811	711 *0%*	561 *-1%*	3846 *0%*	714 *0%*	9570 *0%*	10,842 *0%*
Windows	699 *-1%*	475 *-16%*	3846 *0%*	714 *0%*	9570 *0%*	10,744 *-1%*
No outside air	730 *3%*	532 *-6%*	3846 *0%*	714 *0%*	9570 *0%*	10,832 *0%*
Hot water temperature reset	707 *0%*	561 *-1%*	1114 *-71%*	714 *0%*	4600 *-52%*	5868 *-46%*
Retrofitted	705 *0%*	418 *-26%*	1114 *-71%*	714 *0%*	4600 *-52%*	5723 *-47%*

*Domestic hot water.

Table 31

Retrofit Impact Study in El Paso: Site Energy Consumption, L-Shaped Barracks

El Paso TMY L-Shaped Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Gas (MBtu)	Total Energy (MBtu)
Preretrofit	765	978	3320	714	8502	10,245
Insulation 811	766 *0%*	957 *-2%*	3320 *0%*	714 *0%*	8502 *0%*	10,255 *0%*
Windows	739 *-3%*	842 *-14%*	3320 *0%*	714 *0%*	8502 *0%*	10,083 *-2%*
No outside air	772 *1%*	848 *-13%*	3326 *0%*	714 *0%*	8502 *0%*	10,122 *-1%*
Hot water temperature reset	765 *0%*	977 *0%*	837 *-75%*	714 *0%*	3995 *-53%*	5737 *-44%*
Retrofitted	738 *-4%*	662 *-32%*	837 *-75%*	714 *0%*	3995 *-53%*	5395 *-47%*

*Domestic hot water.

Table 32

Retrofit Impact Study in San Antonio: Site Energy Consumption, L-Shaped Barracks

San Antonio TMY L-Shaped Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Gas (MBtu)	Total Energy (MBtu)
Preretrofit	742	1027	2574	714	7103	8872
Insulation 811	742 *0%*	1002 *-2%*	2574 *0%*	714 *0%*	7103 *0%*	8847 *0%*
Windows	731 *-1%*	902 *-12%*	2574 *0%*	714 *0%*	7103 *0%*	8736 *-2%*
No outside air	738 *-1%*	864 *-16%*	2574 *0%*	714 *0%*	7103 *0%*	8705 *-2%*
Hot water temperature reset	742 *0%*	1027 *0%*	556 *-78%*	714 *0%*	3397 *-52%*	5166 *-42%*
Retrofitted	718 *-3%*	688 *-33%*	556 *-78%*	714 *0%*	3397 *-52%*	4803 *-46%*

*Domestic hot water.

Measured savings of retrofit: 1973 MBtu

Revised BLAST savings for whole bldg:* 4857 MBtu

The savings potential of the envelope was not determined.

This model for the L-shaped barracks is closer to properly operated than as-operated. In the as-operated building, adjustments are made to the heating system after the envelope changes are made in response to service calls about excessive heating. The adjustments to controls are inadequate, however, and overheated conditions persist. In addition, controls are often overridden and no reset benefit is obtained. The insulated envelope does hold some energy in, and the return water is hotter than in a noninsulated building, so the boiler eventually receives feedback from the space even though the space is not maintained at a precise temperature.

An as-operated model would be extremely difficult to develop. Assumptions would often be wild guesses (e.g., as to how many windows are open, how long, how many times, and to what extent occupants tamper with controls).

An attempt to model an as-operated building could include establishing an average reset schedule that achieves the average interior temperature profile. However, the final result would be specific to the modeled building and perhaps not worth the effort. A system with direct feedback, a fan coil system, was modeled and could be used as a baseline for assessing envelope improvements.

Hot Water Temperature. The major savings come from the hot water temperature control retrofit. This retrofit reduces the total hot water consumption more than 61 percent in all climates and reduces total energy consumption about 41 percent. It accounts for at least 90 percent of the total savings in all five climates.

However, the reduction in energy *use* is not directly related to a reduction in energy *needs*. Since the actual delivery of hot water is still controlled by the outdoor temperature, the energy saved is directly related to the amount of hot water delivered. A reduction of 60 percent in the amount of energy used means a reduction of 60 percent in the energy delivered (in Btu). This situation raises the question of whether the space can be maintained at a comfortable temperature with the reduced heat delivery.

The preretrofit building with and without hot water temperature reset and the retrofitted building were simulated on a typical day of the heating season. The daily maximum, 46 °F, and minimum, 30 °F, outside air dry bulb temperatures characteristic of that day were chosen from the season/week model corresponding to winter 1987.

Table 33 presents the daily minimum and maximum inside temperatures for all floors of the barracks wing. As this table shows, on that day, more heat than necessary is delivered to the building in the preretrofit state. This outcome is not surprising since gathered data and observed conditions indicate that considerably more heat than necessary was being delivered to these buildings to the extent that opening windows was a standard method of temperature control. The "Preretrofit Reset" column of Table 33 shows that the hot water temperature reset applied as a stand-alone retrofit will not provide reasonable comfort unless additional improvements to the building envelope are implemented. The last two columns

*No direct connection between heating system and shell.

confirm this fact by showing that the envelope changes in the retrofitted building significantly increase the comfort level in the building. On that typical winter day, the envelope changes bring the preretrofit building (with hot water temperature reset) back to the overheated level of the preretrofit building, but with hot water consumption reduced by 60 percent.

Alternative Heating System. As shown by the Colorado Springs results in Table 28, using a fan coil heating system that would have the same capacity as the installed baseboards would lead to a 41 percent reduction in total hot water consumption. This reduction is less than the hot water temperature control can save. However, the fancoil heating system can provide an appropriate level of comfort inside the building because it is controlled by the inside temperature.

Other Retrofits. Chilled water consumption decreased by 20 percent in Colorado Springs and by 12 percent in San Antonio with the reduced window area and double-pane glazing (assuming closed windows). The insulation retrofit is less effective for cooling—it increases chilled water consumption by 2 percent in a cold climate like Colorado Springs but reduces it by 1 or 2 percent in the warmer climates. During the summer, the cooling load is mostly due to solar gains, especially in cooler climates like Colorado Springs where heat gains by conduction are very small. This is the reason that decreasing the window area has a large impact on chilled water consumption whereas insulation changes have relatively little.

The retrofits that affect the building envelope (insulation, window area reduction, double-pane glazing) may not have as much impact as expected on cooling because the cooling coil units are specified for use only from 5 p.m. to 11 p.m. (consistent with the earlier calibration of Bldg 811). Reducing the window area is probably the main contributor to savings from the envelope retrofits since cooling loads in Colorado Springs are mostly due to the heat gains from the sun.

Double-pane glazing, which reduces the heat loss through the wall during the winter, would be expected to lower hot water consumption if the heating system is controlled by the inside temperature or if, in the case of an outdoor-temperature-controlled system, appropriate hot water resets are made. If no reset adjustments are made to the system, it may contribute to overheating.

Table 33

Inside Temperatures (°F) in Building 811 on a Typical Winter Day*

Location in Barracks Wing	Preretrofit, No Reset		Preretrofit, Reset	Retrofit, Reset	
	Max	Min	Max	Max	Min
First floor	80.1	76.3	61.1	76.8	74.1
Second floor	84.5	80.9	61.9	84.7	82.1
Third floor	81.9	78.5	60.2	82.0	79.7

*Daily maxima and minima are given.

Reducing the outside air is, as expected, most beneficial in warm climates like San Antonio. Chilled water consumption was reduced by 13 percent.

Source Energy. Since the chilled water is not produced onsite, the total electricity consumption does not reflect savings obtained by reducing the chilled water consumption. Electricity for lighting, equipment, and fans is the same for all retrofit measures except when the fan coil heating system is used because, in that case, fans are used all winter. This explains why the electricity increases by 44 percent in that case. For retrofit measures modeled with hot water heating, electrical consumption differences represent changes in electricity used for auxiliaries, e.g., pumps.

Summary

- The most effective retrofit applied to Bldg 811 is the change to the hot water temperature control. No other retrofit will have a significant impact unless the control retrofit is done concurrently.

- Reducing the window area and suppressing the outside air will benefit the buildings' cooling requirements, especially in the warm climates. Heating benefits from adding insulation, using double glazing, and suppressing the outside air could not be achieved due to the lack of modeled connection between envelope changes and exterior temperature control of the heating system, which prevents realization of energy savings from the heat loss reductions of these retrofits.

- Additional simulations could be done by considering a heating system with inside temperature thermostat controls. With internal temperature control, there would be an assumption that comfort conditions are maintained, and energy use would fluctuate in response to modifications that affect the comfort level indoors. Thus, the comfort benefits of envelope and other retrofits would be directly reflected in energy savings for the heating system.

Rolling-Pin Barracks

Building Description

The rolling-pin barracks shown in Figure 67 was modeled in BLAST as a three-story building with a total floor area of 40,404 sq ft. A rectangular shape was chosen rather than the rolling-pin shape to simplify the BLAST model. This change was made while keeping the same proportion of external wall area for a given orientation.

External walls are 4 in. of brick, 1.5 in. of airspace, and another 4 in. of concrete blocks with a total U value of 0.47 Btu/hr·sq ft·°F. The roof is built-up type with 1 in. insulation and 4 in. concrete for a total U value of 0.13 Btu/hr·sq ft·°F. The building floor over a crawl space is 6 in. concrete for a U value of 1.5 Btu/hr·sq ft·°F. The total window area is 4100 sq ft or 24 percent of the external wall area. Windows of the preretrofit building had single-pane glazing. Windows of the retrofitted building have double-pane thermal glazing. All windows have overhangs 2.5 ft wide. Drapes shade about 50 percent of the window area.

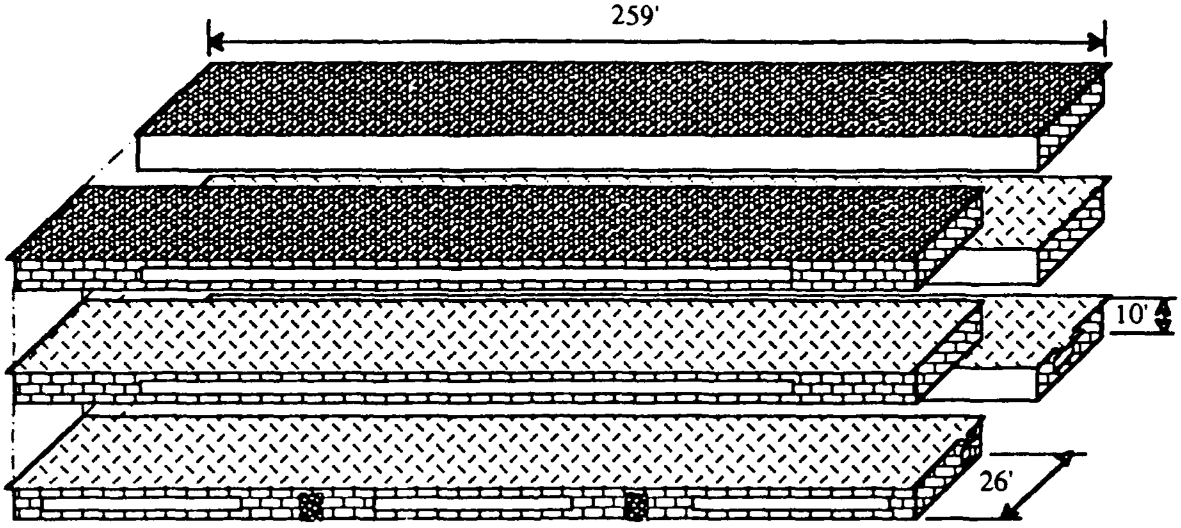

Figure 67. BLAST model of the retrofitted rolling-pin barracks (separate volumes represent separate BLAST zones).

The rolling-pin barracks, Bldg 1363, housed an average of 186 persons during 1986. The average lighting power installed in the building is 0.42 W/sq ft. The average equipment power installed is 0.2 W/sq ft, a low value due to the fact that only a few rooms have television sets and refrigerators. Infiltration was assumed to be 0.5 ACH in the retrofitted building as opposed to 1.0 ACH in the preretrofit building because the retrofit window units close tighter than the previous ones.

The building is heated through the use of baseboards and is cooled by a two-pipe fan coil system. The cooling system operates such that the indoor temperature stays below 75 °F at all times. Outside air is used only to provide the minimum requirement for the toilets and bathrooms. Two controls regulate the hot water temperature circulating inside the baseboards: (1) a reset control decreases the hot water temperature when the outdoor temperature is increasing and (2) another control decreases the hot water temperature from 180 °F to 100 °F when the inside temperature at one of two locations inside the building reaches 72 °F.

The hot water temperature control was modeled in two ways: based on indoor temperature and based on outdoor temperature. Modeling a heating system controlled by indoor temperature had an advantage in allowing the impact of envelope retrofits to be quantified in terms of energy savings. Hot water and chilled water for the building are serviced by a central plant.

Model Calibration

Monthly and annual results were used for comparison. Table 34 shows the annual energy consumption predicted by BLAST and the data measured onsite. Annual results given by BLAST for the period ranging from July 1986 to June 1987 are within 8 percent of the meter readings found in Interim Report E-88/08. The BLAST model of the retrofitted building can thus be used as a baseline for retrofit impact study.

Table 34

Results of the Rolling-Pin Barracks Calibration

Rolling-Pin Barracks 1363	Electricity		Hot Water		Domestic Hot Water		Chilled Water	
Colorado Springs	BLAST (MBtu)	In Situ (MBtu)	BLAST (MBtu)	In Situ (MBtu)	BLAST (MBtu)	In Situ (MBtu)	Blast (MBtu)	In Situ (MBtu)
July 86/June 87	663	678	2151	1411	144	142	282	294
Interim Report Consumption	*-5%*	700	*+8.3%*	1986	*-1%*	145	*+7%*	264

Retrofit Impact Study

A preretrofit 1363 building description was developed from the retrofitted building 1363 used in the calibration process. To study the impact of each retrofit measure, additional BLAST descriptions were prepared by adding individual components of the retrofit package to the preretrofit building. Table 35 lists components of the retrofit package.

Results are presented in Tables 36 through 40 for each of the five locations. The last column, labeled "Total Energy," is the sum of the other four columns. Since the hot water and chilled water are serviced from a central plant, no gas or electricity used for generating heat or for cooling is reported. The electricity reported is used for lighting, equipment, fans, and pumps. These are site results and not source results; the electricity consumed would tend to be more expensive, per Btu, than chilled water or hot water. Percentages in italics represent the improvement over the preretrofit building.

The first part of the tables shows results corresponding to a situation for which the heating system is controlled by the inside temperature. Results for the preretrofit building are presented first, followed by those for each individual retrofit: insulation, double-pane glazing, and low leakage dampers, and finally those for the retrofitted building with each retrofit implemented. Since insulation between the brick and the concrete masonry units was not installed as initially planned,* results obtained for the double-pane glazing retrofit should be regarded as near the results for a retrofitted building.

The second part of the tables shows results corresponding to the situation for which the heating system is controlled by the outside air temperature. This condition is separated from the other one because the hot water consumption with outdoor reset is not affected by the envelope changes.

It should be noted that the hot water temperature reset according to outside air temperature would not have an impact on the heat provided by a two-pipe fan coil heating system controlled by the inside temperature such as the one used in these simulations. The inside temperature control prevails over any

* Details leading to the decision not to install the insulation retrofit are presented in Interim Report E-88/08.

Table 35

Retrofit Package Component Description: Rolling-Pin Barracks

Retrofit Feature	1363 Retrofitted	1363 Preretrofit
Insulation	1.50-in. Insulation between brick and CMU	No insulation
Windows	Double-pane thermal type	Single-pane clear glazing
Low-leakage dampers for intake air	New low-leakage intake air damper	Leaky intake air dampers
Hot water temperature control for baseboard without inside thermostat	Hot water temperature decreases linearly when the outside air temperature is increasing	Hot water temperature stays constant

Table 36

Retrofit Impact Study in Colorado Springs: Site Energy Consumption, Rolling-Pin Barracks

Colorado Springs Rolling-Pin Barracks (1986)	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Total Energy (MBtu)
Preretrofit	663.1	300.7	2024	146.9	3135
Insulation	662.5 *0%*	291.4 *-3%*	1837 *-9%*	146.9 *0%*	2938 *-6%*
Double-pane windows	662.9 *0%*	290.6 *-3%*	1885 *-7%*	146.9 *0%*	2985 *-5%*
Low-leakage dampers	663.1 *0%*	300.7 *-3%*	2001 *-1%*	146.9 *0%*	3112 *-1%*
Retrofitted	661.3 *0%*	289.2 *-4%*	1541 *-24%*	146.9 *0%*	2640 *-16%*
Constant hot water temperature	662.5	290.5	7866	146.9	8966
Hot water temperature reset	662.5 *0%*	290.6 *0%*	3185 *-60%*	146.9 *0%*	4285 *-52%*

*Domestic hot water.

Table 37

Retrofit Impact Study in Washington:
Site Energy Consumption, Rolling-Pin Barracks

Washington TMY Rolling-Pin Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Total Energy (MBtu)
Preretrofit	600.3	541.1	1787	147.4	3076
Insulation	599.3 *0%*	505.1 *-7%*	1638 *-8%*	147.4 *0%*	2890 *-6%*
Double-pane windows	599.6 *0%*	513.1 *-5%*	1677 *-6%*	147.4 *0%*	2937 *-5%*
Low-leakage dampers	600.8 *0%*	541.4 *0%*	1768 *-1%*	147.4 *0%*	3058 *-1%*
Retrofitted	599.7 *0%*	483.5 *-11%*	1405 *-21%*	147.4 *0%*	2636 *-14%*
Constant hot water temperature	599.0	514.2	3409	147.4	4670
Hot water temperature reset	598.8 *0%*	513.3 *0%*	1281 *-62%*	147.4 *0%*	2541 *-46%*

*Domestic hot water.

Table 38

Retrofit Impact Study in Raleigh:
Site Energy Consumption, Rolling-Pin Barracks

Raleigh TMY Rolling-Pin Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Total Energy (MBtu)
Preretrofit	650.6	1376	786	147	2960
Insulation	649.1 *0%*	1297 *-6%*	725 *-8%*	147 *0%*	2818 *-5%*
Double-pane windows	649.4 *0%*	1319 *-4%*	738 *-6%*	147 *0%*	2853 *-4%*
Low-leakage dampers	651.2 *0%*	1376 *0%*	778 *-1%*	147 *0%*	2952 *0%*
Retrofitted	648.8 *0%*	1242 *-10%*	619 *-21%*	147 *0%*	2657 *-10%*
Constant hot water temperature	649.1	1322	1860	147	3978
Hot water temperature reset	649.1 *0%*	1322 *0%*	489 *-74%*	147 *0%*	2608 *-34%*

*Domestic hot water.

Table 39

Retrofit Impact Study in El Paso: Site Energy Consumption, Rolling-Pin Barracks

El Paso TMY Rolling-Pin Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Total Energy (MBtu)
Preretrofit	650.6	1376	786	147	2960
Insulation	649.1 *0%*	1297 *-6%*	725 *-8%*	147 *0%*	2818 *-5%*
Double-pane windows	649.4 *0%*	1319 *-4%*	738 *-6%*	147 *0%*	2853 *-4%*
Low-leakage dampers	651.2 *0%*	1376 *0%*	778 *-1%*	147 *0%*	2952 *0%*
Retrofitted	648.8 *0%*	1242 *-10%*	619 *-21%*	147 *0%*	2657 *-10%*
Constant hot water temperature	649.1	1322	1860	147	3978
Hot water temperature reset	649.1 *0%*	1322 *0%*	489 *-74%*	147 *0%*	2608 *-34%*

*Domestic hot water.

Table 40

Retrofit Impact Study in San Antonio: Site Energy Consumption, Rolling-Pin Barracks

San Antonio TMY Rolling-Pin Barracks	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	DHW* (MBtu)	Total Energy (MBtu)
Preretrofit	637	1561	552.4	147	2,898
Insulation	636 *0%*	1474 *-6%*	508.3 *-8%*	147 *0%*	2,766 *-5%*
Double-pane windows	637 *0%*	1500 *-4%*	515.7 *-7%*	147 *0%*	2,800 *-3%*
Low-leakage dampers	638 *0%*	1561 *0%*	546.3 *-1%*	147 *0%*	2,892 *0%*
Retrofitted	636 *0%*	1406 *-10%*	435.7 *-21%*	147 *0%*	2,625 *-9%*
Constant hot water temperature	636	1503	1241	147	3,563
Hot water temperature reset	636 *0%*	1503 *0%*	277 *-78%*	147 *0%*	2,563 *-27%*

*Domestic hot water.

other control to adjust the hot water temperature so that the constant volume of air supplied by the heating system matches the building needs. However, the reset control would have an impact on the source energy used.

Discussion

Notes on Model Interpretation. The rolling-pin barracks was modeled with a heating system having interior temperature control and hot water reset. This configuration allowed USACERL to estimate the savings due to the envelope retrofits. It was also modeled with no indoor temperature control and with (1) a reset and (2) constant-temperature hot water. The results are summarized as follows:

Original BLAST savings for whole bldg:	3343 MBtu
Measured savings of retrofit:	1777 MBtu
Revised BLAST savings* for whole bldg:	818 MBtu

Envelope Retrofits. The 1.5 in. of insulation and the double-pane glazing reduce the global U value of the wall. Each reduces the chilled water consumption by about 5 percent and the hot water consumption by about 8 percent in all climates. Having both insulation and double-pane glazing installed in the building would reduce the chilled water consumption by 10 percent and the hot water consumption by 15 percent.

Low-Leakage Dampers. No data were gathered on the reduction of infiltration due to the replacement of air intake dampers with new low-leakage dampers. These dampers are located at the basement level, protected from direct wind effects, and represent only 1.3 percent of the total window area. It was assumed that this retrofit would mostly affect the building during the heating season when the dampers are fully closed and that it would reduce the infiltration rate in the building by 5 percent. With these assumptions, this retrofit has no major impact on the total energy consumed by the building.

Hot Water Temperature. If the heating system is not controlled by indoor temperature, major savings can be obtained by installing a reset system that decreases the hot water temperature of the heating system linearly when the outdoor temperature is increasing. This retrofit reduces the total hot water consumption more than 61 percent in all climates and reduces total energy consumption from 52 percent in a cold climate like Colorado Springs to 27 percent in a warm climate like San Antonio.

Source Energy. Both the hot and chilled water are produced offsite. The total electricity consumption does not reflect savings obtained by reducing the chilled water consumption. Electricity used for lighting, equipment, and fans is the same for all retrofit measures.

Summary

- If the heating system has no control based on the indoor temperature, the most effective retrofit applied to Bldg 1363 is the change to the hot water temperature control. No other retrofit will have a significant impact unless the temperature control retrofit is done concurrently.

*Envelope only, well operated, no reset impact.

- Adding insulation and using double-pane thermal window units will lower the building's cooling requirements by reducing the chilled water consumption about 10 percent. Heating requirements would benefit from the retrofits if the heating system is controlled by the indoor temperature or appropriate reset adjustments are made; in that case, a 15 percent reduction in hot water consumption could be obtained. Using low-leakage air intake dampers will only slightly benefit the building.

Mess Hall

Building Description

The mess hall shown in Figure 68 is a one-story building with a total floor area of 10,968 sq ft. The dining room is 6192 sq ft and the kitchen is 4386 sq ft. The small office located at the entrance is used by the officers in charge of the building. Two mezzanines located above the kitchen contain the ventilation equipment.

The external walls of the building are 4 in. of brick, 1 in. of insulation and 6 in. of CMU for a total U value of 0.17 Btu/hr·sq ft·°F. The roof is built-up type with galvanized steel support. There is a suspended ceiling over the dining hall with R11 Batt insulation for a U value of 0.09 Btu/hr·sq ft·°F. The building floor is 6 in. slab concrete for a U value of 1.5 Btu/hr·sq ft·°F. Windows on both preretrofit and retrofit have single-pane glazing. The total window area in the preretrofit building is 1438 sq ft or 30 percent of the external wall area. In the retrofitted building, 55 percent of the glazing area has been covered by insulated panels, reducing the window area to 636 sq ft or 14 percent of the external wall area. Visits to the building showed that about 40 percent of the window area is shaded by drapes.

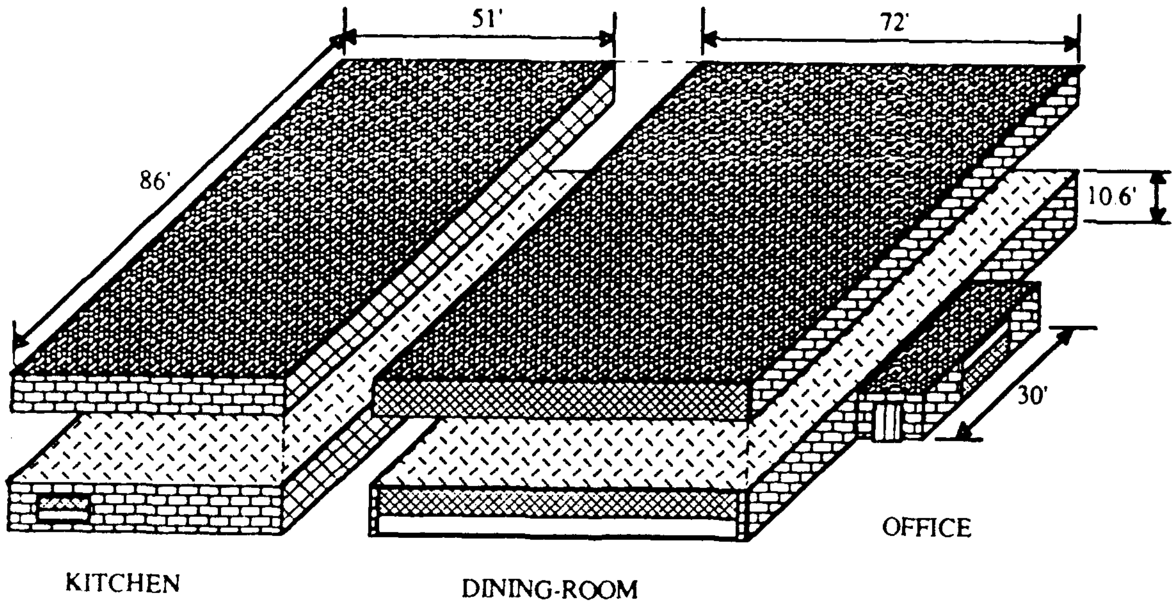

Figure 68. BLAST model of the retrofitted mess hall (separate volumes represent separate BLAST zones).

An average of nine persons usually work in the kitchen. The dining hall capacity is 110 persons; four officers work in the office. The installed lighting power is 1.1 W/sq ft in the kitchen, 0.8 W/sq ft in the dining hall, and 1.6 W/sq ft in the office. Most of the kitchen equipment uses gas. A smaller fraction of the equipment, such as food processors and coffee grinders, use electricity. There is no electrical equipment in the dining hall. The installed electrical equipment in the office is 0.5 W/sq ft. The infiltration rate, 1ACH, was based on the *ASHRAE Handbook of Fundamentals*.[9]

The kitchen is equipped with a small unit heater. However, visits to the building showed that the heater is never used and that the cooks heat the kitchen using fryers, griddles, and steam tables. The kitchen was modeled as having no heating system; it was assumed that the equipment was providing an acceptable level of comfort. The dining hall is heated with baseboards and the office with two fan coil heaters. Heating is usually needed in Colorado Springs from October 15 through May 15; however, site visits and field data showed some buildings with no heat until December. In Colorado Springs, the entire building is not cooled during the summer; however, in the other climates, it was modeled as being conditioned by a fan coil cooling system. The HVAC system control is based on indoor temperature with thermostat settings at 68 °F and at 75 °F. Hot and chilled water are provided by a central plant.

Model Calibration

Monthly results of the measurements made *in situ* were used for the analysis to allow fine adjustments. The initial results from the BLAST simulations raised some questions about the electricity usage. Analysis of the hourly data showed that the peak hourly electricity in the building over the whole period of measurement never exceeded 5 kWh, which corresponds to 0.45 W/sq ft. This result is too low since the kitchen alone has an installed lighting power of 1.1 W/sq ft and lights around the kitchen hoods should be on most of the day. Further, information on the number of meals served indicated normal occupancy during winter 1986-87.

Because the overall electricity consumption measured was in line with the total electricity reported by BLAST for the dining room and the office, it was assumed that the kitchen and dining room have separate electrical services. However, no field trip was conducted to confirm this assumption.

Table 41 shows the site energy consumptions predicted by BLAST for the dining hall and the office and those derived from the data measured on the mess hall building. Good agreement is obtained between BLAST monthly results and data collected from January to July 1987. The hot water consumption measured from October 1986 to December 1986 showed that the building was unheated during that period. Since results on a conditioned building were desired, annual estimates presented in the Interim Report were used.

Annual results given by BLAST for the period ranging from July 1986 to June 1987 were judged to be acceptable. The electricity consumption reported by the BLAST simulation for the dining hall and the office is 25 percent larger than the measured data. The hot water consumption reported by the BLAST simulation for the dining hall and the office (in fact, for the whole building since the kitchen is not heated) is within 5 percent of the annualized data. Therefore, the BLAST model of the 1363 retrofitted building can be used as a baseline for retrofit impact study.

[9] *ASHRAE Handbook of Fundamentals 1985*, Chapter 22, 22.3.

Retrofit Impact Study

A preretrofit 1361 building description was developed from the retrofitted 1361 building used in the calibration process by removing every component of the retrofit package. To study the impact of each retrofit measure, additional BLAST descriptions were prepared by adding individual components of the retrofit package to the preretrofit building. A summer cooling system was added to the preretrofit and retrofitted building descriptions for all climates, even though there was no such system in Colorado Springs. Table 42 lists components of the retrofit package.

Note that two of the implemented retrofits are not taken into account in Table 42. The kitchen hood ventilating system "short-circuiting" was not modeled because there was no information gathered on the reduction of conditioned air exhausted from the building space during hood operation. Replacement of some of the incandescent lights in the foyers and kitchen area was not considered. A visit to several mess hall buildings at Fort Carson showed that most of them had had their foyers remodeled as office space, which included replacement of the incandescent lights in that part of the building. There were so few other incandescent lights to replace in the kitchen area that this retrofit was considered to have insignificant impact.

Table 41

Results of the Mess Hall Calibration

	Electricity		Hot Water	
Mess Hall 1361 Colorado Springs	**BLAST Dining Hall Office (MBtu)**	**In Situ (MBtu)**	**BLAST Dining Hall Office (MBtu)**	**In Situ (MBtu)**
January 1986	*2.7*	1.6	*49*	37
February	*2.5*	2.6	*47*	41
March	*2.8*	1.8	*33*	36
April	*2.8*	0.0	*26*	37
May	*3.2*	0.2	*6*	8
June	*3.3*	0.3	*0*	19
July	*3.2*	0.2	*0*	0
August	*3.2*	0.6	*0*	0
September	*3.3*	2.2	*0*	0
October	*3.4*	2.6	*10*	2
November	*2.5*	3.6	*42*	2
December	*2.8*	2.9	*62*	1
January 1987	*2.4*	3.4	*62*	39
February	*2.2*	3.1	*49*	51
March	*2.5*	1.7	*47*	49
April	*2.5*	2.8	*26*	34
May	*3.1*	5.5	*6*	26
June	*3.3*	2.2	*0*	0
July	*3.2*	1.2	*0*	0
July 86/June 87	*34.4*	30.6	*303*	204
Interim Report Consumption	*25%*	28.0	*-5%*	318

Table 42

Retrofit Package Component Description: Mess Hall

Retrofit	1361 Retrofitted	1361 Preretrofit
System Operation: (a) Night setback (b) Night + weekend setback	 Night setback at 63°F Night and weekend setback at 63 °F	 No setback thermostat at 68 °F
Window area reduction	55 percent of the preretrofit window area is covered by insulated panels	Window area: 1438 sq ft
Entrance doors	Steel doors	Doors in poor condition
Hot water temperature control in case of baseboard without inside thermostat	Hot water temperature decreases linearly from 180 °F to 100 °F when the outside air temperature is increasing from 0 °F to 65 °F	Hot water temperature stays constant at 180 °F

Results are presented in Tables 43 to 47 for the five climates. The last column, labeled "Total Energy," is the sum of the other three columns. Since the hot and chilled water are provided by a central plant, any gas or electricity used for generating heat or for cooling was not reported. The electricity reported is used for lighting, equipment, and fans for the dining room and the office as explained in the model calibration. These are site results and not source results; the electricity consumed would tend to be more expensive, per Btu, than chilled water or hot water.

The first part of the tables shows results corresponding to a situation for which the heating system is controlled by the inside temperature. Results for the preretrofit building are presented first, followed by those for each individual retrofit: night setback operation, night and weekend setback operation, window area reduction, and entrance doors, and finally, those for the retrofitted building with each retrofit implemented.

The second part of the tables shows results corresponding to the situation for which the heating system is controlled by the outside air temperature. This condition is separated from the other one because the hot water consumption with outdoor reset is not directly affected by the envelope changes.

It should be noted that the hot water temperature reset according to outside air temperature would not have an impact on the heat delivered by a two-pipe fan coil heating system controlled by the inside temperature such as the one used in these simulations. The inside temperature control prevails over any other control to adjust the hot water temperature so that the constant volume of air supplied by the heating system matches the building needs. However, reset would have an affect on source energy consumption.

Table 43

Retrofit Impact Study in Colorado Springs: Site Energy Consumption, Mess Hall

Colorado Springs Dining Hall and Office (1986)	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	Total Energy (MBtu)
Preretrofit	38.2	31.4	361	430
Night setback	36.0 *-6%*	26.8 *-14%*	299 *-17%*	362 *-16%*
Night + weekend setback	35.6 *-7%*	24.5 *-22%*	291 *-19%*	351 *-18%*
Window area reduction	38.1 *0%*	20.8 *-34%*	342 *-5%*	401 *-7%*
Entrance doors	38.2 *0%*	31.4 *0%*	321 *-12%*	391 *-9%*
Retrofitted	35.5 *-7%*	16.5 *-47%*	238 *-34%*	290 *-32%*
Constant	35.6	16.7	1127	1179
Linear	35.6 *0%*	16.7 *0%*	456 *-60%*	508 *-57%*

Table 44

Retrofit Impact Study in Washington: Site Energy Consumption, Mess Hall

Washington TMY Dining Hall and Office	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	Total Energy (MBtu)
Preretrofit	36.3	51.4	294	382
Night setback	34.2 *-6%*	43.7 *-15%*	237 *-19%*	315 *-17%*
Night + weekend setback	33.7 *-7%*	40.0 *-22%*	228 *-22%*	302 *-21%*
Window area reduction	36.1 *-1%*	37.5 *-27%*	276 *-6%*	350 *-8%*
Entrance doors	38.6 *6%*	50.8 *-1%*	259 *-12%*	348 *-9%*
Retrofitted	33.7 *-7%*	29.4 *-43%*	181 *-38%*	244 *-36%*
Constant	33.7	29.8	838	902
Linear	33.7 *0%*	29.8 *0%*	324 *61%*	388 *-57%*

Table 45

Retrofit Impact Study in Raleigh:
Site Energy Consumption, Mess Hall

Raleigh TMY Dining Hall and Office	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	Total Energy (MBtu)
Preretrofit	36.6	80.6	208	325
Night setback	34.1 *-7%*	65.9 *-18%*	153 *-27%*	253 *-22%*
Night + weekend setback	33.6 *-8%*	58.0 *-28%*	145 *-30%*	237 *-27%*
Window area reduction	36.5 *0%*	62.5 *-22%*	193 *-7%*	292 *-10%*
Entrance doors	37.4 *2%*	80.2 *0%*	180 *-13%*	298 *-8%*
Retrofitted	33.4 *-9%*	44.7 *-44%*	110 *-47%*	188 *-42%*
Constant	33.5	45.2	637	716
Linear	33.5 *0%*	45.2 *0%*	194 *-70%*	272 *-62%*

Table 46

Retrofit Impact Study in El Paso:
Site Energy Consumption, Mess Hall

El Paso TMY Dining Hall and Office	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	Total Energy (MBtu)
Preretrofit	41.9	155.3	81.6	279
Night setback	36.0 *-14%*	111.3 *-31%*	39.5 *-52%*	187 *-33%*
Night + weekend setback	35.0 *-16%*	106.2 *-40%*	35.6 *-56%*	167 *-40%*
Window area reduction	41.9 *0%*	150.3 *-15%*	70.4 *-14%*	237 *-15%*
Entrance doors	42.6 *2%*	174.6 *-1%*	67.3 *-17%*	262 *-6%*
Retrofitted	34.9 *-17%*	88.0 *-50%*	19.3 *-76%*	127 *-54%*
Constant	35.0	88.8	402.6	513
Linear	35.0 *0%*	88.8 *0%*	108.0 *-73%*	218 *-57%*

Table 47

Retrofit Impact Study in San Antonio:
Site Energy Consumption, Mess Hall

San Antonio TMY Dining Hall and Office	Electricity (MBtu)	Chilled Water (MBtu)	Hot Water (MBtu)	Total Energy (MBtu)
Preretrofit	41.3	176.7	71.8	290
Night setback	35.5 *-14%*	121.7 *-31%*	37.6 *-48%*	195 *-33%*
Night + weekend setback	34.6 *-16%*	106.2 *-40%*	34.5 *-52%*	175 *-40%*
Window area reduction	41.2 *0%*	150.3 *-15%*	62.9 *-12%*	254 *-12%*
Entrance doors	42.9 *2%*	174.6 *-1%*	58.8 *-18%*	276 *-5%*
Retrofitted	34.0 *-17%*	88.0 *-50%*	19.7 *-72%*	142 *-51%*
Constant	34.6	88.8	287.6	411
Linear	34.6 *0%*	88.8 *0%*	64.3 *-73%*	188 *-54%*

Discussion

Notes on Model Interpretation. The data from the dining hall are very difficult to interpret. Study of the data indicated long periods (about 3 months) during which the buildings were not heated. Ventilation systems were found to be disabled, reducing heating and electricity requirements, although probably ignoring air quality standards. Also, for significant periods during the monitored season, some dining halls were not used. These conditions resulted in annual electrical energy totals inconsistent with models of properly operated, steadily used buildings. Heating totals were in good agreement with annual heating totals extrapolated from part-year use.

For the modeled dining hall, it was assumed that installed indoor temperature controls are maintained and that separate electrical services are available. However, field inspection and data review showed that controls had been bypassed or disabled. Electricity totals may be low due to lack of building use, operation with daylighting, and disabled ventilation. Heating totals are close to the measured data.

Retrofits on lighting changes and the short-circuiting hood were not modeled. The dining hall savings are considerably lower than original estimates and suggest that cost-effectiveness of the implemented retrofits is improbable. The results are summarized as follows:

Original BLAST savings for whole bldg:	3620 MBtu
Measured savings of retrofit:	64 MBtu
Revised BLAST savings:*	214 MBtu

The mess hall was also modeled with constant-temperature hot water and no indoor air control.

System Operation. The night setback retrofit allows total site energy savings which range from 16 percent in Colorado Springs to 33 percent in El Paso or San Antonio. Adding a weekend setback operation to a night setback operation will provide additional savings of only 2 percent in a cold climate like Colorado Springs and 7 percent in warm climates like San Antonio and El Paso. In El Paso, half of the total hot water consumption and a third of the chilled water consumption can be saved by using a night setback. System retrofits again seem to be the most effective and should be applied first.

Envelope Changes. The window retrofit reduces solar gains and decreases the wall's global U value by covering about half of the window area with insulated panels. Reducing the window area in Colorado Springs brings a savings of 34 percent in chilled water consumption because most of the cooling loads in this cold climate are due to the solar gains. In the warmer climates, this retrofit saves only 15 percent of the chilled water consumption because the cooling loads are more dependent on the outside temperature than on the solar gains.

Reducing the window area suppresses some of the free heating that was provided by solar gains during the winter. Thus, even though the global U value is decreased by covering part of the windows by insulated panels, in cold climates like Colorado Springs, the hot water consumption is reduced by only 5 percent. In warmer climates, it is reduced by 12 to 14 percent. Total site energy savings obtained from this retrofit range from 7 percent in Colorado Springs to 15 percent in El Paso.

The entrance doors retrofit reduces the infiltration rate in the dining hall from 1.0 ACH to 0.75 ACH. This decreases the hot water consumption by about 12 percent in cold and mild climates and by about 18 percent in warm climates. The chilled water consumption is reduced by only 2 percent in San Antonio and El Paso.

Hot Water Temperature. If the heating system is not controlled by indoor temperatures, major savings can be obtained by installing a reset system that decreases the hot water temperature of the heating system linearly when the outdoor temperature is increasing. This measure reduces the total hot water consumption more than 60 percent in all climates and reduces the total energy consumption from 57 percent in a cold climate like Colorado Springs to 54 percent in a warm climate like San Antonio.

*Well operated, no light or hood changes.

Source Energy. Both the hot and chilled water are produced offsite. The total electricity consumption does not reflect savings obtained by reducing the chilled water consumption. Lighting and equipment electricity are the same for all retrofit measures.

Summary

- If the heating system has no control based on the indoor temperature, the most effective retrofit applied to Bldg 1361 is the change in the hot water temperature control. No other retrofit will have a significant impact unless the temperature control retrofit is done first.

- Reducing the window area by covering half of the windows with insulated panels will lower the buildings' cooling requirements by providing chilled water consumption savings from about 30 percent in cold climates like Colorado Springs to 15 percent in warmer climates like San Antonio or El Paso. Heating requirements will benefit from the retrofits if the heating system is controlled by indoor temperature or appropriate resets are made. In that case, a total reduction of 7 to 15 percent in hot water consumption can be obtained.

- Installing a night setback to a system controlled by indoor temperature will provide total energy savings as high as 33 percent in El Paso and San Antonio. An additional 7 percent will be obtained by adding a weekend setback.

- Total energy savings obtained by applying these individual retrofits will range from 24 percent in Colorado Springs to 50 percent in El Paso. Adding interior insulation to the wall and to the metal panels would greatly lower the heating requirements in cold climates.

Motor Vehicle Repair Shop

Building Description

The motor vehicle repair shop building shown in Figure 69 is a one-story rectangular facility with a total floor area of 4800 sq ft. The retrofitted building consists of two distinct areas separated by an insulated wall: a 960 sq ft office and a 3840 sq ft repair bay area. In the preretrofit building, the office and the repair area were separated by a noninsulated wall that did not extend to the ceiling. The preretrofit motor shop was then modeled in BLAST as a unique space. The repair bay area is 15 ft high and the office is 10 ft high. On the southwest side of the building are six doors, 11 by 14 ft, for vehicle access to the repair area.

The external walls are 8-in. CMU backed by 1/4-in. plywood for a total U value of 0.52 Btu/hr·sq ft·°F. The roof is gypsum and steel deck for a total U value of 0.8 Btu/hr·sq ft·°F. Windows have single-pane glazing. The total window area in the preretrofit building is 882.2 sq ft or 20 percent of the external wall area. The total window area in the retrofitted building is 509.5 sq ft or 12 percent of the external wall area. In the retrofitted building, 42 percent of the glazing area has been replaced by galvanized steel backed on the inside by an R11 batt insulation covered by 5/8 in. gypboard for a total U value of 0.086 Btu/hr·sq ft·°F. The garage doors, which were 1/8 in. masonite in the preretrofit building, have been changed to consist of two aluminum layers separated by 1.5 in. of fiberglass for a total U value of 0.17 Btu/hr·sq ft·°F.

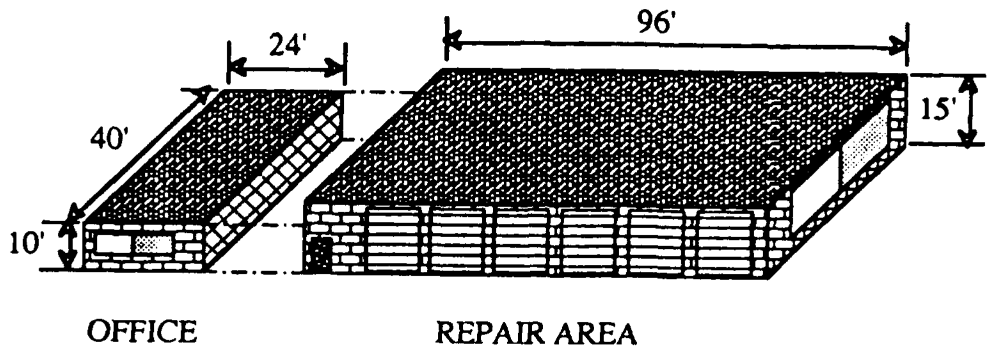

Figure 69. BLAST model of the retrofitted motor vehicle repair shop (separate volumes represent separate BLAST zones).

Sixteen people work in the motor shop—six in the office and 10 in the repair bay area. The installed lighting power is 1.5 W/sq ft in the office and 1.45 W/sq ft in the repair bay area. The installed equipment power is 0.25 W/sq ft both in the office and the repair area. Visits to the site showed that the office had only a few mechanical typewriters and that there was very little electrical equipment in the repair bay area.

Infiltration in the preretrofit motor shop was a concern because some of the garage doors were badly damaged and also because it was difficult to predict how often workers were opening the doors. In the retrofitted building, assumed infiltration was 0.5 ACH in the office, 6 ACH in the repair bay area when the doors are open, and 2 ACH when the doors are closed. In the preretrofit building, assumed infiltration was 6 ACH when the doors are open and 4 ACH when the doors are closed. During the summer, the workers are assumed to keep the doors open for the whole day; in the winter, they are assumed to open the doors for only 1 hr during the day.

The building is heated with unit heaters. In Colorado Springs, the building is not cooled during the summer. However, cooling was assumed in climates like San Antonio and El Paso. The heating system was modeled as a two-pipe fan coil system that would allow cooling in all climates. The heating system is controlled through thermostats at 68 °F, allowing night setback temperatures at 63 °F. Hot water delivered to the unit heaters is produced by a boiler rated at 1200 kBtu/hr.

Model Calibration

Monthly and annual results were used for the analysis. Table 48 shows the annual energy consumption predicted by BLAST and the data measured onsite.

Table 48

Results of the Motor Shop Calibration

Motor Shop 633	Electricity		Gas	
July 86/June 87	76.1	60.6	1691	585
Interim Report Consumptions	19%	64.0	59%	1061

The electricity consumption given by BLAST for the period July 1986 to June 1987 is within 19 percent of the site meter reading. The gas consumption given by BLAST for the same period is 60 percent higher than the site consumption.

The electricity measured onsite is lower than would normally be expected. The earlier BLAST simulations predicted a site electricity consumption of 298 MBtu for the retrofitted building. Visits to the site and a thorough analysis of the design plans allowed major improvement upon the first BLAST results. However, an annual electricity consumption of 64 MBtu assumes that lights are used only 2 hr/day and that the installed equipment power is only 0.25 W/sq ft. A problem with the measured electricity is that the monthly variations do not quite follow what could be expected: because of the use of lights and unit heater fans in the winter, monthly electricity consumption should be noticeably larger in winter months than in summer months. However, the electricity consumption is twice as much in April 1987 as in January 1987.

The gas consumption is also low compared with the BLAST simulation. This result may be due to the infiltration levels used in the BLAST model. However, an infiltration level of 2 ACH in the repair a area does not seem too high. One possible explanation is that the motor shop may not have been used for some weeks during the winter. That could explain why the gas consumption measured in January 1987 is lower than in March 1987. This assumption is difficult to confirm because the motor shop was unfortunately the only building for which occupancy information was not available. Another explanation may be that the persons working in the building altered the thermostat settings or that the batteries running the internal clock of the thermostat went out without anybody knowing it. That situation was observed during one site visit.

Much of the measured data appear inconsistent with assumed building operations. A more focused monitoring effort is necessary to characterize the building's performance. The retrofit impact analysis could not be performed on this building.

Discussion

Notes on Model Development. The motor pool could not be modeled with the data available. The electricity trends would have been very difficult to model since information on building activities is limited. In addition, the heating trends may well have been off due to nonuse of the building.

An additional BLAST run to estimate the impact of the implemented retrofits, even though the baseline is higher than observed, could be instructive for assessing if steadily operated buildings should be retrofitted. No such run was performed in this study. The original predictions and measured savings for the retrofitted motor pool are as follows:

Original BLAST run savings:	1040 MBtu
Measured savings:	744 MBtu
Revised BLAST run savings:	Not Available

Summary of Findings

The BLAST analyses showed that:

- A thorough analysis of the building design plans during visits to the site allowed the buildings to be described in BLAST with a high degree of confidence. The energy consumption values estimated by the BLAST simulations were close to the actual usage. Some problems still exist in the mess hall and particularly in the motor vehicle repair shop, for which additional measured data are necessary to characterize the building energy performance.

- The largest savings can be obtained from system modifications, which could include changes in system operation, hot water temperature controls, and similar measures. However, they will be effective only if the thermostats are not accessible to uninformed personnel, or if they remain accessible, they should be checked by a designated energy manager.

- Based on the results provided by this study, it appears that the more consistently a system is operated, the closer the building simulation is to the real situation, taking into account both the approximations made by the simulation program and the errors induced by the sensors.

- The models developed for this study can be used as a beginning building description for assessing whether similar (or other) retrofit packages might be effective on similar buildings.

7 CONCLUSIONS AND RECOMMENDATIONS

USACERL has tested retrofit measures for energy conservation on four standard Army facility types: a dining hall, a motor pool repair shop, an L-shaped barracks, and a rolling-pin-shaped barracks. The results were analyzed to determine if these retrofits affected energy use and if their cost could be justified on similar buildings within the Army. The retrofits were tested at Fort Carson, CO, under FEAP.

Conclusions

1. The original retrofit packages saved a significant amount of energy but substantially less than anticipated.

Direct comparison of energy consumption between test and reference buildings provided the first estimate of energy savings due to the original retrofit measures. These savings in total building energy represent a substantial percentage of baseline consumption for all building categories: between 17 and 35 percent. However, absolute magnitudes (in Btus) of the energy saved for all buildings were considerably less than original savings estimates: 4 to 73 percent of anticipated Btus. Further, variations in operating conditions and in energy totals between baseline buildings suggested the need for closer data inspection and savings adjustments.

A statistical analysis was performed in an attempt to compensate for operating differences between buildings, thus refining direct comparison saving estimates. This analysis showed that the retrofit packages installed for three of the four original tests achieved significant energy savings in heating. Data for the dining halls, and for cooling, electricity, and DHW use in the other buildings, did not allow model development and no conclusion was reached. Evaluation of energy savings for these cases is not statistically supportable.

The savings found in regression analysis were credited to the retrofits for the L-shaped barracks, the rolling-pin barracks, and the motor vehicle repair shop. Here, significant savings were identified for heating only. Direct comparison data were used for the dining hall, for which statistical models could not be developed. Again, heating energy savings were the only energy differences assumed to be nonrandom. The credited savings achieved 2 to 72 percent of anticipated savings (Table 49).

2. Building operation is one factor that compromises savings.

3. Prime targets for savings in system efficiencies were identified.

Interim energy results prompted efforts to improve operations at an L-shaped barracks by lowering interior temperatures, increasing heating control, and improving heating and DHW system efficiencies. DHW consumption and weather-adjusted heating consumption were compared before and after operational retrofits. Savings from improved operations were most encouraging, with a 28 percent reduction in gas use from the previous season. Energy savings in percentages and Btus met simplified engineering estimates.

4. None of the original retrofit packages are life-cycle cost-effective with the observed savings and today's prices of fuel and materials.

Table 49

Energy Savings From the Retrofits vs. Expected Savings

Building*	Energy Saved (MBtu)	Percent of Baseline	Expected Savings (MBtu)	Percent of Expected
633(MP)	744	41	1040	72
811(LS)	1973	27	3339	59
811op(LSop)	1741	28	2003	87
1361(DH)	64	24	3620	1.8
1363(RP)	1777	41	3343	53

*MP = motor vehicle repair shop, LS = L-shaped barracks, LSOP = L-shaped barracks with improved operations, DH = enlisted personnel dining facility, RP = rolling-pin shaped barracks.

5. The improved operations effort at the L-shaped barracks is cost-effective, with a return on investment of 5:1.

Economic analysis was conducted on the retrofit packages. Actual costs and new estimates of the original packages' construction costs for the project year and the current year were reviewed. New cost estimates were prepared because actual implementation costs were greater than expected and because market conditions could have changed since the project year.

The economic results indicated that, based on actual construction costs and measured savings, the retrofit at the rolling-pin barracks and the L-shaped barracks improved operations retrofit met the ECIP criterion of SIR $\geq$ 1 for the year implemented. Using project year estimated costs for the original retrofits, the motor pool retrofit meets this criterion. With current year estimated costs and current fuel prices, none of the original retrofits meet the ECIP criteria. (See Table 50 for current year economics.)

6. Cost scenarios for fuel and construction have been developed under which the implemented packages would be cost-effective with the measured energy savings. Three of the original retrofits may become life-cycle cost-effective in the future.

Market scenarios were developed to examine under what conditions the four retrofit packages would meet the ECIP criterion of SIR $\geq$ 1.0. Parameters examined were construction cost, annual energy savings, fuel cost, and annual nonenergy savings. The scenarios were examined by developing an equation expressing the relationship between the parameters when the ECIP criterion is satisfied.

The market scenarios indicated that, even with the low energy savings achieved, the original retrofits have some merit. Examination of the 25-year life scenarios allowed USACERL to calculate, for the current year cost estimates, what natural gas prices would have to be (in DOE region 8) for the retrofits to have an SIR = 1. These prices are shown in Table 51. (Information for the improved operations retrofit with a 15-year life scenario is also included.) With the exception of the retrofit at the dining hall, all of the retrofits could possibly become cost-effective in the near future. (Current average cost for natural gas at Fort Carson is $3.11/MBtu.) This estimate assumes that contract solicitation would result in contract costs no higher than the current cost estimates.

Table 50

Current Year Cost-Effectiveness of the Retrofits

Building*	Project Life (Years)	Fiscal Year	SIR	Simple Payback (Years)
633(MP)	25	89	0.99	23
811(LS)	25	89	0.46	49
811op(LSop)	15	88	5.14	2.8
1361(DH)	25	89	.04	502
1363(RP)	25	89	.78	29

*MP = motor vehicle repair shop, LS = L-shaped barracks, LSop = L-shaped barracks with improved operations, DH = enlisted personnel dining facility, RP = rolling-pin-shaped barracks.

Table 51

Gas Energy Prices for SIR = 1.0
With 1988 Estimated Retrofit Costs ($/MBtu)

Building*	Natural Gas Cost
633(MP)	3.13
811(LS)	6.69
811op(LSop)	.70
1361(DH)	87.18
1363(RP)	3.99

*MP = motor vehicle repair shop, LS = L-shaped barracks, LSop = L-shaped barracks with improved operations, DH = enlisted personnel dining facility, RP = rolling-pin shaped barracks.

7. The building energy use models developed for this study will help in assessing retrofit applicability at other locations.

Successful building energy consumption models were developed during statistical analysis for the L-shaped and rolling-pin barracks and the motor repair shop. These models of baseline and retrofit building heating energy consumption will allow evaluation of energy savings for these retrofit packages at other locations. This evaluation can be done by simply using bin temperature data from the location of concern in the models of the retrofit and baseline buildings. Savings for energy flows other than those for which equations have been developed will have to be estimated by other means.

8. Operational retrofits are higher priority than envelope retrofits and are necessary for envelope retrofits to be fully effective.

9. Operational retrofits require some continued effort to be successful.

Results from the improved operations retrofit at the L-shaped barracks were most encouraging. Improvements in interior temperature trends, control capabilities, system part-load efficiencies, and heating and DHW loads resulted in substantial fuel savings. Energy savings from improved operations almost equaled savings from the original retrofit, which was considerably more costly. However, continued return on investment requires some upkeep of the mechanical equipment, informed responses to calls about heating problems, repair of equipment as it fails, and prevention of vandalism to the installed equipment.

10. Comprehensive energy programs are more effective than any single or combined retrofit measures.

The insights gained during this project were valuable and stressed the need for a comprehensive energy program. That is, several factors--building envelope, building controls, mechanical operations, and the actions of operators and occupants--together affect the total building energy consumption. The entire building system needs to be assessed and remedied appropriately to bring buildings to their full potential for energy effectiveness.

Recommendations

Based on these findings, the following actions are recommmended:

1. Assess and improve building operations as a first step for energy conservation.

Chapter 5 gives an overview of the operational improvements made to the L-shaped barracks. A Technical Report will be published detailing these improvements. It is hoped that these or similar changes will be used to advantage in other L-shaped barracks or buildings with similar heating/DHW systems. Similar improvement strategies should be implemented elsewhere.

2. Review and improve routine M&R practices for mechanical equipment.

Some specific areas to address include boiler tune-up, control and air compressor servicing, steam trap repair, air-bound hydronic heating systems, and radiator dampers. Review the local definition of "broken" equipment. "Totally inoperative" is too strict a definition. "Insufficiently operating" is a more reasonable compromise and ultimately more cost-effective.

3. Upgrade operator knowledge.

Much of the opportunity for improved operations depends on adequate operator education and coordination. Increase job-specific training programs for operators to include guidelines for trouble-shooting building HVAC complaints. Test the technical skills of building operators as part of a training program. Initiate an in-house log book of service calls, including problems reported and responses taken.

4. Identify a staff controls expert.

It is necessary for each installation to have at least one controls expert on staff. This may require hiring someone or training existing staff. This person would be responsible for making, or at least overseeing, all controls adjustments. The potential for monetary savings with appropriately set and maintained building controls is substantial and justifies the expense of a trained controls engineer.

5. Expand occupant education programs.

Simple occupant modifications such as clothing and bedding adjustments, strategic furniture positioning, and passive humidification can greatly enhance personal comfort. Making select occupants aware of heating control capabilities that do exist in buildings could increase interior comfort and decrease service calls.

6. Consider comfort in building operations.

Drastic measures for energy conservation such as the disabling of heating, ventilation or DHW, do cut energy costs but increase other (albeit less quantifiable) costs as occupant morale and health are lowered.

7. Review applicability of the implemented retrofits in the future.

Keep the original retrofit packages in mind as fuel and construction costs change. If the calculated payback periods are acceptable within a reasonable margin of error, implement the retrofit measures.

The original retrofit packages were not cost effective based on energy savings alone; however, other nonenergy benefits were achieved which were not quantified in dollars. These include improved functioning, appearance, comfort, productivity and morale and decreased maintenance. If buildings are being renovated or repaired, the items used in these retrofit packages, which have a bias toward energy conservation, should be considered. The energy savings may not justify the entire cost of the implemented products but may well justify the incremental cost over less expensive, nonenergy conservative options.

METRIC CONVERSION TABLE

$$°C = 0.55(°F-32)$$
$$1 \text{ Btu} = 1.055 \text{ kJ}$$
$$1 \text{ kWh} = 3.6 \text{ J}$$

APPENDIX A:

VARIABLES CONTAINED IN THE DATA SET

Tables A1 through A4 list the variables used in the data set for the four building types.

Table A1

L-Shaped Barracks

Time of Day
Date

Outdoor temperature
1st zone east temperature
1st zone west temperature
2nd zone east temperature
2nd zone west temperature
3rd zone east temperature
Mess hall temperature

Hot water supply temp. - 3rd zone
Hot water return temp. - 3rd zone
Hot water supply temp. - 2nd zone
Hot water return temp. - 2nd zone
Hot water supply temp. - 1st zone
Hot water return temp. - 1st zone

Hot water flow - 1st zone
Hot wtaer flow - 2nd zone
Hot water flow - 3rd zone

Cold water feed temp.
Circulating DHW temp.

Cold water feed flow
Chilled water supply temp.

Chilled water return temp.
Chilled water flow

Electric use
Number of electric reads

Scans per hour

Sum of squares of electric data
Sum of squares of gas data

Btu Heat - 3rd zone
Number of Btu heat - 3rd zone <> 0
Sum of squares of Btu heat - 3rd zone

Btu heat - 2nd zone
Number of Btu heat - 2nd zone

Btu heat - 1st zone
Number of Btu heat - 1st zone <> 0
Sum of squares of Btu heat - 1st zone

Btu circulating DHW
Btu circulating DHW <> 0
Sum of squres of Btu circ. DHW

Btu cooling
Number of btu cooling <> 0
Sum of squares of Btu cooling

TAll - average seven space temps.
TDrm - average of six space temps., not including mess hall

OAT - average of outdoor tmeps. as measured at 811, 812, and 813

Table A2

Motor Repair Shops

Time of day
Date

North temperature

South temperature

Electric use
Number of electric reads

Gas use
Number of gas reads

Scans per hour

Sum of squares of electric data
Sum of squares of gas data

OAT - average of outdoor temps. as measured at 811, 812, and 813

Table A3

Rolling-Pin Barracks

Time of day
Date

1st floor temp.
2nd floor temp.
3rd floor temp.

Hot water supply temp.
Hot water return temp.
Hot water flow

Chilled water supply temp.
Chilled water return temp.
Chilled water flow

Circulating DHW temp.
Cold Water feed flow

Electric use
Number of electric reads

Scans per hour

Sum of squares of electric data

Btu heat
Number of Btu heat <> 0
Sum of squares of Btu Heat

Btu circulating DHW
No. of Btu circulating DHW <> 0
Sum of squares of Btu circulating DHW

Btu cooling
No. of Btu cooling <> 0
Sum of squares of Btu cooling

TA11 - average of three space temps.

OAT - average of outdoor temps. as measured at 811, 812, and 813

Table A4

Dining Halls

Time of day
Date

Space temperature
Hot water supply temp.
Hot water return temp.

Hot water flow
Cold water feed temp.
Cold water feed flow

Steam converter flow

Electric use
Number of electric reads

Autograph temp.

Scans per hour

Sum of squares of electric data
Sum of squares of gas data

Btu heat
Nol of Btu heat <> 0
Sum of squres of Btu heat

Btu steam
No. Btu steam <> 0
Sum of squares of Btu steam

Btu circulating DHW
No. of Btu circulating DHW <> 0

Sum of squares of Btu circulating DHW
OAT - average of outdoor temps. as measured at 811, 812, and 813

APPENDIX B:

DETAILED ENERGY TABLES

Tables B1 through B8 present data on energy use observed during this project. These tables list energy use at the building site, as well as the source energy totals that refer to estimated energy use (in fossil fuel) at the source of power or heat production. Motor shops and L-shaped barracks have their own heat plant (boilers), so site and source energy use for gas are synonymous. For each building type, data are included for the test building and each reference building as well as the average value of the reference buildings.

Each site energy table is divided into five major sections. These sections, from left to right, represent: annual energy totals for all component energies; a savings summary, which presents the savings observed for a given pair of buildings (energy savings if the difference is positive, energy loss if the difference is negative); an energy use per square foot, which allows a customary comparison to other buildings of similar type; a savings per square foot summary for a standardized magnitude of savings; and an annual percentage savings for a given pair of buildings. Note that the average data values of reference buildings of a given type are also included on these charts.

The annual energy totals are in millions of Btus (MBtus). Unless the data are specified as manual meter readings, the results are projected using season/week modeling from energy use recorded by the data loggers.

The savings summary lists the computed annual energy savings (Esvgs) in MBtu for each test building. This value is calculated by subtracting energy used by the test building (Etst) from the energy used by the specified reference building or the mean of the reference buildings (Eref), or Esvgs = Eref - Etst.

The energy use per square foot is calculated by dividing the energy used by the square footage over which that energy is used. In cases where the square footage varies by energy type, this is pointed out in the key at the bottom of each table. These results are in thousands of Btus per square foot (kBtu/sq ft).

The energy savings per square foot summary presents annual energy savings divided by the amount of floor space, yielding units of thousands of Btus per square foot (kBtu/sq ft).

The percentage savings summaries are calculated from the energy savings divided by the individual (or mean) energy consumption of the reference buildings: (Eref-Etst)/Eref.

The source energy tables give annual totals of energy used at the source of heat, cooling or power production, and energy differences (savings or loss) between the test and reference buildings. Anticipated energy totals are listed under the BLAST reference model.

The source energy tables were constructed by dividing the observed energy use by an assumed efficiency of the process that was used to generate that energy. For instance, it was assumed that when electricity is being generated, only 30 percent of the energy used in the process is actually delivered to the user. Similarly, heating was modeled with a source efficiency of 60 percent. Cooling was assumed to be produced with a chiller having a coefficient of performance (COP) of 3.0, thus being produced with an overall efficiency of 90 percent (which is calculated from COP times power production efficiency). These source efficiencies are the same efficiencies used by BLAST for its projections.

Data listed as BLAST-normalized* have been adjusted for differences in weather conditions (heating degree days [HDDs] and cooling degree days [CDDs]) between the field test year and the BLAST-modeled year. Quantities listed under the BLAST model heading are the results from the computer simulations summarized in TR E-183. For the L- shaped barracks, the BLAST model did not include the whole building, but only the barracks wing (zones 1 and 2) for its energy estimates.

Variable Names for L-Shaped Barracks - Gas

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
ELMSM	kWh	Daily electricity consumption.
GASMSM	Btu	Daily gas consumption.
BTU3SM	Btu	Daily heating consumption for zone 3.
BTU2SM	Btu	Daily heating consumption for zone 2.
BTU1SM	Btu	Daily heating consumption for zone 1.
BTUDHWSM	Btu	Daily domestic hot water energy consumption.
BTUCLGSM	Btu	Daily cooling energy consumption.
T1EAV	°F	Daily average temperature, zone 1 east.
T1WAV	°F	Daily average temperature, zone 1 west.
T2EAV	°F	Daily average temperature, zone 2 east.
T2WAV	°F	Daily average temperature, zone 2 west.
T3EAV	°F	Daily average temperature, zone 3 east.
T3WAV	°F	Daily average temperature, zone 3 west.
TMHAV	°F	Daily average temperature, mess hall.
ELMN	None	Number of hourly values included in ELMSM.
GASMN	None	Number of hourly values included in GASMSM.
BTU3N	None	Number of hourly values included in BTU3SM.
BTU2N	None	Number of hourly values included in BTU2SM.
BTU1N	None	Number of hourly values included in BTU1SM.
BTUDHWN	None	Number of hourly values included in BTUDHWSM.
BTUCLGN	None	Number of hourly values included in BTUCLGSM.
MOAT	°F	Daily average outdoor air temperature, building 811, from building 811 data file.
COUNT	None	Count of hourly data points included in daily total.
OATAV	°F	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
MOATAV	°F	Daily average outdoor air temperature, building 811, from outdoor air temperature file.
NOATAV	°F	Daily average outdoor air temperature, building 812, from outdoor air temperature file.
OOATAV	°F	Daily average outdoor air temperature, building 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.
MOATN	None	Number of hourly values included in MOATAV.
NOATN	None	Number of hourly values included in NOATAV.
OOATN	None	Number of hourly values included in OOATAV.
TALLMAV	°F	Average of T1EAV, T1WAV, T2EAV, T2WAV, T3EAV, T3WAV, and TMHAV.

The variable names listed above are those used for building 811. Buildings 812 and 813 used similar names, except that an N or an O was added to the name for buildings 812 and 813, respectively.

Data Included If: Gas > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F, and
For building 811, date not 1/2/87.

*Field energy totals were divided by observed degree days and then multiplied by degree days for the BLAST-modeled year to allow comparison with BLAST results. Observed degree days were obtained from the National Oceanic and Atmospheric Administration (NOAA).

Table B1

Direct Comparison of Annual Site Energy Consumption—Motor Pool

Energy Type	Annual Energy Totals: Bldg 633 MBTU	Bldg 634 MBTU	Bldg 635 MBTU	Bldg 636 MBTU	Mean Ref MBTU	Energy Savings: 633 vs 634 MBTU	633 vs 635 MBTU	633 vs 636 MBTU	633 vs Mean Ref MBTU
Gas *	1061	1498	1328	1838	1555	437	267	777	494
Electricity *	64	83	15	56	51	19	-49	-8	-13
Total	1125	1581	1343	1894	1606	456	218	769	481

Energy Type	Energy Use / Sq. Foot: Bldg 633 KBTU	Bldg 634 KBTU	Bldg 635 KBTU	Bldg 636 KBTU	Mean Ref KBTU	Savings / Sq. Foot: 633 vs 634 KBTU	633 vs 635 KBTU	633 vs 636 KBTU	633 vs Mean Ref KBTU	Percent Savings: 633 vs 634 (%)	633 vs 635 (%)	633 vs 636 (%)	633 vs Mean Ref (%)
Gas *	221	312	277	383	324	91.0	55.6	161.9	102.8	29.2%	20.1%	42.3%	31.8
Electricity *	13	17	3	12	11	4.0	-10.2	-1.7	-2.6	22.9%	-326.7%	-14.3%	-24.7
Total	234	329	280	395	335	95.0	45.4	160.2	100.2	28.84%	16.23%	40.60%	29.95

Key

Floor Space = 4800 Square Foot 1 MBtu == 10^6 Btu 1 KBtu == 10^3 Btu 1 Kwh == 3413 Btu	Building 633 == Test Building 634 == Reference Building 635 == Reference Building 636 == Reference	* From Meter Readings:

Table B2

Direct Comparison of Annual Source Energy Consumption—Motor Pool

	Annual source Energy Totals							Source Energy Savings				
Energy Type	Percent Effic.	Bldg 633 MBTU	Bldg 634 MBTU	Bldg 635 MBTU	Bldg 636 MBTU	Mean Ref MBTU	Original Blast Ref Model MBTU	633 vs 634 MBTU	633 vs 635 MBTU	633 vs 636 MBTU	633 vs Mean Ref MBTU	Original Blast Model Savings MBTU
Gas	100%	1061	1498	1328	1838	1555						
Gas *	100%	1140	1610	1427	1976	1671	1799	549	366	915	610	1029
Electricity	30%	213	277	50	187	171	1004	213	-14	123	107	11
Total		1354	1887	1477	2162	1842	2803	762	352	1037	717	1040

Key

From Meter Readings: June 1986 through May 1987		Building 633 == Test
		Building 634 == Reference
1986-86 Heating Degree Days:	5968	Building 635 == Reference
Blast Heating Degree Days:	6415	Building 636 == Reference
		1 MBtu == 10^6 Btu
Floor Space =	4800 Square Foot	1 Kwh == 3413 Btu

*Normalized to the Blast Heating Degree Year.

Table B3

Direct Comparison of Site Energy Consumption—L-Shaped Barracks *

Energy Type	Date	Annual Energy Totals: Bldg 811 MBTU	Bldg 812 MBTU	Bldg 813 MBTU	Mean Ref MBTU	Energy Savings: 811 vs 812 MBTU	811 vs 813 MBTU	811 vs Mean Ref MBTU	Energy Use / Sq. Foot: Bldg 811 KBTU	Bldg 812 KBTU	Bldg 813 KBTU	Mean Ref KBTU	Savings / Sq. Foot: 811 vs 812 KBTU	811 vs 813 KBTU	811 vs Mean Ref KBTU	Percent Savings: 811 vs 812 (%)	811 vs 813 (%)	811 vs Mean Ref (%)
Gas Btus	86-87:	6150.7	8552.7	7755.4	8154.1	2402.0	1604.7	2003.4	161.9	225.1	204.1	214.6	63.2	42.2	52.7	28.1%	20.7%	24.6%
	87-88:	4540.1	7581.5	7338.6	7460.0	3041.4	2798.5	2919.9	119.5	199.5	193.1	196.3	80.0	73.6	76.8	40.1%	38.1%	39.1%
Heat Zone 1	86-87:	1034.0	1204.2	1416.1	1310.1	170.2	382.1	276.1	66.4	77.4	91.0	84.2	10.9	24.6	17.7	14.1%	27.0%	21.1%
	87-88:	475.1	1156.7	1214.9	1185.8	681.6	739.8	710.7	30.5	74.3	78.1	76.2	43.8	47.5	45.7	58.9%	60.9%	59.9%
Heat Zone 2	86-87:	877.9	1223.9	881.1	1052.5	346.0	3.2	174.6	56.4	78.7	56.6	67.6	22.2	0.2	11.2	28.3%	0.4%	16.5%
	87-88:	448.1	978.6	560.8	769.7	530.5	112.6	321.6	28.8	62.9	36.0	49.5	34.1	7.2	20.7	54.2%	20.1%	41.8%
Heat Zone 3	86-87:	100.6	172.5	86.6	129.5	71.9	-14.1	28.9	14.6	25.1	12.6	18.8	10.4	-2.0	4.2	41.7%	-16.2%	22.3%
	87-88:	99.3	202.9	504.1	353.5	103.6	404.8	254.2	14.4	29.5	73.3	51.4	15.1	58.9	37.0	51.1%	80.3%	71.9%
Electricity	86-87:	678.0	811.9	738.9	775.4	134.0	60.9	97.4	17.8	21.4	19.4	20.4	3.5	1.6	2.6	16.5%	8.2%	12.6%
	87-88:	769.2	749.8	770.7	760.2	-19.4	1.5	-9.0	20.2	19.7	20.3	20.0	-0.5	0.0	-0.2	-2.6%	0.2%	-1.2%
DHW	86-87:	732.3	815.0	806.4	810.7													
	87-88:	646.3	683.5	551.8	617.6	37.2	-94.5	-28.7	17.0	18.0	14.5	16.3	1.0	-2.5	-0.8	5.4%	-17.1%	-4.6%
Cooling	86-87:	174.0	367.3	191.5	279.4	193.3	17.5	105.4	4.6	9.7	5.0	7.4	5.1	0.5	2.8	52.6%	9.1%	37.7%
	87-88:	98.9	0.0	235.9	117.9	-98.9	136.9	19.0	2.6	0.0	6.2	3.1	-2.6	3.6	0.5	0.0%	58.1%	16.1%
Gas & Elec	86-87:	6828.7	9364.7	8494.3	8929.5	2536.0	1665.6	2100.8	179.7	246.4	223.5	235.0	66.7	43.8	55.3	27.1%	19.6%	23.5%
	87-88:	5309.3	8331.2	8109.3	8220.3	3021.9	2800.0	2911.0	139.7	219.2	213.4	216.3	79.5	73.7	76.6	36.3%	34.5%	35.4%
Zone 1 & 2 Heating	86-87:	1911.9	2428.1	2297.2	2362.7	516.2	385.3	450.8	61.4	78.0	73.8	75.9	16.6	12.4	14.5	21.3%	16.8%	19.1%
	87-88:	923.2	2135.3	1775.6	1955.5	1212.1	852.4	1032.3	29.7	68.6	57.1	62.8	38.9	27.4	33.2	56.8%	48.0%	52.8%
All Zones Heating	86-87:	2012.5	2600.6	2383.8	2492.2	588.0	371.3	479.7	53.0	68.4	62.7	65.6	15.5	9.8	12.6	22.6%	15.6%	19.2%
	87-88:	1022.5	2338.2	2279.8	2309.0	1315.7	1257.3	1286.5	26.9	61.5	60.0	60.8	34.6	33.1	33.9	56.3%	55.1%	55.7%

* Caveat: Because the data represents different seasons, only percentages may be compared down the columns.

Key

Floor Space =	38000 Sq. Ft. -- Elec, Gas, DHW & Cool	Building 811 == Test	1 KBtu == 10^3 Btu	86-87 is June 1986 - May 1987
	15561 Sq. Ft. -- Zones 1 & 2	Building 812 == Reference	1 MBtu == 10^6 Btu	87-88 is June 1987 - May 1988
	6878 Sq. Ft. -- Zone 3	Building 813 == Reference	1986-87 HDD == 5968	86-88 is June 1986 - May 1988
			1987-88 HDD == 6095	

Table B4

Direct Comparison of Source Energy Consumption—L-Shaped Barracks

		Annual Source Data Summary						Source Energy Savings			
Data Type	Data Source	Percent Effic.	Bldg 811 MBTU	Bldg 812 MBTU	Bldg 813 MBTU	Mean Ref MBTU	Original Blast Ref Model MBTU	811 vs 812 MBTU	811 vs 813 MBTU	811 vs Mean Ref MBTU	Original Blast Ref Model MBTU
Gas Btus	86-87:	100%	6150.7	8552.7	7755.4	8154.1		2402.0	1604.7	2003.4	
	87-88:	100%	4540.1	7581.5	7338.6	7460.0		3041.4	2798.5	2919.9	
Heat Zone 1	86-87:	60%	1723.3	2006.9	2360.2	2183.6		283.6	636.9	460.2	
	87-88:	60%	791.8	1927.8	2024.8	1976.3		1136.0	1233.0	1184.5	
Heat Zone 2	86-87:	60%	1463.2	2039.9	1468.5	1754.2		576.7	5.3	291.0	
	87-88:	60%	746.8	1631.0	934.6	1282.8		884.2	187.7	536.0	
Heat Zone 3	86-87:	60%	167.7	287.5	144.3	215.9		119.8	-23.4	48.2	
	87-88:	60%	165.4	338.1	840.2	589.2		172.7	674.7	423.7	
Electricity	86-87:	30%	2259.9	2706.4	2462.9	2584.7	2260.0	446.6	203.1	324.8	196.0
	87-88:	30%	2563.9	2499.2	2568.8	2534.0	2260.0	-64.7	4.9	-29.9	196.0
Cooling	86:	90%	193.3	408.1	212.7	310.4		214.8	19.4	117.1	
	86*:	90%	207.8	438.7	228.7	333.7	922.0	230.9	20.9	125.9	719.0
	87:	90%	109.9	0.0	262.1	131.0		-109.9	152.1	21.1	
DHW	86-87:	60%	1220.5	1358.4	1344.0	1351.2					
	87-88:	60%	1077.1	1139.1	919.7	1029.4		61.9	-157.5	-47.8	
Gas & Elec Totals	86-87:		8410.6	11259.2	10218.4	10738.8		2848.6	1807.8	2328.2	
	87-88:		7104.0	10080.7	9907.5	9994.1		2976.7	2803.4	2890.1	
Zone 1 & 2 Totals	86-87:		3186.5	4046.8	3828.7	3937.8		860.3	642.2	751.3	
	86-87*:		3425.2	4349.9	4115.5	4232.7	4133.0	924.7	690.3	807.5	2424.0
	87-88:		1538.7	3558.8	2959.4	3259.1		2020.1	1420.7	1720.4	
	87-88*:		1619.5	3745.7	3114.8	3430.2	4133.0	2126.2	1495.3	1810.8	2424.0
All Zones Totals	86-87:		3354.2	4334.3	3973.0	4153.7		980.1	618.8	799.4	
	87-88:		1704.1	3897.0	3799.6	3848.3		2192.9	2095.5	2144.2	

* Normalized to Blast model Degree Days.

Key

Floor Space =	38000 Sq. Ft. -- Elec, Gas & DHW 15561 Sq. Ft. -- Zones 1 & 2 6878 Sq. Ft. -- Zone 3	Building 811 == Test Building 812 == Reference Building 813 == Reference
1986-87 HDD == 1987-88 HDD == blast HDD ==	5968 6095 6415	86-87 is June 1986 - May 1987 87-88 is June 1987 - May 1988 1 MBtu == 10^6 Btu

Table B5

Direct Comparison of Site Energy Use—Dining Hall

Energy Type		Annual Energy Totals * Bldg 1361 MBTU	Bldg 1369 MBTU	Bldg 1669 MBTU	Mean Ref MBTU	Energy Savings 1361 vs 1369 MBTU	1361 vs 1669 MBTU	1361 vs Mean Ref MBTU	Energy Use / Sq. Foot Bldg 1361 KBTU	Bldg 1369 KBTU	Bldg 1669 KBTU	Mean Ref KBTU	Savings / Sq. Foot 1361 vs 1369 KBTU	1361 vs 1669 KBTU	1361 vs Mean Ref KBTU	Percent Savings 1361 vs 1369 (%)	1361 vs 1669 (%)	1361 vs Mean Ref (%)
Elec	1986-87	33.6	87.3	23.5	55.4	53.7	-10.0	21.8	3.2	8.2	2.2	5.2	5.1	-0.9	2.1	61.5%	-42.6%	39.4%
Gas (cooking)	1986-87	3120.5	199.1	758.5	478.8				293.8	18.7	71.4	45.1						
Heat	1986-87	122.6	250.9	71.9	161.4	128.3	-50.7	38.8	11.5	23.6	6.8	15.2	12.1	-4.8	3.7	51.1%	-70.5%	24.1%
Steam (Cooking)	1986-87	4148.7	57.0	4407.2	2232.1				390.7	5.4	415.0	210.2						
Dhw	1986-87		100.5							9.5								

Notes:

* Due to the lack of heating in the Buildings during the full season, heating totals were projected by dividing the season usage by the seasonal heating degree days and multiplying by the annual heating degree days.
Because electricity, gas, steam and domestic hot water are *independent of degree days*, these data types have been projected by the average daily use during the sample season multiplied by 365.

Key

Floor Space = 10620 Sq. Ft.
1 MBtu == 10^6 Btu
1 KBtu == 10^3 Btu
1 Kwh == 3413 Btu

Building 1361 == Test
Building 1369 == Reference
Building 1669 == Reference

Spring Heating Degree Days: 1368.87
Fall/Winter Heating Degree Days: 4605.48

This data represents Week 9-18 for both 1986 and 1987.

Table B6

Direct Comparison of Source Energy Use—Dining Hall

Energy Type			Bldg 1361 MBTU	Bldg 1369 MBTU	Bldg 1669 MBTU	Mean Ref MBTU	Original Blast Ref Model MBTU	1361 vs 1369 MBTU	1361 vs 1669 MBTU	1361 vs Mean Ref MBTU	Original Blast Savings MBTU
		Annual Energy Totals *						Source Energy Savings			
Elec	1986-87	30.0%	111.9	290.9	78.5	184.7	2255.0	179.0	-33.4	72.8	486.0
Gas	1986-87	100.0%	3120.5	199.1	758.5	478.8					
Heat	1986-87	60.0%	204.3	418.2	119.8	269.0		213.9	-84.5	64.7	
Heat * **		60.0%	219.4	449.1	128.7	288.9	4498.0	229.7	-90.7	69.5	3134.0
Steam	1986-87	60.0%	6914.5	95.0	7345.3	3720.2					
Dhw	1986-87	60.0%		167.6							

** Normalized to Blast model heating degree days.

Notes:

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* Due to the lack of heating in the Buildings during the full season, heating totals were projected by dividing the season usage by the seasonal heating degree days and multiplying by the annual heating degree days.

Because electricity, gas, steam and domestic hot water are independent of degree days, these data types have been projected by the average daily use during the sample season multiplied by 365.

Key

Floor Space =	10620 Sq. Ft.	Building 1361 == Test
1 MBtu == 10^6 Btu		Building 1369 == Reference
1 KBtu == 10^3 Btu		Building 1669 == Reference
1 Kwh == 3413 Btu		

Spring Heating Degree Days:	1369
Fall/Winter Heating Degree Days:	4605
Blast Heating Degree Days:	6415

Table B7

Direct Comparison of Site Energy Consumption—Rolling-Pin Barracks

DHW BTUs for Weeks	Annualized Energy Totals Bldg 1363 MBTU	Bldg 1663 MBTU	Bldg 1666 MBTU	Bldg 1667 MBTU	Mean Ref MBTU	Energy Savings 1363 vs 1663 MBTU	1363 vs 1666 MBTU	1363 vs 1667 MBTU	1363 vs Mean Ref MBTU	Energy Use / Sq. Foot Bldg 1363 KBTU	Bldg 1663 KBTU	Bldg 1666 KBTU	Bldg 1667 KBTU	Mean Ref KBTU	Savings / Sq. Foot 1363 vs 1663 KBTU	1363 vs 1666 KBTU	1363 vs 1667 KBTU	1363 vs Mean Ref KBTU	Percent Savings 1363 vs 1663 (%)	1363 vs 1666 (%)	1363 vs 1667 (%)	1363 vs Mean Ref (%)
Heating	1406.3	2624.2	2861.0	2420.4	2635.2	1217.9	1454.7	1014.1	1228.9	34.6	64.5	70.3	59.5	64.7	29.9	35.7	24.9	30.2	46.4%	50.8%	41.9%	46.6%
DHW	136.4	77.4	471.4	320.9	289.9																	
Electricity	633.1	128.4	42.1	640.3	270.3	-504.6	-591.0	7.3	-362.8	15.6	3.2	1.0	15.7	6.6	-12.4	-14.5	0.2	-8.9	-392.9%	-1404.4%	1.1%	-134.2%
Total	2175.7	2830.1	3374.5	3381.7	3195.4	654.3	1198.7	[illegible]05.9	1019.7	53.5	69.5	82.9	83.1	78.5	16.1	29.5	29.6	25.1	23.1%	35.5%	35.7%	31.9%

Key

Floor Space = 40698 Sq.Ft.	1 MBtu == 10^6 Btu	Building 1363 == Test	Building 1666 == Reference
1 Kwh == 3413 Btu	1 KBtu == 10^3 Btu	Building 1369 == Reference	Building 1667 == Reference

Table B8

Direct Comparison of Source Energy Consuymption—Rolling-Pin Barracks

Energy Type	Percent Effic.	Bldg 1363 MBTU	Bldg 1663 MBTU	Bldg 1666 MBTU	Bldg 1667 MBTU	Mean Ref MBTU	Original Blast Ref Model MBTU	1363 vs 1663 MBTU	1363 vs 1666 MBTU	1363 vs 1667 MBTU	1363 vs Mean Ref MBTU	Original Blast Savings MBTU
	Annual Source Energy Totals							Source Energy Savings				
Heating	60%	2343.8	4373.7	4768.3	403[illegible].0	4392.0		2029.9	2424.5	1690.2	2048.2	
Heating *	60%	2519.3	4701.2	5125.4	4336.1	4720.9	5572.0	2181.9	2606.1	1816.8	2201.6	3334.0
DHW	60%	227.3	129.0	785.7	534.9	483.2						
Electricity	30%	2110.2	428.1	140.3	2134.4	900.9	2447.0	-1682.1	-1970.0	24.2	-1209.3	3.0
Heating & Electric		4856.9	5258.4	6051.4	7005.5	6105.1		401.5	1194.5	2148.6	1248.2	

Key

Floor Space =	40698 Sq.Ft.	Building 1363 == Test	1986-1987 Heating Degree Days:	5968
1 Kwh == 3413 Btu		Building 1369 == Reference	Blast Heating Degree Days:	6415
1 MBtu == 10^6 Btu		Building 1666 == Reference		
1 KBtu == 10^3 Btu		Building 1667 == Reference		

* *Heating has been normalized to the BLAST model heating degree days.*

APPENDIX C:

GRAPHS OF DAYS USED IN THE DATA SET AS A PERCENTAGE OF TOTAL AVAILABLE

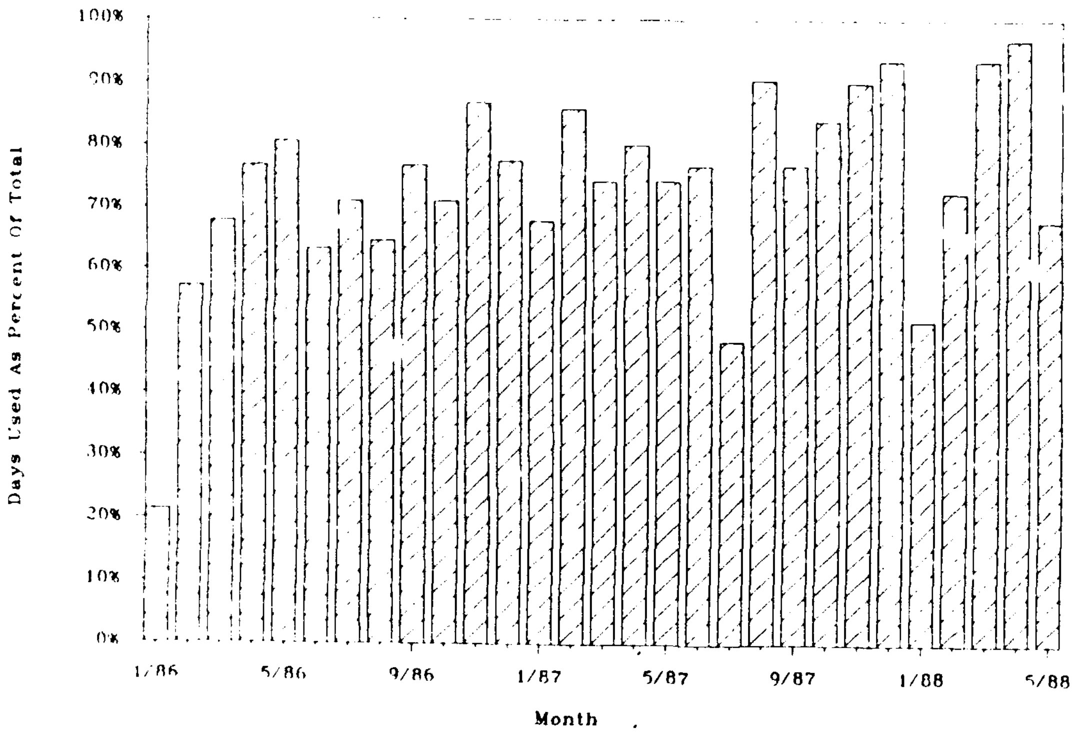

Figure C1. Data days used, L-shaped barracks, Bldg 811.

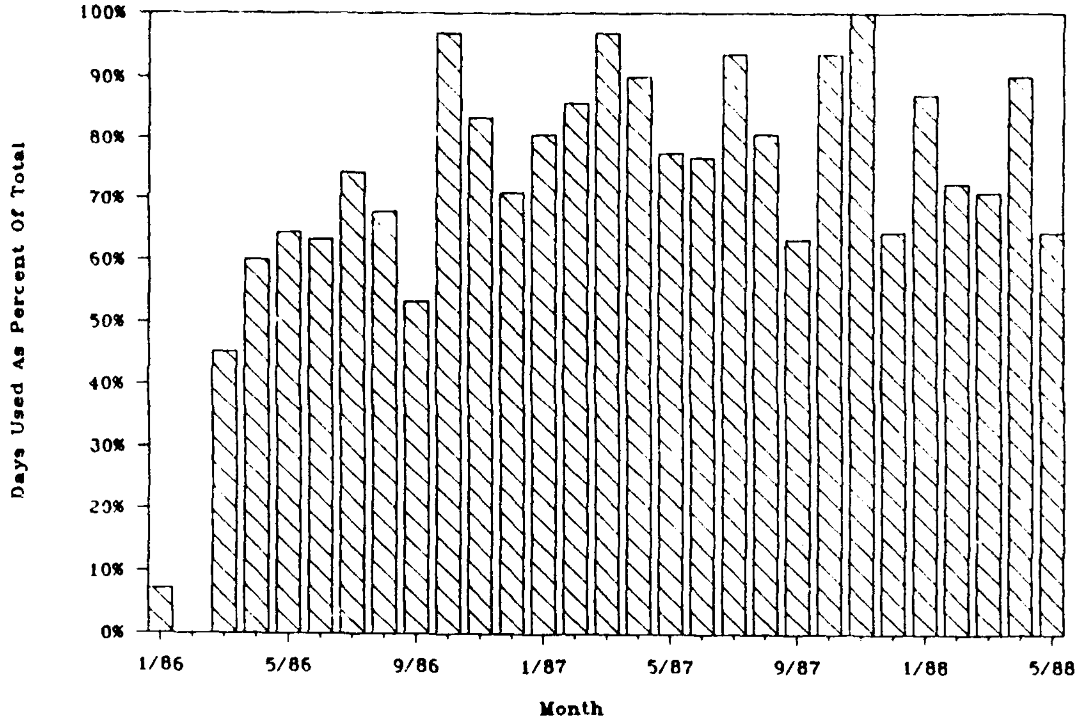

Figure C2. Data days used, L-shaped barracks, Bldg 812.

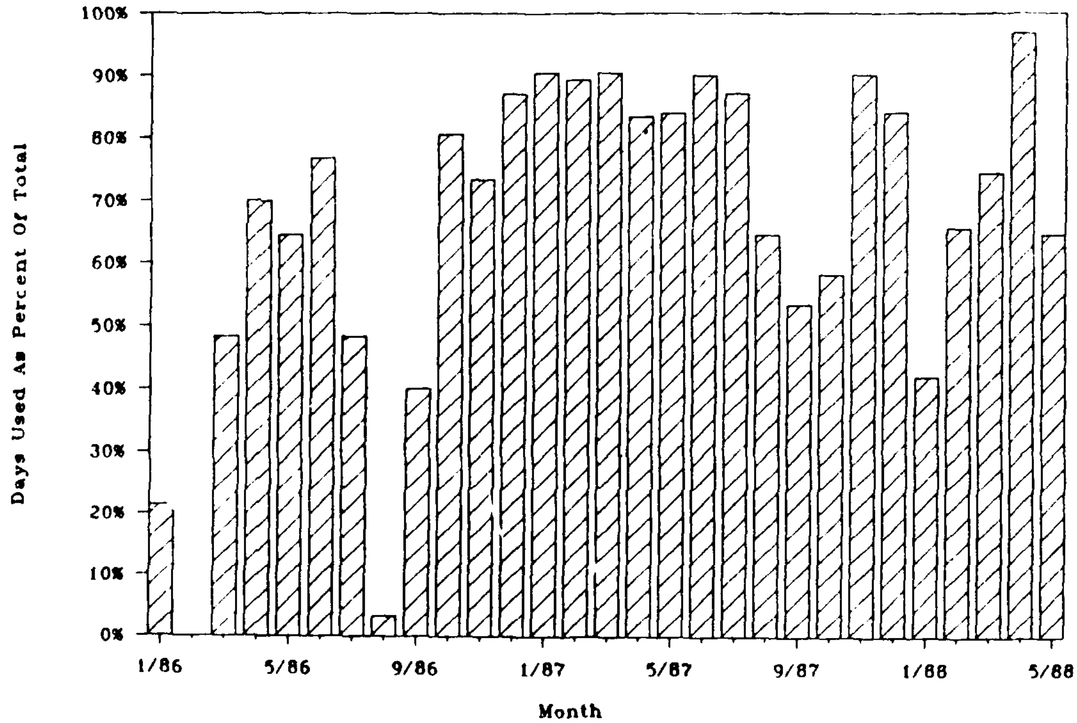

Figure C3. Data days used, L-shaped barracks, Bldg 813.

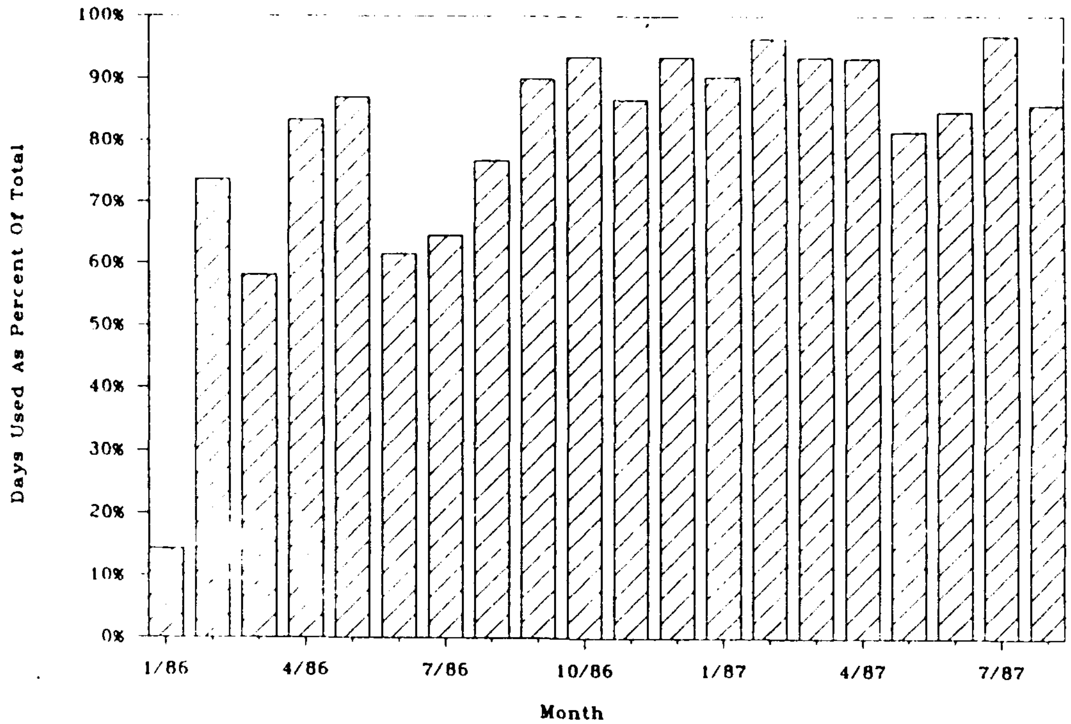

Figure C4. Data days used, rolling-pin barracks, Bldg 1363.

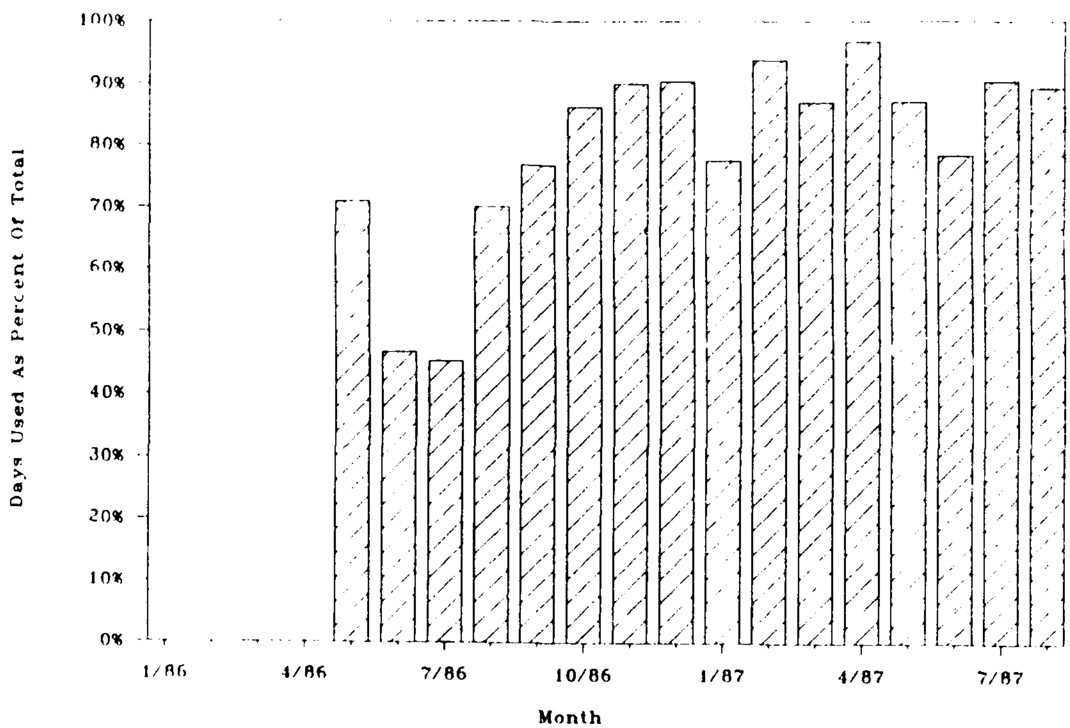

Figure C5. Data days used, rolling-pin barracks, Bldg 1663.

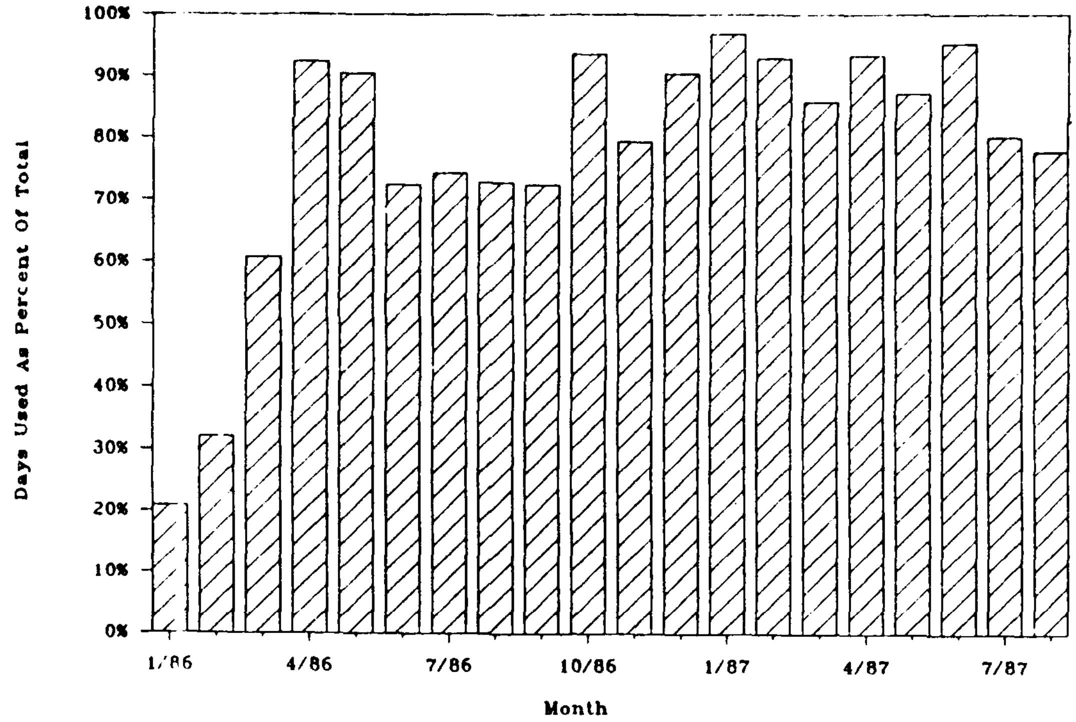

Figure C6. Data days used, rolling-pin barracks, Bldg 1666.

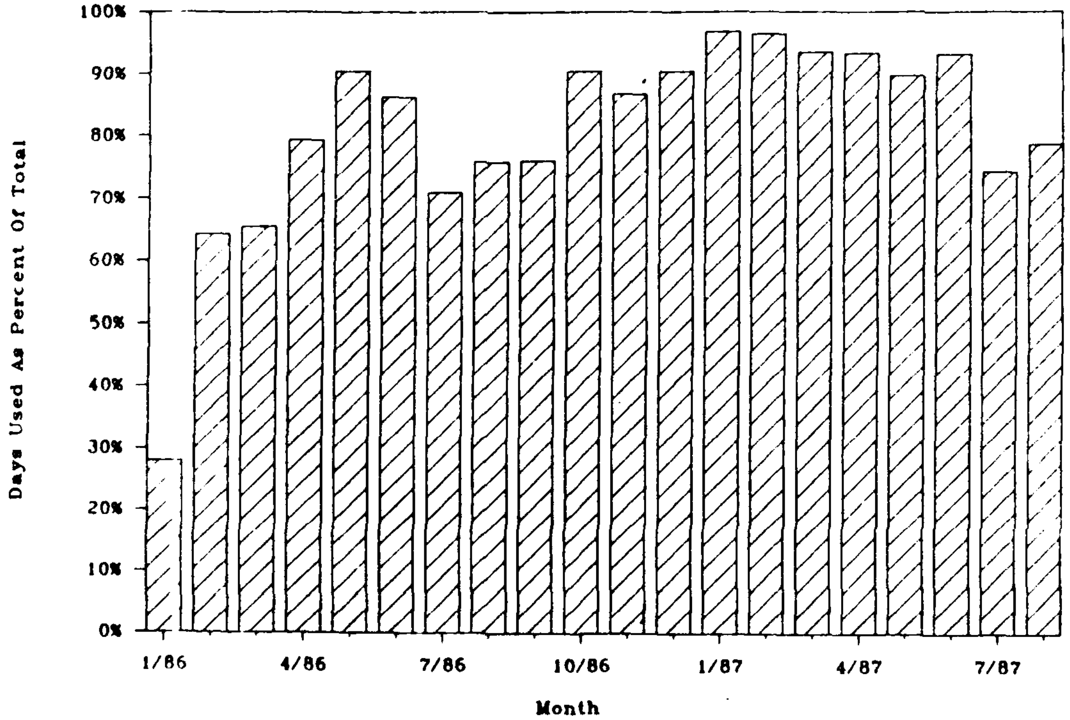

Figure C7. Data days used, rolling-pin barracks, Bldg 1667.

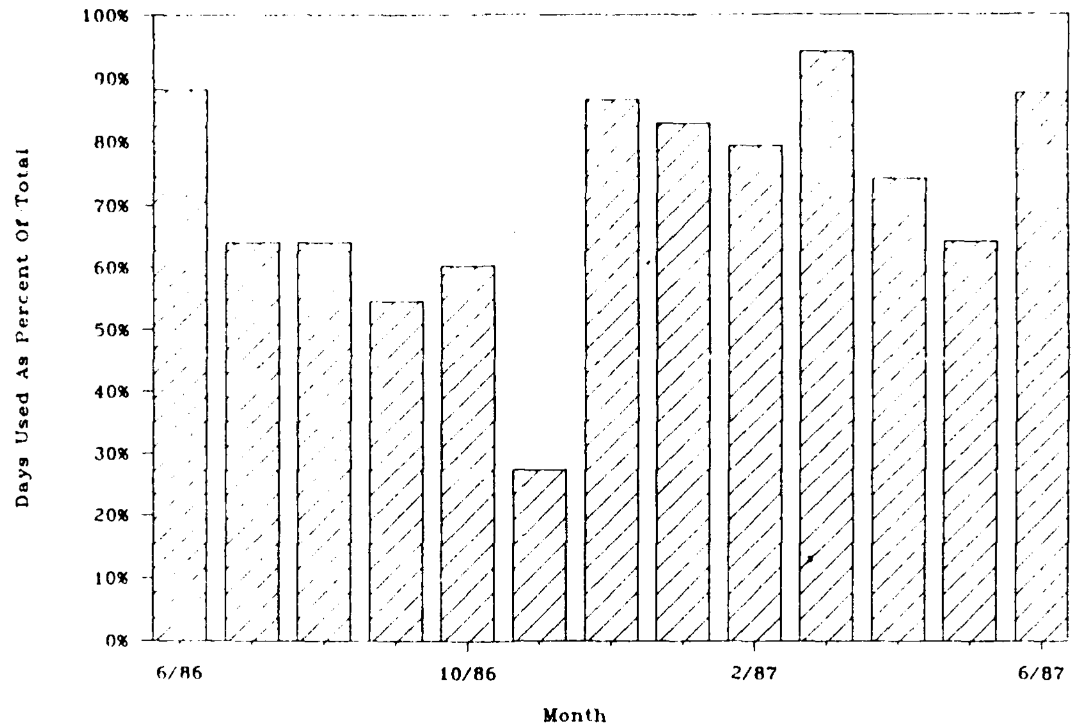

Figure C8. Data days used, motor repair shops.

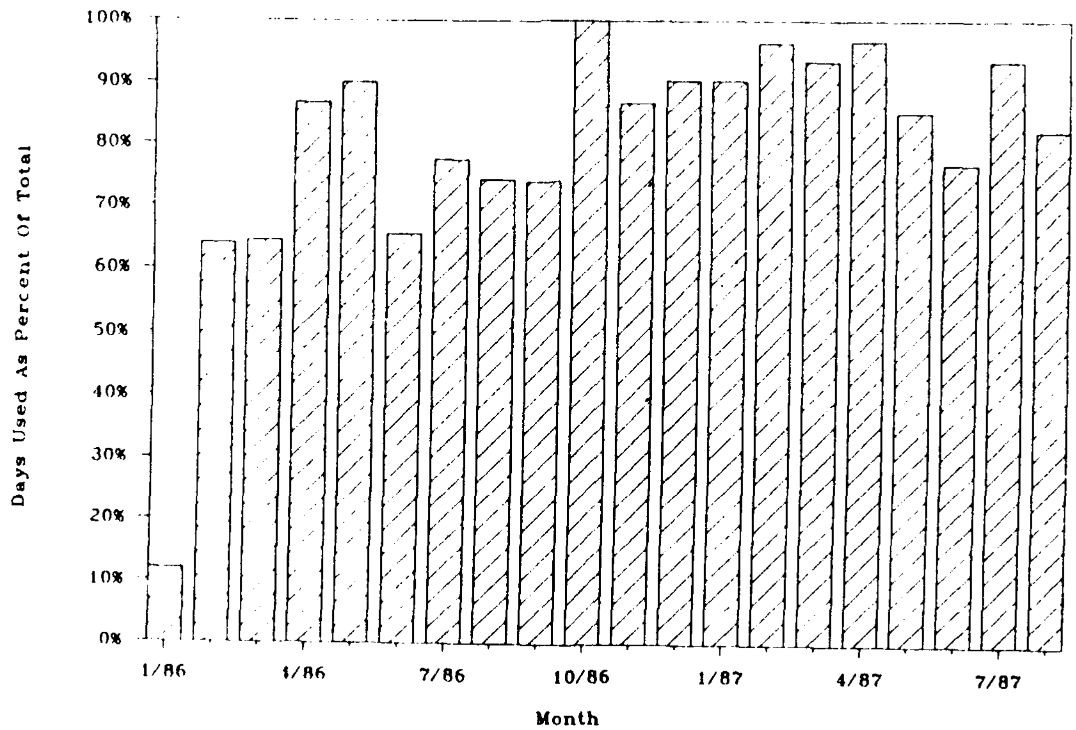

Figure C9. Data days used, dining hall, Bldg 1361.

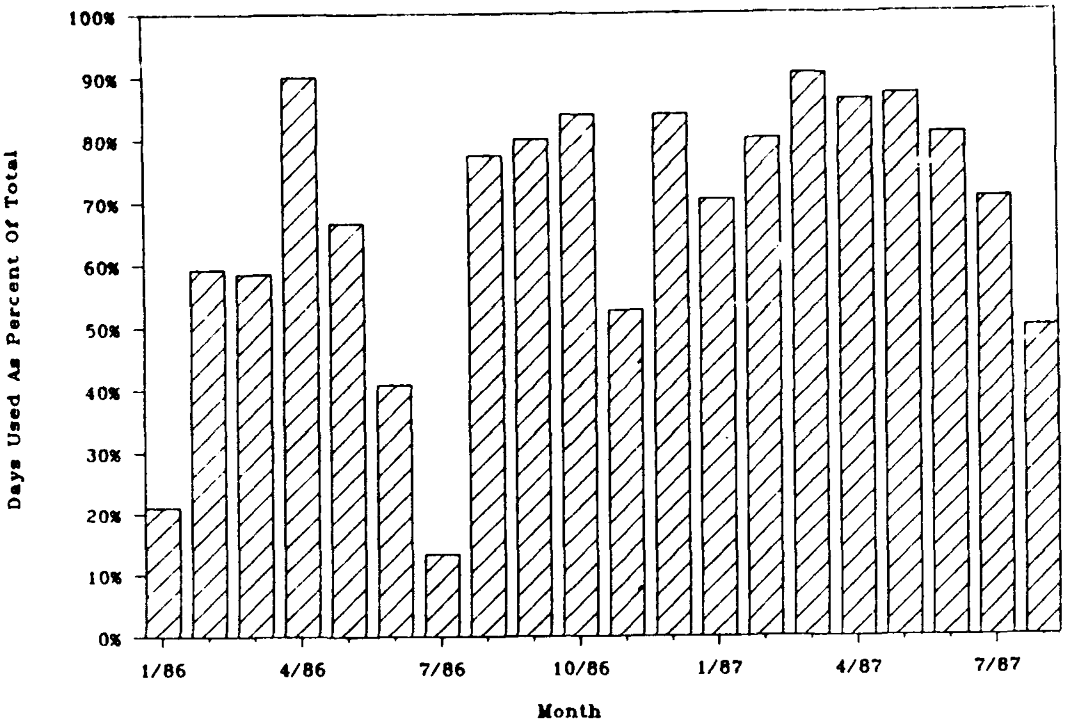

Figure C10. Data days used, dining hall, Bldg 1369.

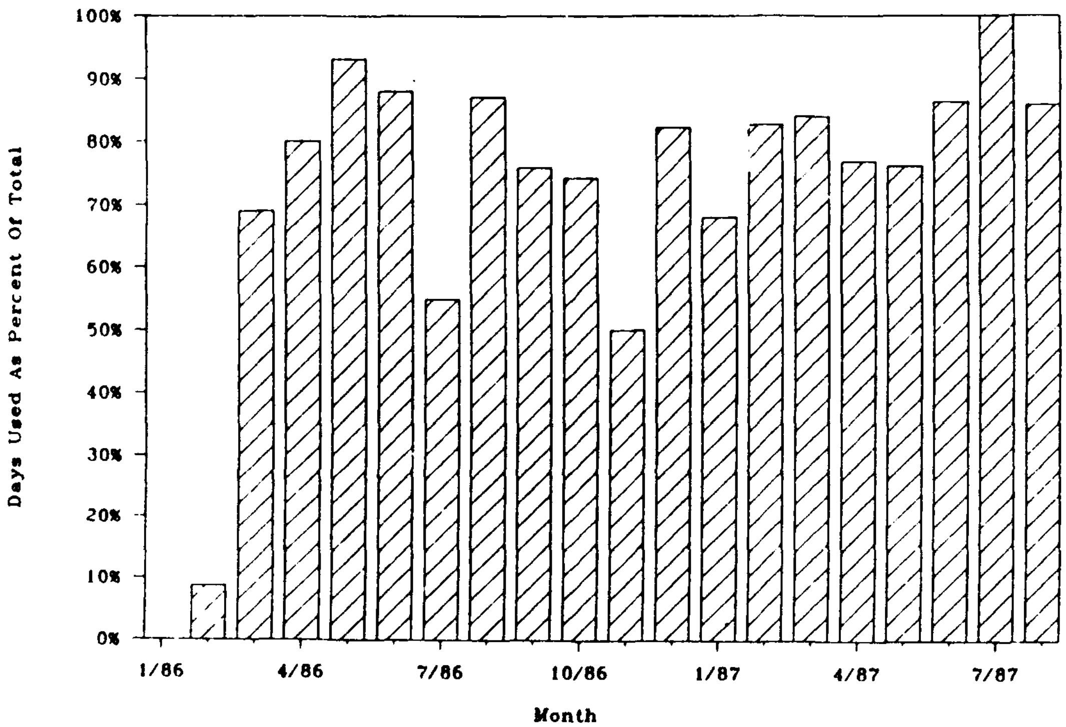

Figure C11. Data days used, dining hall, Bldg 1669.

APPENDIX D:

FINAL REGRESSION RUN OUTPUT--SUMMARY STATISTICS CORRELATION/COVARIANCE MATRICES

L-Shaped Barracks

```
The SPSS/PC+ system file is read from
    file d:\m\sys\mbas1.sys
The file was created on  8/19/88 at  9:07:23
and is titled L-Shaped - M - Replaced Data
The SPSS/PC+ system file contains
    649 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
-----------------------------------------------------------------------------
Page   2   Building 811 - prior to September, 1987 - Heating          11/22/88

This procedure was completed at 14:11:50
The raw data or transformation pass is proceeding
    263 cases are written to the uncompressed active file.
-----------------------------------------------------------------------------
Page   3   Building 811 - prior to September, 1987 - Heating          11/22/88


Number of Valid Observations (Listwise) =       157.00
```

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31707.10	153.31	31439.00	32020.00	263	
ELMSM	538.75	58.69	385.96	761.16	263	
GASMSM	18944227	10702191.6	177191.0	49081560	263	
BTU3SM	247486.13	354936.65	.00	1465530	260	
BTU2SM	1698000.5	2215299.61	-160.78	10632794	226	
BTU1SM	1986165.3	2618188.83	-67.81	10879172	204	
BTUDHWSM	2204936.1	541710.83	43091.53	4456639	263	
BTUCLGSM	83496.77	434445.16	-1291195	3597188	242	
T1EAV	74.54	9.20	58.73	131.18	263	
T1WAV	76.23	6.04	67.13	132.56	263	
T2EAV	76.33	5.07	65.77	117.40	263	
T2WAV	76.63	5.08	65.95	122.34	263	
T3EAV	74.98	5.18	59.45	114.83	263	
T3WAV	76.34	4.55	68.76	119.27	263	
TMHAV	73.54	6.44	56.95	104.15	263	
ELMN	24.00	.00	24.00	24.00	263	
GASMN	24.00	.00	24.00	24.00	263	
BTU3N	24.00	.00	24.00	24.00	263	
BTU2N	24.00	.00	24.00	24.00	263	
BTU1N	24.00	.00	24.00	24.00	263	
BTUDHWN	24.00	.00	24.00	24.00	263	
BTUCLGN	24.00	.00	24.00	24.00	263	
MOAT	45.97	13.86	7.38	72.23	263	
COUNT	23.86	.34	23	24	263	
OATAV	46.37	13.56	7.38	64.99	263	
MOATAV	45.85	13.80	7.38	66.68	263	
NOATAV	47.46	12.88	11.60	70.46	229	
OOATAV	46.21	13.19	11.15	70.28	217	
OATN	23.86	.35	23	24	263	
MOATN	23.54	1.52	7	24	263	
NOATN	19.87	8.31	0	24	263	
OOATN	18.43	9.40	0	24	263	
TALLMAV	75.51	4.70	68.54	120.25	263	

```
-----------------------------------------------------------------------------
Page   4   Building 811 - prior to September, 1987 - Heating          11/22/88

This procedure was completed at 14:12:19
```

Page 5 Building 811 - prior to September, 1987 - Heating 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 263

Correlation, Covariance:

	GASMSM	OATAV	TALLMAV	BTUDHWSM
GASMSM	1.000	-.880	.540	.270
	114536905698535	-127778938.002	27173399.732	1563006678580.8
OATAV	-.880	1.000	-.388	-.133
	-127778938.002	183.951	-24.777	-974896.333
TALLMAV	.540	-.388	1.000	-.115
	27173399.732	-24.777	22.116	-292101.360
BTUDHWSM	.270	-.133	-.115	1.000
	1563006678580.8	-974896.333	-292101.360	293450628725.29

Page 6 Building 811 - prior to September, 1987 - Heating 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. GASMSM

Beginning Block Number 1. Method: Enter OATAV TALLMAV BTUDHWSM

Variable(s) Entered on Step Number 1.. BTUDHWSM
2.. TALLMAV
3.. OATAV

Multiple R	.92721		
R Square	.85971	R Square Change	.85971
Adjusted R Square	.85809	F Change	529.07596
Standard Error	4031630.4347	Signif F Change	.0000

F = 529.07596 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWSM	3.98380	.47177	3.05480	4.91279	.20165	.94986	8.444	.0000
TALLMAV	620332.74852	58452.72645	505229.65249	735435.84455	.27259	.82099	10.613	.0000
OATAV	-589969.9091	20313.97879	-629971.4966	-549968.3216	-.74767	.81728	-29.043	.0000
(Constant)	-9327695.261	5193637.926	-19554828.22	899437.69252			-1.796	.0737

End Block Number 1 All requested variables entered.

Page 7 Building 811 - prior to September, 1987 - Heating 11/22/88

This procedure was completed at 14:12:28
The SPSS/PC+ system file is read from
file d:\m\sys\mbas1.sys
The file was created on 8/19/88 at 9:07:23
and is titled L-Shaped - M - Replaced Data
The SPSS/PC+ system file contains
649 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 8 Building 811 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:12:34
The raw data or transformation pass is proceeding
173 cases are written to the uncompressed active file.

Page 9 Building 811 - after August, 1987 - Heating 11/22/88

Number of Valid Observations (Listwise) = 146.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32156.03	66.88	32025.00	32262.00	173	
ELMSM	616.98	50.89	474.26	711.31	173	
GASMSM	16308861	7315806.73	3972367	32692200	173	
BTU3SM	401967.24	433050.07	.00	1483223	173	
BTU2SM	1999580.5	1696252.41	.00	8677462	172	
BTU1SM	2049273.6	1610422.53	.00	6174991	173	
BTUDHWSM	1766701.2	308991.79	1045247	2701786	173	
BTUCLGSM	918.39	12104.71	-328.96	159210.4	173	
T1EAV	71.42	6.63	37.18	109.45	173	
T1WAV	73.59	3.97	65.22	100.30	173	
T2EAV	72.82	3.48	65.99	102.50	173	
T2WAV	72.88	4.26	64.95	100.37	173	
T3EAV	71.10	3.66	62.92	99.49	173	
T3WAV	75.31	4.25	64.79	103.29	173	
TMHAV	73.01	5.26	53.18	105.16	173	
ELMN	24.00	.00	24.00	24.00	173	
GASMN	24.00	.00	24.00	24.00	173	
BTU3N	24.00	.00	24.00	24.00	173	
BTU2N	24.00	.00	24.00	24.00	173	
BTU1N	24.00	.00	24.00	24.00	173	
BTUDHWN	24.00	.00	24.00	24.00	173	
BTUCLGN	24.00	.00	24.00	24.00	173	
MOAT	40.43	12.45	14.50	87.38	173	
COUNT	23.79	.41	23	24	173	
OATAV	40.66	12.24	14.40	63.34	173	
MOATAV	40.33	12.04	14.50	62.42	173	
NOATAV	40.54	12.62	13.50	64.72	168	
OOATAV	41.99	11.99	8.14	63.82	151	
OATN	23.79	.41	23	24	173	
MOATN	23.46	1.68	7	24	173	
NOATN	22.05	5.29	0	24	173	
OOATN	18.83	8.84	0	24	173	
TALLMAV	72.88	3.59	61.28	101.27	173	

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This procedure was completed at 14:13:00

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 173

Correlation, Covariance:

	GASMSM	OATAV	TALLMAV	BTUDHWSM
GASMSM	1.000	-.856	.377	.270
	53521028111349	-76621530.857	9916763.440	609702597690.26
OATAV	-.856	1.000	-.099	-.221
	-76621530.857	149.748	-4.346	-836465.671
TALLMAV	.377	-.099	1.000	.154
	9916763.440	-4.346	12.918	171017.438
BTUDHWSM	.270	-.221	.154	1.000
	609702597690.26	-836465.671	171017.438	95475925303.985

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. GASMSM

Beginning Block Number 1. Method: Enter OATAV TALLMAV BTUDHWSM

Variable(s) Entered on Step Number 1.. BTUDHWSM
2.. TALLMAV
3.. OATAV

Multiple R	.90597		
R Square	.82079	R Square Change	.82079
Adjusted R Square	.81761	F Change	258.00407
Standard Error	3124408.3690	Signif F Change	.0000

F = 258.00407 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWSM	1.04869	.79802	-.52668	2.62407	.04429	.93343	1.314	.1906
TALLMAV	589369.83542	67236.52068	456638.18832	722101.48253	.28955	.97188	8.766	.0000
OATAV	-488705.1138	20007.88560	-528202.6902	-449207.5375	-.81746	.94677	-24.426	.0000
(Constant)	-8625503.538	5084459.991	-18662738.40	1411731.3222			-1.696	.0916

End Block Number 1 All requested variables entered.

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This procedure was completed at 14:13:06

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**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

N of Cases = 173

Correlation, Covariance:

	GASMSM	OATAV	TALLMAV	BTUDHWSM
GASMSM	1.000	-.856	.377	.270
	53521028111349	-76621530.857	9916763.440	609702597690.26
OATAV	-.856	1.000	-.099	-.221
	-76621530.857	149.748	-4.346	-836465.671
TALLMAV	.377	-.099	1.000	.154
	9916763.440	-4.346	12.918	171017.438
BTUDHWSM	.270	-.221	.154	1.000
	609702597690.26	-836465.671	171017.438	95475925303.985

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**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. GASMSM

Beginning Block Number 1. Method: Enter OATAV TALLMAV BTUDHWSM

Variable(s) Entered on Step Number 1.. BTUDHWSM
2.. TALLMAV
3.. OATAV

Multiple R	.90597		
R Square	.82079	R Square Change	.82079
Adjusted R Square	.81761	F Change	258.00407
Standard Error	3124408.3690	Signif F Change	.0000

F = 258.00407 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWSM	1.04869	.79802	-.52668	2.62407	.04429	.93343	1.314	.1906
TALLMAV	589369.83542	67236.52068	456638.18832	722101.48253	.28955	.97188	8.766	.0000
OATAV	-488705.1138	20007.88560	-528202.6902	-449207.5375	-.81746	.94677	-24.426	.0000
(Constant)	-8625503.538	5084459.991	-18662738.40	1411731.3222			-1.696	.0916

End Block Number 1 All requested variables entered.

Page 13 Building 811 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:13:06

```
The SPSS/PC+ system file is read from
    file d:\n\sys\nbas1.sys
The file was created on  8/19/88 at  9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
    632 cases, each consisting of
      35 variables (including system variables).
      35 variables will be used in this session.
--------------------------------------------------------------------------------
Page   2   Building 812 - prior to September, 1987 - Heating                11/22/88

This procedure was completed at 14:32:37
The raw data or transformation pass is proceeding
    292 cases are written to the uncompressed active file.
--------------------------------------------------------------------------------
Page   3   Building 812 - prior to September, 1987 - Heating                11/22/88
```

Number of Valid Observations (Listwise) = 246.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31749.97	136.57	31472.00	32020.00	292	
ELNSM	658.51	68.35	431.09	821.13	292	
GASNSM	29028153	13590440.1	3007600	58032260	292	
BTU3NSM	695023.99	754558.90	-152732	3900926	269	
BTU2NSM	3996119.0	3056827.40	.00	9661266	269	
BTU1NSM	4019770.5	3488546.90	.00	11008842	269	
BTUDHWNS	2365053.1	633829.77	513924.6	4463644	292	
BTUCLGNS	-308627.4	877180.12	-1203635	10372560	289	
T1ENAV	76.93	3.98	64.48	84.90	292	
T1WNAV	78.31	5.47	65.36	88.89	292	
T2ENAV	77.26	4.79	62.22	86.05	292	
T2WNAV	77.87	4.41	68.66	89.21	292	
T3ENAV	78.23	4.35	68.02	93.04	292	
T3WNAV	76.13	4.83	65.60	90.71	292	
TMHNAV	77.49	5.23	64.80	91.77	292	
ELNN	24.00	.00	24.00	24.00	292	
GASNN	24.00	.00	24.00	24.00	292	
BTU3NN	24.00	.00	24.00	24.00	292	
BTU2NN	24.00	.00	24.00	24.00	292	
BTU1NN	24.00	.00	24.00	24.00	292	
BTUDHWNN	24.00	.00	24.00	24.00	292	
BTUCLGNN	24.00	.00	24.00	24.00	292	
NOAT	47.35	11.92	11.60	65.39	292	
COUNT	23.83	.38	23	24	292	
OATAV	46.47	12.21	11.41	64.99	292	
MOATAV	45.56	12.85	10.59	72.11	278	
NOATAV	47.39	11.91	11.60	65.39	292	
OOATAV	45.40	12.45	11.15	65.97	271	
OATN	23.82	.38	23	24	292	
MOATN	21.60	6.10	0	24	292	
NOATN	23.65	.51	21	24	292	
OOATN	20.85	7.01	0	24	292	
TALLNAV	77.46	4.01	67.54	85.21	292	

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--------------------------------------------------------------------------------
Page   4   Building 812 - prior to September, 1987 - Heating                11/22/88

This procedure was completed at 14:33:08
```

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* * * * M U L T I P L E   R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 292

Correlation, Covariance:

	GASNSM	OATAV	TALLNAV	BTUDHWNS
GASNSM	1.000	-.649	.470	.538
	184700063313717	-107692184.877	25570365.360	4636966366231.3
OATAV	-.649	1.000	.162	-.394
	-107692184.877	149.037	7.940	-3050697.594
TALLNAV	.470	.162	1.000	.118
	25570365.360	7.940	16.057	299315.003
BTUDHWNS	.538	-.394	.118	1.000
	4636966366231.3	-3050697.594	299315.003	401740181535.62

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* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. GASNSM

Beginning Block Number 1. Method: Enter OATAV TALLNAV BTUDHWNS

Variable(s) Entered on Step Number
1.. BTUDHWNS
2.. TALLNAV
3.. OATAV

Multiple R	.89361		
R Square	.79854	R Square Change	.79854
Adjusted R Square	.79644	F Change	380.52841
Standard Error	6131616.5618	Signif F Change	.0000

F = 380.52841 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWNS	4.62995	.62987	3.39021	5.86968	.21593	.81060	7.351	.0000
TALLNAV	1865735.5961	92790.47603	1683102.1099	2048369.0823	.55011	.93451	20.107	.0000
OATAV	-727206.7868	32910.69090	-791982.7689	-662430.8048	-.65324	.80037	-22.096	.0000
(Constant)	-92651149.83	6996386.009	-106421683.4	-78880616.23			-13.243	.0000

End Block Number 1 All requested variables entered.

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This procedure was completed at 14:33:15
The SPSS/PC+ system file is read from
file d:\n\sys\nbas1.sys
The file was created on 8/19/88 at 9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
632 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 2 Building 813 - prior to September, 1987 - Heating 11/22/88

This procedure was completed at 14:42:27
The raw data or transformation pass is proceeding
289 cases are written to the uncompressed active file.

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Number of Valid Observations (Listwise) = 233.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31744.69	142.59	31416.00	32020.00	289	
ELOSM	590.17	44.37	433.34	783.82	289	
GASOSM	27453367	10913026.0	2698600	48000000	289	
BTU3OSM	363801.41	619999.80	-235512	2198591	254	
BTU2OSM	2788822.9	2015274.37	-183498	7235829	269	
BTU1OSM	4425423.5	3192089.47	.00	10819161	269	
BTUDHWOS	2208015.3	751401.47	711831.6	3925908	289	
BTUCLGOS	57312.41	180472.14	-317784	1504873	289	
T1EOAV	76.58	3.42	65.05	89.80	289	
T1WOAV	77.75	3.83	66.81	90.71	289	
T2EOAV	75.39	3.01	64.70	84.54	289	
T2WOAV	77.72	3.28	66.01	86.28	289	
T3EOAV	73.96	3.40	63.29	83.73	289	
T3WOAV	76.50	3.65	66.21	84.54	289	
TMHOAV	74.45	5.31	60.68	88.82	289	
ELON	24.00	.00	24.00	24.00	289	
GASON	24.00	.00	24.00	24.00	289	
BTU3ON	24.00	.00	24.00	24.00	289	
BTU2ON	24.00	.00	24.00	24.00	289	
BTU1ON	24.00	.00	24.00	24.00	289	
BTUDHWON	24.00	.00	24.00	24.00	289	
BTUCLGON	24.00	.00	24.00	24.00	289	
OOAT	45.39	12.72	11.15	65.16	289	
COUNT	23.87	.34	23	24	289	
OATAV	45.60	12.54	11.41	64.91	289	
MOATAV	44.95	13.15	10.59	72.11	274	
NOATAV	46.02	12.22	11.60	71.66	271	
OOATAV	45.43	12.71	11.15	65.50	289	
OATN	23.86	.35	23	24	289	
MOATN	21.37	6.35	0	24	289	
NOATN	21.48	6.35	0	24	289	
OOATN	23.66	.48	22	24	289	
TALLOAV	76.05	3.07	66.22	85.35	289	

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This procedure was completed at 14:42:58

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**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 289

Correlation, Covariance:

	GASOSM	OATAV	TALLOAV	BTUDHWOS
GASOSM	1.000 119094137430059	-.763 -104508687.667	.090 3005255.381	.560 4592434667865.3
OATAV	-.763 -104508687.667	1.000 157.328	.403 15.540	-.497 -4688507.505
TALLOAV	.090 3005255.381	.403 15.540	1.000 9.439	-.017 -39851.566
BTUDHWOS	.560 4592434667865.3	-.497 -4688507.505	-.017 -39851.566	1.000 564604171522.81

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**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. GASOSM

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number
1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.88535		
R Square	.78384	R Square Change	.78384
Adjusted R Square	.78156	F Change	344.48619
Standard Error	5100446.4729	Signif F Change	.0000

F = 344.48619 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	1.90000	.47390	.96722	2.83278	.13082	.71238	4.009	.0001
TALLOAV	1584589.0644	109875.4835	1368318.6632	1800859.4656	.44610	.79269	14.422	.0000
OATAV	-764174.4387	31019.11282	-825230.0606	-703118.8169	-.87831	.59671	-24.636	.0000
(Constant)	-62407437.95	7733159.461	-77628790.75	-47186085.14			-8.070	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 813 - prior to September, 1987 - Heating 11/22/88

This procedure was completed at 14:43:05
The SPSS/PC+ system file is read from
file d:\o\sys\obas1.sys
The file was created on 8/18/88 at 14:27:00
and is titled L-Shaped - O - Replaced Data
The SPSS/PC+ system file contains
584 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 8 Building 813 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:43:07
The raw data or transformation pass is proceeding
153 cases are written to the uncompressed active file.

Page 9 Building 813 - after August, 1987 - Heating 11/22/88

Number of Valid Observations (Listwise) = 141.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32149.64	72.34	32029.00	32262.00	153	
ELOSM	593.16	56.28	429.71	714.16	153	
GASOSM	25917199	10991464.0	3635900	46535400	153	
BTU3OSM	357536.01	592632.95	-53457.2	2036385	153	
BTU2OSM	2532132.8	2162263.75	-138694	7349898	153	
BTU1OSM	4784791.7	3079602.01	.00	10405000	153	
BTUDHWOS	1608734.5	470742.42	717176.2	2914026	153	
BTUCLGOS	-45735.91	263762.36	-1916580	112370.9	153	
T1EOAV	74.38	3.58	67.06	84.88	153	
T1WOAV	76.31	3.69	66.98	83.37	153	
T2EOAV	75.49	3.02	68.83	80.99	153	
T2WOAV	75.60	2.93	67.51	81.36	153	
T3EOAV	72.76	2.89	66.75	79.18	153	
T3WOAV	75.13	3.07	66.12	82.66	153	
TMHOAV	74.30	5.38	59.26	83.59	153	
ELON	24.00	.00	24.00	24.00	153	
GASON	24.00	.00	24.00	24.00	153	
BTU3ON	24.00	.00	24.00	24.00	153	
BTU2ON	24.00	.00	24.00	24.00	153	
BTU1ON	24.00	.00	24.00	24.00	153	
BTUDHWON	24.00	.00	24.00	24.00	153	
BTUCLGON	24.00	.00	24.00	24.00	153	
OOAT	42.77	12.13	12.85	63.34	153	
COUNT	23.80	.40	23	24	153	
OATAV	42.46	12.47	12.24	63.34	153	
MOATAV	41.69	12.13	14.64	61.95	144	
NOATAV	42.19	12.84	10.16	64.72	150	
OOATAV	42.83	12.16	12.85	63.34	153	
OATN	23.80	.40	23	24	153	
MOATN	21.56	6.34	0	24	153	
NOATN	22.42	4.72	0	24	153	
OOATN	23.69	.46	23	24	153	
TALLOAV	74.85	2.72	67.84	80.67	153	

Page 10 Building 813 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:43:32

*** * * * M U L T I P L E R E G R E S S I O N * * * ***

Listwise Deletion of Missing Data

N of Cases = 153

Correlation, Covariance:

	GASOSM	OATAV	TALLOAV	BTUDHWOS
GASOSM	1.000 120812281443539	-.862 -118100265.404	.196 5872619.454	.505 2611536567632.2
OATAV	-.862 -118100265.404	1.000 155.532	.197 6.671	-.433 -2544694.159
TALLOAV	.196 5872619.454	.197 6.671	1.000 7.410	-.098 -124967.387
BTUDHWOS	.505 2611536567632.2	-.433 -2544694.159	-.098 -124967.387	1.000 221598428225.48

*** * * * M U L T I P L E R E G R E S S I O N * * * ***

Equation Number 1 Dependent Variable.. GASOSM

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number
1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.95083		
R Square	.90407	R Square Change	.90407
Adjusted R Square	.90214	F Change	468.07596
Standard Error	3438426.5060	Signif F Change	.0000

F = 468.07596 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	3.91018	.65749	2.61097	5.20938	.16747	.81196	5.947	.0000
TALLOAV	1544064.0237	104499.3229	1337571.9839	1750556.0635	.38241	.96120	14.776	.0000
OATAV	-761586.5627	25190.54990	-811363.4214	-711809.7040	-.86412	.78810	-30.233	.0000
(Constant)	-63614755.30	7863985.387	-79154094.10	-48075416.50			-8.089	.0000

End Block Number 1 All requested variables entered.

This procedure was completed at 14:43:37

Variable Names for L-Shaped Barracks - Heating

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
ELMSM	kWh	Daily electricity consumption.
GASMSM	Btu	Daily gas consumption.
BTU3SM	Btu	Daily heating consumption for zone 3.
BTU2SM	Btu	Daily heating consumption for zone 2.
BTU1SM	Btu	Daily heating consumption for zone 1.
BTUDHWSM	Btu	Daily domestic hot water energy consumption.
BTUCLGSM	Btu	Daily cooling energy consumption.
T1EAV	°F	Daily average temperature, zone 1 east.
T1WAV	°F	Daily average temperature, zone 1 west.
T2EAV	°F	Daily average temperature, zone 2 east.
T2WAV	°F	Daily average temperature, zone 2 west.
T3EAV	°F	Daily average temperature, zone 3 east.
T3WAV	°F	Daily average temperature, zone 3 west.
TMHAV	°F	Daily average temperature, mess hall.
ELMN	None	Number of hourly values included in ELMSM.
GASMN	None	Number of hourly values included in GASMSM.
BTU3N	None	Number of hourly values included in BTU3SM.
BTU2N	None	Number of hourly values included in BTU2SM.
BTU1N	None	Number of hourly values included in BTU1SM.
BTUDHWN	None	Number of hourly values included in BTUDHWSM.
BTUCLGN	None	Number of hourly values included in BTUCLGSM.
MOAT	°F	Daily average outdoor air temperature, from building 811 data file.
COUNT	None	Count of hourly data points included in daily total.
OATAV	°F	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
MOATAV	°F	Daily average outdoor air temperature, building 811, from outdoor air temperature file.
NOATAV	°F	Daily average outdoor air temperature, building 812, from outdoor air temperature file.
OOATAV	°F	Daily average outdoor air temperature, building 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.
MOATN	None	Number of hourly values included in MOATAV.
NOATN	None	Number of hourly values included in NOATAV.
OOATN	None	Number of hourly values included in OOATAV.
BTUHTM	Btu	Total daily heating consumption, sum of BTU1SM, BTU2SM and BTU3SM.
TALLMAV	°F	Average of T1EAV, T1WAV, T2EAV, T2WAV, T3EAV, T3WAV, and TMHAV.

The variable names listed above are those used for building 811. Buildings 812 and 813 used similar names, except that an N or an O was added to the name for buildings 812 and 813, respectively.

Data Included If: Heating > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F,
Date after 8/25/86, and
For building 811, date not 1/2/87.

The SPSS/PC+ system file is read from
    file d:\m\sys\mbas1.sys
The file was created on 8/19/88 at 9:07:23
and is titled L-Shaped - M - Replaced Data
The SPSS/PC+ system file contains
    649 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.

This procedure was completed at 14:14:24
The raw data or transformation pass is proceeding
     99 cases are written to the uncompressed active file.

Number of Valid Observations (Listwise) = 91.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31785.93	76.57	31679.00	31905.00	99	
ELMSM	552.64	35.18	459.29	630.50	99	
GASMSM	22637824	9660799.12	8569600	49081560	99	
BTU3SM	321364.84	392061.47	.00	1275596	99	
BTU2SM	3246221.3	2386604.00	.00	10632794	99	
BTU1SM	3464131.4	3018107.86	6786.39	10879172	99	
BTUDHWSM	2236005.4	414850.37	968427.3	2977585	99	
BTUCLGSM	6614.18	305670.42	-1291195	979876.6	99	
T1EAV	77.30	10.95	58.73	114.07	99	
T1WAV	78.28	4.89	67.53	93.87	99	
T2EAV	78.04	4.90	71.15	100.70	99	
T2WAV	78.02	4.11	69.25	99.24	99	
T3EAV	76.19	4.89	67.92	96.18	99	
T3WAV	77.33	4.12	72.35	102.09	99	
TMHAV	73.18	5.61	57.30	104.12	99	
ELMN	24.00	.00	24.00	24.00	99	
GASMN	24.00	.00	24.00	24.00	99	
BTU3N	24.00	.00	24.00	24.00	99	
BTU2N	24.00	.00	24.00	24.00	99	
BTU1N	24.00	.00	24.00	24.00	99	
BTUDHWN	24.00	.00	24.00	24.00	99	
BTUCLGN	24.00	.00	24.00	24.00	99	
MOAT	42.12	12.68	10.59	72.23	99	
COUNT	23.81	.40	23	24	99	
OATAV	42.75	12.01	11.41	64.24	99	
MOATAV	41.91	12.36	10.59	63.69	99	
NOATAV	43.80	11.77	12.38	63.99	99	
OOATAV	41.79	12.34	11.15	64.49	91	
OATN	23.81	.40	23	24	99	
MOATN	23.44	1.74	7	24	99	
NOATN	23.38	1.65	10	24	99	
OOATN	20.76	7.22	0	24	99	
BTUHTM	7031717.6	5634671.15	161381.4	22508955	99	
TALLMAV	76.90	4.56	69.78	98.94	99	

This procedure was completed at 14:14:46

Page 5 Building 811 (86/87) - 6th Regression - BTU Heat 11/22/88

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

N of Cases = 99

Correlation, Covariance:

	BTUHTM	OATAV	TALLMAV	BTUDHWSM
BTUHTM	1.000	-.864	.560	-.155
	31749518933395	-58433687.561	14402816.359	-363127196718.7
OATAV	-.864	1.000	-.351	.098
	-58433687.561	144.187	-19.241	487057.301
TALLMAV	.560	-.351	1.000	-.289
	14402816.359	-19.241	20.827	-546237.159
BTUDHWSM	-.155	.098	-.289	1.000
	-363127196718.7	487057.301	-546237.159	172100829847.80

Page 6 Building 811 (86/87) - 6th Regression - BTU Heat 11/22/88

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. BTUHTM

Beginning Block Number 1. Method: Enter OATAV TALLMAV BTUDHWSM

Variable(s) Entered on Step Number 1.. BTUDHWSM
2.. OATAV
3.. TALLMAV

Multiple R	.90617		
R Square	.82114	R Square Change	.82114
Adjusted R Square	.81550	F Change	145.38526
Standard Error	2420308.1293	Signif F Change	.0000

F = 145.38526 Signif F = .0000

Variables in the Equation

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWSM	.05293	.61552	-1.16904	1.27489	3.8968E-03	.91674	.086	.9317
OATAV	-356982.6620	21745.36854	-400152.6782	-313812.6459	-.76075	.87671	-16.416	.0000
TALLMAV	363148.19391	59471.20829	245082.91407	481213.47375	.29412	.81148	6.106	.0000
(Constant)	-5751442.665	5482825.761	-16636228.37	5133343.0385			-1.049	.2968

End Block Number 1 All requested variables entered.

Page 7 Building 811 (86/87) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:14:50
The SPSS/PC+ system file is read from
file d:\m\sys\mbas1.sys
The file was created on 8/19/88 at 9:07:23
and is titled L-Shaped - M - Replaced Data
The SPSS/PC+ system file contains
649 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 8 Building 811 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:14:53
The raw data or transformation pass is proceeding
153 cases are written to the uncompressed active file.

Page 9 Building 811 (87/88) - 6th Regression - BTU Heat 11/22/88

Number of Valid Observations (Listwise) = 132.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32163.27	60.02	32064.00	32261.00	153	
ELMSM	618.82	52.08	474.26	711.31	153	
GASMSM	17796649	6403801.56	6339307	32692200	153	
BTU3SM	454360.19	433939.69	.00	1483223	153	
BTU2SM	2247894.4	1635565.82	40804.08	8677462	153	
BTU1SM	2316304.5	1521101.60	62190.41	6174991	153	
BTUDHWSM	1778269.6	309231.77	1045247	2701786	153	
BTUCLGSM	.00	.00	.00	.00	153	
T1EAV	71.48	6.67	37.18	109.45	153	
T1WAV	73.63	3.51	65.22	81.33	153	
T2EAV	72.62	2.71	65.99	80.07	153	
T2WAV	72.73	3.86	64.95	81.15	153	
T3EAV	70.62	2.83	62.92	79.13	153	
T3WAV	74.96	3.76	64.79	84.74	153	
TMHAV	73.20	4.76	53.18	82.27	153	
ELMN	24.00	.00	24.00	24.00	153	
GASMN	24.00	.00	24.00	24.00	153	
BTU3N	24.00	.00	24.00	24.00	153	
BTU2N	24[illegible]	.00	24.00	24.00	153	
BTU1N	24.00	.00	24.00	24.00	153	
BTUDHWN	24.00	.00	24.00	24.00	153	
BTUCLGN	24.00	.00	24.00	24.00	153	
MOAT	38.20	10.97	14.50	56.05	153	
COUNT	23.78	.41	23	24	153	
OATAV	38.53	11.15	14.40	56.73	153	
MOATAV	38.25	11.00	14.50	56.05	153	
NOATAV	38.55	11.47	13.50	59.67	151	
OOATAV	39.90	10.99	8.14	57.64	133	
OATN	23.78	.42	23	24	153	
MOATN	23.69	.48	22	24	153	
NOATN	22.46	4.33	0	24	153	
OOATN	18.69	9.00	0	24	153	
BTUHTM	5018559.1	3182717.49	203698.1	13104562	153	
TALLMAV	72.75	2.97	61.28	80.76	153	

Page 10 Building 811 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:15:21

Page 11 Building 811 (87/88) - 6th Regression - BTU Heat 11/22/88

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

N of Cases = 153

Correlation, Covariance:

	BTUHTM	OATAV	TALLMAV	BTUDHWSM
BTUHTM	1.000 10129690623418	-.869 -30837083.686	.507 4795091.694	.189 186246843145.41
OATAV	-.869 -30837083.686	1.000 124.416	-.272 -9.018	-.223 -769128.588
TALLMAV	.507 4795091.694	-.272 -9.018	1.000 8.830	.056 51599.735
BTUDHWSM	.189 186246843145.41	-.223 -769128.588	.056 51599.735	1.000 95624287817.723

Page 12 Building 811 (87/88) - 6th Regression - BTU Heat 11/22/88

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. BTUHTM

Beginning Block Number 1. Method: Enter OATAV TALLMAV BTUDHWSM

Variable(s) Entered on Step Number 1.. BTUDHWSM
2.. TALLMAV
3.. OATAV

Multiple R	.91305		
R Square	.83367	R Square Change	.83367
Adjusted R Square	.83032	F Change	248.92946
Standard Error	1311043.7142	Signif F Change	.0000

F = 248.92946 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWSM	-.03397	.35277	-.73105	.66310	-3.301E-03	.95026	-.096	.9234
TALLMAV	313087.38366	37189.86238	239599.72529	386575.04203	.29231	.92596	8.419	.0000
OATAV	-225372.2864	10147.32127	-245423.5270	-205321.0458	-.78984	.88270	-22.210	.0000
(Constant)	-9014913.041	2926418.719	-14797555.01	-3232271.071			-3.081	.0025

End Block Number 1 All requested variables entered.

Page 13 Building 811 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:15:26

The SPSS/PC+ system file is read from
    file d:\n\sys\nbas1.sys
The file was created on 8/19/88 at 9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
    632 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.

Page 2 Building 812 (86/87) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:36:19
The raw data or transformation pass is proceeding
    177 cases are written to the uncompressed active file.

Page 3 Building 812 (86/87) - 6th Regression - BTU Heat 11/22/88

Number of Valid Observations (Listwise) = 163.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31784.38	63.28	31679.00	31918.00	177	
ELNSM	682.88	58.58	476.53	821.13	177	
GASNSM	34207038	11098490.1	4627275	58032260	177	
BTU3NSM	927000.51	672482.62	-152732	2499657	177	
BTU2NSM	5630361.1	2202906.78	114527.9	9661266	177	
BTU1NSM	5630924.0	3051058.72	253931.8	11008842	177	
BTUDHWNS	2579942.6	541405.83	868496.5	3813281	177	
BTUCLGNS	-577396.0	290908.61	-1203635	378354.9	177	
T1ENAV	77.77	3.11	65.82	84.90	177	
T1WNAV	78.07	4.68	67.20	88.89	177	
T2ENAV	78.52	3.14	69.09	84.11	177	
T2WNAV	77.16	4.35	68.66	89.21	177	
T3ENAV	76.32	2.93	68.02	81.57	177	
T3WNAV	75.46	5.22	65.60	90.71	177	
TMHNAV	76.79	4.15	64.80	88.24	177	
ELNN	24.00	.00	24.00	24.00	177	
GASNN	24.00	.00	24.00	24.00	177	
BTU3NN	24.00	.00	24.00	24.00	177	
BTU2NN	24.00	.00	24.00	24.00	177	
BTU1NN	24.00	.00	24.00	24.00	177	
BTUDHWNN	24.00	.00	24.00	24.00	177	
BTUCLGNN	24.00	.00	24.00	24.00	177	
NOAT	41.04	10.16	11.60	65.12	177	
COUNT	23.78	.42	23	24	177	
OATAV	39.77	10.08	11.41	63.05	177	
MOATAV	38.56	10.51	10.59	61.57	170	
NOATAV	41.09	10.14	11.60	65.12	177	
OOATAV	38.85	10.02	11.15	62.93	170	
OATN	23.77	.42	23	24	177	
MOATN	21.67	5.95	0	24	177	
NOATN	23.67	.47	23	24	177	
OOATN	21.90	5.59	0	24	177	
BTUHTN	12188286	5007612.59	368459.7	22289010	177	
TALLNAV	77.16	3.53	67.54	84.31	177	

Page 4 Building 812 (86/87) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:36:45

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 177

Correlation, Covariance:

	BTUHTN	OATAV	TALLNAV	BTUDHWNS
BTUHTN	1.000 25076183841013	-.754 -38031040.265	.395 6979885.883	.201 544035631712.64
OATAV	-.754 -38031040.265	1.000 101.571	.137 4.855	-.163 -888642.193
TALLNAV	.395 6979885.883	.137 4.855	1.000 12.427	.117 223527.726
BTUDHWNS	.201 544035631712.64	-.163 -888642.193	.117 223527.726	1.000 293120277094.91

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUHTN

Beginning Block Number 1. Method: Enter OATAV TALLNAV BTUDHWNS

Variable(s) Entered on Step Number
1.. BTUDHWNS
2.. TALLNAV
3.. OATAV

Multiple R	.90611		
R Square	.82103	R Square Change	.82103
Adjusted R Square	.81793	F Change	264.55605
Standard Error	2136723.6115	Signif F Change	.0000

F = 264.55605 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWNS	.06938	.30463	-.53189	.67064	7.5007E-03	.95368	.228	.8201
TALLNAV	719929.71862	46597.78885	627956.33878	811903.09847	.50681	.96137	15.450	.0000
OATAV	-408236.2274	16405.92801	-440617.7778	-375854.6770	-.82161	.94888	-24.883	.0000
(Constant)	-27302473.42	3553879.218	-34317018.34	-20287928.49			-7.682	.0000

End Block Number 1 All requested variables entered.

```
Page  7  Building 812 (86/87) - 6th Regression - BTU Heat            11/22/88

This procedure was completed at 14:36:51
The SPSS/PC+ system file is read from
    file d:\n\sys\nbas1.sys
The file was created on  8/19/88 at  9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
    632 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
```

```
Page  8  Building 812 (87/88) - 6th Regression - BTU Heat            11/22/88

This procedure was completed at 14:36:56
The raw data or transformation pass is proceeding
    135 cases are written to the uncompressed active file.
```

```
Page  9  Building 812 (87/88) - 6th Regression - BTU Heat            11/22/88
```

Number of Valid Observations (Listwise) = 108.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32149.92	52.04	32066.00	32260.00	135	
ELNSM	646.23	70.62	346.99	766.46	135	
GASNSM	33059221	10336185.5	4212700	47029800	135	
BTU3NSM	1168447.9	705420.41	-76196.5	2307655	135	
BTU2NSM	5737943.7	2802421.36	150559.7	10288930	135	
BTU1NSM	6738175.9	3539960.28	.00	10816812	135	
BTUDHWNS	2158458.8	501197.14	308156.2	3225652	135	
BTUCLGNS	-110.33	166.14	-484.34	.00	135	
T1ENAV	79.10	3.41	68.57	84.29	135	
T1WNAV	79.82	4.73	67.02	87.83	135	
T2ENAV	77.73	3.04	68.74	83.01	135	
T2WNAV	75.64	3.57	67.79	84.99	135	
T3ENAV	76.72	2.90	68.75	82.35	135	
T3WNAV	73.28	3.38	66.83	81.08	135	
TMHNAV	76.87	4.17	67.38	85.27	135	
ELNN	24.00	.00	24.00	24.00	135	
GASNN	24.00	.00	24.00	24.00	135	
BTU3NN	24.00	.00	24.00	24.00	135	
BTU2NN	24.00	.00	24.00	24.00	135	
BTU1NN	24.00	.00	24.00	24.00	135	
BTUDHWNN	24.00	.00	24.00	24.00	135	
BTUCLGNN	24.00	.00	24.00	24.00	135	
NOAT	35.90	11.27	10.16	56.43	135	
COUNT	23.87	.33	23	24	135	
OATAV	36.05	10.84	12.24	56.27	135	
MOATAV	36.41	10.39	14.64	56.05	127	
NOATAV	35.94	11.29	10.16	56.27	135	
OOATAV	37.21	10.93	8.14	56.88	109	
OATN	23.85	.36	23	24	135	
MOATN	21.23	6.67	0	24	135	
NOATN	23.81	.40	23	24	135	
OOATN	17.19	10.11	0	24	135	
BTUHTN	13644567	6882207.36	150559.7	23053367	135	
TALLNAV	77.02	2.86	68.46	80.56	135	

Page 2 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:48:55
The raw data or transformation pass is proceeding
196 cases are written to the uncompressed active file.

Page 3 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

Number of Valid Observations (Listwise) = 190.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31803.49	66.44	31686.00	31915.00	196	
ELOSM	601.18	30.43	512.86	667.33	196	
GASOSM	31316041	7183653.73	12298200	46308800	196	
BTU3OSM	383386.34	635077.48	.00	2094241	196	
BTU2OSM	3673405.3	1477476.80	39243.01	7235829	196	
BTU1OSM	5930563.0	2266924.54	671572.0	10819161	196	
BTUDHWOS	2571335.8	613224.51	1158197	3925908	196	
BTUCLGOS	41573.16	93177.23	.00	395969.8	196	
T1EOAV	77.78	2.71	65.05	89.80	196	
T1WOAV	78.08	2.85	69.88	88.52	196	
T2EOAV	76.00	2.63	64.70	84.54	196	
T2WOAV	78.18	3.22	66.01	86.28	196	
T3EOAV	73.93	3.35	63.29	83.73	196	
T3WOAV	75.98	3.59	67.02	84.37	196	
TMHOAV	74.06	5.64	63.38	88.82	196	
ELON	24.00	.00	24.00	24.00	196	
GASON	24.00	.00	24.00	24.00	196	
BTU3ON	24.00	.00	24.00	24.00	196	
BTU2ON	24.00	.00	24.00	24.00	196	
BTU1ON	24.00	.00	24.00	24.00	196	
BTUDHWON	24.00	.00	24.00	24.00	196	
BTUCLGON	24.00	.00	24.00	24.00	196	
OOAT	41.06	12.05	11.15	65.16	196	
COUNT	23.84	.37	23	24	196	
OATAV	41.30	11.82	11.41	64.84	196	
MOATAV	40.16	12.24	10.59	64.11	190	
NOATAV	42.50	11.73	11.60	65.39	196	
OOATAV	41.12	12.07	11.15	65.50	196	
OATN	23.84	.37	23	24	196	
MOATN	21.73	5.74	0	24	196	
NOATN	23.32	2.32	2	24	196	
OOATN	23.63	.49	22	24	196	
BTUHTO	9987354.7	3823943.26	837605.8	18951419	196	
TALLOAV	76.29	2.95	66.22	85.85	196	

Page 4 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:49:22

Page 5 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 196

Correlation, Covariance:

	BTUHTO	OATAV	TALLOAV	BTUDHWOS
BTUHTO	1.000	-.830	-.392	.213
	14622542058514	-37526391.150	-4418162.463	499434890737.57
OATAV	-.830	1.000	.729	-.229
	-37526391.150	139.783	25.398	-1660637.710
TALLOAV	-.392	.729	1.000	-.165
	-4418162.463	25.398	8.675	-297430.101
BTUDHWOS	.213	-.229	-.165	1.000
	499434890737.57	-1660637.710	-297430.101	376044301737.92

Page 6 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUHTO

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number 1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.88685		
R Square	.78651	R Square Change	.78651
Adjusted R Square	.78317	F Change	235.77375
Standard Error	1780620.2928	Signif F Change	.0000

F = 235.77375 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	.14333	.21362	-.27801	.56468	.02299	.94752	.671	.5030
TALLOAV	591010.90087	63281.86777	466193.96680	715827.83494	.45522	.46803	9.339	.0000
OATAV	-374144.8999	15974.25577	-405652.4659	-342637.3338	-1.15679	.45584	-23.422	.0000
(Constant)	-20014694.21	4423532.565	-28739654.33	-11289734.09			-4.525	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:49:28
The SPSS/PC+ system file is read from
file d:\o\sys\obas1.sys
The file was created on 8/18/88 at 14:27:00
and is titled L-Shaped - 0 - Replaced Data
The SPSS/PC+ system file contains
584 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 8 Building 813 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:49:31
The raw data or transformation pass is proceeding
126 cases are written to the uncompressed active file.

Page 9 Building 813 (87/88) - 6th Regression - BTU Heat 11/22/88

Number of Valid Observations (Listwise) = 125.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32166.71	60.93	32071.00	32260.00	126	
ELOSM	596.98	55.60	429.71	714.16	126	
GASOSM	29214703	8670432.62	8240000	46535400	126	
BTU3OSM	434150.88	627333.64	-53457.2	2036385	126	
BTU2OSM	3074732.7	2000892.60	-138694	7349898	126	
BTU1OSM	5810104.2	2351095.83	679395.0	10405000	126	
BTUDHWOS	1696766.8	456259.34	717176.2	2914026	126	
BTUCLGOS	.00	.00	.00	.00	126	
T1EOAV	74.47	3.60	67.06	84.88	126	
T1WOAV	76.82	3.28	66.98	83.37	126	
T2EOAV	76.07	2.69	69.09	80.99	126	
T2WOAV	76.17	2.67	67.51	81.36	126	
T3EOAV	72.80	3.02	66.75	79.18	126	
T3WOAV	75.28	3.25	66.12	82.66	126	
TMHOAV	74.07	5.43	59.26	83.32	126	
ELON	24.00	.00	24.00	24.00	126	
GASON	24.00	.00	24.00	24.00	126	
BTU3ON	24.00	.00	24.00	24.00	126	
BTU2ON	24.00	.00	24.00	24.00	126	
BTU1ON	24.00	.00	24.00	24.00	126	
BTUDHWON	24.00	.00	24.00	24.00	126	
BTUCLGON	24.00	.00	24.00	24.00	126	
OOAT	39.85	11.15	12.85	59.64	126	
COUNT	23.77	.42	23	24	126	
OATAV	39.42	11.40	12.24	59.78	126	
MOATAV	39.28	11.07	14.64	58.25	125	
NOATAV	39.31	11.70	10.16	61.45	126	
OOATAV	39.91	11.19	12.85	59.64	126	
OATN	23.77	.42	23	24	126	
MOATN	22.96	3.52	0	24	126	
NOATN	22.90	3.28	1	24	126	
OOATN	23.67	.47	23	24	126	
BTUHTO	9318987.7	4406707.54	1367389	17754898	126	
TALLOAV	75.10	2.61	67.84	80.67	126	

Page 10 Building 813 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:49:55

Page 11 Building 813 (87/88) - 6th Regression - BTU Heat 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 126

Correlation, Covariance:

	BTUHTO	OATAV	TALLOAV	BTUDHWOS
BTUHTO	1.000 19419071370893	-.815 -40981914.488	.024 278343.822	.304 611173497477.66
OATAV	-.815 -40981914.488	1.000 130.072	.412 12.261	-.283 -1472696.968
TALLOAV	.024 278343.822	.412 12.261	1.000 6.792	-.186 -221148.212
BTUDHWOS	.304 611173497477.66	-.283 -1472696.968	-.186 -221148.212	1.000 208172584834.07

Page 12 Building 813 (87/88) - 6th Regression - BTU Heat 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. BTUHTO

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number 1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.91284		
R Square	.83328	R Square Change	.83328
Adjusted R Square	.82918	F Change	203.25752
Standard Error	1821298.6733	Signif F Change	.0000

F = 203.25752 Signif F = .0000

Variables in the Equation

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	1.09124	.37343	.35200	1.83049	.11298	.91413	2.922	.0041
TALLOAV	750658.97821	68830.77734	614401.57464	886916.38178	.44396	.82464	10.906	.0000
OATAV	-373473.8772	16113.41831	-405371.9993	-341575.7550	-.96658	.78576	-23.178	.0000
(Constant)	-34180655.30	5074049.458	-44225243.37	-24136067.24			-6.736	.0000

End Block Number 1 All requested variables entered.

Page 13 Building 813 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:50:00

Variable Names for Rolling-Pin Barracks

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
T1QAV	°F	Daily average temperature, 1st floor.
T2QAV	°F	Daily average temperature, 2nd floor.
T3QAV	°F	Daily average temperature, 3rd floor.
TDHWQAV	°F	Daily average domestic hot water temperature.
THWSQAV	°F	Daily average heating hot water supply temperature.
THWRQAV	°F	Daily average heating hot water return temperature.
TCWSQAV	°F	Daily average chilled water supply temperature.
TCWRQAV	°F	Daily average chilled water return temperature.
ELQSM	kWh	Daily electricity consumption.
BTUHTQSM	Btu	Daily heating consumption.
BTUHWQSM	Btu	Daily domestic hot water energy consumption.
BTUCLQSM	Btu	Daily cooling energy consumption.
ELQN	None	Number of hourly values included in ELMSM.
BTUHTQN	None	Number of hourly values included in BTUHTQSM.
BTUHWQN	None	Number of hourly values included in BTUHWQSM.
BTUCLQN	None	Number of hourly values included in BTUCLQSM.
COUNT	None	Count of hourly data points included in daily total.
OATAV	°F	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
MOATAV	°F	Daily average outdoor air temperature, building 811, from outdoor air temperature file.
NOATAV	°F	Daily average outdoor air temperature, building 812, from outdoor air temperature file.
OOATAV	°F	Daily average outdoor air temperature, building 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.
MOATN	None	Number of hourly values included in MOATAV.
NOATN	None	Number of hourly values included in NOATAV.
OOATN	None	Number of hourly values included in OOATAV.
TALLQAV	°F	Average of T1QAV, T2QAV, and T3QAV.

The variable names listed above are those used for building 1363. Buildings 1663, 1666 and 1667 used similar names, except that the Q in the names was replaced with an S, T, or U for buildings 1663, 1666 and 1667, respectively.

Data Included If: Gas > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F,
For building 1363, date not 4/2-3/87, and
For building 1667, date not 11/28/86-12/1/86.

The SPSS/PC+ system file is read from
file d:\q\sys\qbas1.sys
The file was created on 9/7/88 at 9:02:19
and is titled Rolling Pin - Q - Replaced Data
The SPSS/PC+ system file contains
468 cases, each consisting of
29 variables (including system variables).
29 variables will be used in this session.

This procedure was completed at 14:51:19
The raw data or transformation pass is proceeding
236 cases are written to the uncompressed active file.

Number of Valid Observations (Listwise) = 216.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31724.34	140.61	31439.00	31904.00	236	
T1QAV	76.08	3.16	67.06	83.75	236	
T2QAV	70.79	3.33	64.15	82.63	236	
T3QAV	74.63	3.90	65.05	86.03	236	
TDHWQAV	54.95	8.11	44.53	85.62	236	
THWSQAV	146.31	31.29	84.42	206.08	236	
THWRQAV	139.58	28.80	80.47	193.93	236	
TCWSQAV	76.82	2.73	69.40	84.90	236	
TCWRQAV	78.87	2.74	73.12	87.20	236	
ELQSM	419.27	92.76	206.58	599.52	236	
BTUHTQSM	6029675.4	3652638.36	138533.1	14835127	236	
BTUHWQSM	661637.19	856467.01	.00	4199102	236	
BTUCLQSM	26632.55	117736.62	.00	768394.1	236	
ELQN	24.00	.00	24.00	24.00	236	
BTUHTQN	24.00	.00	24.00	24.00	236	
BTUHWQN	24.00	.00	24.00	24.00	236	
BTUCLQN	24.00	.00	24.00	24.00	236	
COUNT	23.82	.40	22	24	236	
OATAV	40.89	12.26	7.38	64.84	236	
MOATAV	40.02	12.64	7.38	64.11	233	
NOATAV	42.59	11.53	11.60	67.89	220	
OOATAV	41.30	11.80	11.15	65.50	222	
OATN	23.80	.44	21	24	236	
MOATN	22.45	4.37	0	24	236	
NOATN	21.17	6.66	0	24	235	
OOATN	21 58	6.26	0	24	236	
TALLQAV	73.84	3.20	66.98	83.92	236	

This procedure was completed at 14:51:40

Page 5 Building 1363 - Heating - 6th Regressions 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 236

Correlation, Covariance:

	BTUHTQSM	OATAV	TALLQAV	BTUHWQSM
BTUHTQSM	1.000 13341767023692	-.842 -37688336.361	.416 4860675.639	-.164 -514083815235.2
OATAV	-.842 -37688336.361	1.000 150.273	-.329 -12.905	-.137 -1436930.923
TALLQAV	.416 4860675.639	-.329 -12.905	1.000 10.212	-.235 -642788.072
BTUHWQSM	-.164 -514083815235.2	-.137 -1436930.923	-.235 -642788.072	1.000 733535730739.16

Page 6 Building 1363 - Heating - 6th Regressions 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. BTUHTQSM

Beginning Block Number 1. Method: Enter OATAV TALLQAV BTUHWQSM

Variable(s) Entered on Step Number 1.. BTUHWQSM
2.. OATAV
3.. TALLQAV

Multiple R	.89019		
R Square	.79244	R Square Change	.79244
Adjusted R Square	.78976	F Change	295.25558
Standard Error	1674807.9578	Signif F Change	.0000

F = 295.25558 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUHWQSM	-1.12584	.13496	-1.39174	-.85993	-.26399	.89336	-8.342	.0000
OATAV	-254381.5562	9707.34064	-273507.3666	-235255.7457	-.85373	.84291	-26.205	.0000
TALLQAV	83651.06523	37948.31178	8883.70665	158418.42381	.07319	.81162	2.204	.0285
(Constant)	10998624.623	3004945.409	5078154.9001	16919094.347			3.660	.0003

End Block Number 1 All requested variables entered.

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This procedure was completed at 14:51:46

The SPSS/PC+ system file is read from
file d:\s\sys\sbas1.sys
The file was created on 9/7/88 at 15:10:59
and is titled Rolling Pin - S - Replaced Data
The SPSS/PC+ system file contains
36' cases, each consisting of
29 variables (including system variables).
29 variables will be used in this session.

This procedure was completed at 14:54:06
The raw data or transformation pass is proceeding
196 cases are written to the uncompressed active file.

Number of Valid Observations (Listwise) = 187.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31785.17	93.39	31541.00	31917.00	196	
T1SAV	73.06	3.28	61.30	80.22	196	
T2SAV	71.30	4.16	53.42	79.61	196	
T3SAV	71.34	3.46	53.51	78.71	196	
TDHWSAV	55.29	4.43	47.01	63.68	196	
THWSSAV	137.38	14.02	80.21	166.29	196	
THWRSAV	132.08	12.05	80.01	155.52	196	
TCWSSAV	72.21	4.17	61.85	102.23	196	
TCWRSAV	71.09	4.13	62.06	101.15	196	
ELSSM	107.19	37.21	41.51	254.02	196	
BTUHTSSM	10992364	3841573.36	324201.6	20508898	196	
BTUHWSSM	264447.04	266227.72	.00	1395026	196	
BTUCLSSM	-152954.1	244164.49	-2434157	.00	196	
ELSN	24.00	.00	24.00	24.00	196	
BTUHTSN	24.00	.00	24.00	24.00	196	
BTUHWSN	24.00	.00	24.00	24.00	196	
BTUCLSN	24.00	.00	24.00	24.00	196	
COUNT	23.82	.40	22	24	196	
OATAV	43.20	12.36	11.41	64.84	196	
MOATAV	42.42	12.80	10.59	65.80	190	
NOATAV	44.08	12.36	11.60	65.39	196	
OOATAV	42.94	12.58	11.15	65.50	193	
OATN	23.81	.41	22	24	196	
MOATN	21.69	5.69	0	24	196	
NOATN	22.96	3.16	2	24	196	
OOATN	22.56	4.33	0	24	196	
TALLSAV	71.90	3.34	57.59	79.42	196	

This procedure was completed at 14:54:25

Page 5 Building 1663 - Heating - 6th Regressions 11/22/88

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

N of Cases = 196

Correlation, Covariance:

	BTUHTSSM	OATAV	TALLSAV	BTUHWSSM
BTUHTSSM	1.000	-.959	-.640	.262
	14757685853389	-45551297.790	-8210535.905	267499317417.27
OATAV	-.959	1.000	.607	-.242
	-45551297.790	152.832	25.082	-795787.303
TALLSAV	-.640	.607	1.000	.113
	-8210535.905	25.082	11.154	100592.633
BTUHWSSM	.262	-.242	.113	1.000
	267499317417.27	-795787.303	100592.633	70877197665.174

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**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. BTUHTSSM

Beginning Block Number 1. Method: Enter OATAV TALLSAV BTUHWSSM

Variable(s) Entered on Step Number 1.. BTUHWSSM
2.. TALLSAV
3.. OATAV

Multiple R	.96362		
R Square	.92856	R Square Change	.92856
Adjusted R Square	.92744	F Change	831.82499
Standard Error	1034794.7661	Signif F Change	.0000

F = 831.82499 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUHWSSM	.92091	.30472	.31989	1.52194	.06382	.83439	3.022	.0029
TALLSAV	-134688.1385	29671.48148	-193212.0645	-76164.21252	-.11710	.55918	-4.539	.0000
OATAV	-271148.2465	8208.00642	-287337.6896	-254958.8035	-.87258	.53331	-33.035	.0000
(Constant)	32145206.341	1897099.379	28403374.180	35887038.502			16.944	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 1663 - Heating - 6th Regressions 11/22/88

This procedure was completed at 14:54:34

```
The SPSS/PC+ system file is read from
    file d:\t\sys\tbas1.sys
The file was created on  9/9/88  at 11:21:59
and is titled Rolling Pin - T - Replaced Data
The SPSS/PC+ system file contains
    444 cases, each consisting of
     29 variables (including system variables).
     29 variables will be used in this session.
--------------------------------------------------------------------------------
Page    2   Building 1666 - Heating - 6th Regressions                    11/22/88

This procedure was completed at 14:55:49
The raw data or transformation pass is proceeding
    215 cases are written to the uncompressed active file.
--------------------------------------------------------------------------------
Page    3   Building 1666 - Heating - 6th Regressions                    11/22/88


Number of Valid Observations (Listwise) =        164.00
```

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31754.88	141.05	31416.00	31917.00	215	
T1TAV	80.50	4.52	71.41	90.99	215	
T2TAV	77.58	3.96	63.60	87.72	215	
T3TAV	71.26	5.57	60.24	84.30	215	
TDHWTAV	49.94	4.29	38.42	68.39	215	
THWSTAV	168.04	7.75	134.04	182.70	215	
THWRTAV	157.39	10.31	108.47	171.65	215	
TCWSTAV	72.21	5.43	54.93	83.48	215	
TCWRTAV	71.52	4.92	55.78	83.68	177	
ELTSM	29.27	15.71	1.22	107.54	215	
BTUHTTSM	11524541	2625712.76	2756466	22777834	215	
BTUHWTSM	1780563.3	1368410.58	.00	6168092	215	
BTUCLTSM	11569.64	29465.84	-9554.19	188684.3	215	
ELTN	24.00	.00	24.00	24.00	215	
BTUHTTN	24.00	.00	24.00	24.00	215	
BTUHWTN	24.00	.00	24.00	24.00	215	
BTUCLTN	24.00	.00	24.00	24.00	215	
COUNT	23.81	.39	23	24	215	
OATAV	43.03	12.45	11.41	64.84	215	
MOATAV	42.36	13.15	10.59	64.11	204	
NOATAV	43.94	12.23	11.60	67.89	205	
OOATAV	42.59	12.72	11.15	65.50	213	
OATN	23.80	.40	23	24	215	
MOATN	21.23	6.38	0	24	215	
NOATN	21.44	6.08	0	24	215	
OOATN	22.62	3.86	0	24	215	
TALLTAV	76.45	4.08	66.92	86.86	215	

```
--------------------------------------------------------------------------------
Page    4   Building 1666 - Heating - 6th Regressions                    11/22/88

This procedure was completed at 14:56:08
```

Page 5 Building 1666 - Heating - 6th Regressions 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 215

Correlation, Covariance:

	BTUHTTSM	OATAV	TALLTAV	BTUHWTSM
BTUHTTSM	1.000	-.442	-.399	-.062
	68943675051117.1	-14452729.615	-4271468.351	-221790581863.6
OATAV	-.442	1.000	.728	-.146
	-14452729.615	155.102	37.016	-2485354.133
TALLTAV	-.399	.728	1.000	-.353
	-4271468.351	37.016	16.653	-1972293.833
BTUHWTSM	-.062	-.146	-.353	1.000
	-221790581863.6	-2485354.133	-1972293.833	1872547506978.6

Page 6 Building 1666 - Heating - 6th Regressions 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. BTUHTTSM

Beginning Block Number 1. Method: Enter OATAV TALLTAV BTUHWTSM

Variable(s) Entered on Step Number 1.. BTUHWTSM
2.. OATAV
3.. TALLTAV

Multiple R	.49046		
R Square	.24056	R Square Change	.24056
Adjusted R Square	.22976	F Change	22.27826
Standard Error	2304415.5081	Signif F Change	.0000

F = 22.27826 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUHWTSM	-.37648	.12495	-.62279	-.13018	-.19621	.84883	-3.013	.0029
OATAV	-58270.96768	18744.57533	-95221.59944	-21320.33592	-.27638	.45534	-3.109	.0021
TALLTAV	-171558.3675	60491.92099	-290804.3178	-52312.41730	-.26663	.40720	-2.836	.0050
(Constant)	27817445.400	4164489.051	19608110.235	36026780.564			6.680	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 1666 - Heating - 6th Regressions 11/22/88

This procedure was completed at 14:56:17

```
The SPSS/PC+ system file is read from
    file d:\u\sys\ubas1.sys
The file was created on  9/9/88  at 13:15:45
and is titled Rolling Pin - U - Replaced Data
The SPSS/PC+ system file contains
    477 cases, each consisting of
     29 variables (including system variables).
     29 variables will be used in this session.
```

Page 2 Building 1667 - Heating - 6th Regressions 11/22/88

```
This procedure was completed at 14:57:06
The raw data or transformation pass is proceeding
    205 cases are written to the uncompressed active file.
```

Page 3 Building 1667 - Heating - 6th Regressions 11/22/88

Number of Valid Observations (Listwise) = 196.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31806.54	66.64	31688.00	31917.00	205	
T1UAV	83.08	6.89	71.70	97.54	205	
T2UAV	75.50	2.69	67.93	81.25	205	
T3UAV	73.15	3.12	64.53	80.40	205	
TDHWUAV	56.96	5.45	49.24	70.36	205	
THWSUAV	148.37	8.82	122.41	171.55	205	
THWRUAV	139.55	10.02	113.61	163.66	205	
TCWSUAV	74.53	5.11	64.24	84.27	205	
TCWRUAV	76.59	5.11	65.85	86.35	205	
ELUSM	420.63	87.56	206.53	607.37	205	
BTUHTUSM	10104804	2575874.55	4442415	15747865	205	
BTUHWUSM	1179286.1	892277.72	23824.50	4804627	205	
BTUCLUSM	36443.18	91916.78	.00	514010.5	205	
ELUN	24.00	.00	24.00	24.00	205	
BTUHTUN	24.00	.00	24.00	24.00	205	
BTUHWUN	24.00	.00	24.00	24.00	205	
BTUCLUN	24.00	.00	24.00	24.00	205	
COUNT	23.80	.40	23	24	205	
OATAV	41.27	11.74	11.41	64.84	205	
MOATAV	40.31	12.25	10.59	64.11	198	
NOATAV	42.36	11.63	11.60	65.39	205	
OOATAV	41.04	12.04	11.15	65.50	203	
OATN	23.79	.41	23	24	205	
MOATN	21.79	5.56	0	24	205	
NOATN	23.15	2.71	2	24	205	
OOATN	22.69	3.92	0	24	205	
TALLUAV	77.24	3.09	71.08	84.01	205	

Page 4 Building 1667 - Heating - 6th Regressions 11/22/88

This procedure was completed at 14:57:28

Page 5 Building 1667 - Heating - 6th Regressions 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 205

Correlation, Covariance:

	BTUHTUSM	OATAV	TALLUAV	BTUHWUSM
BTUHTUSM	1.000	-.803	-.841	.228
	6635129717039.1	-24305612.950	-6707244.471	523015369492.03
OATAV	-.803	1.000	.792	.011
	-24305612.950	137.917	28.785	112379.285
TALLUAV	-.841	.792	1.000	-.182
	-6707244.471	28.785	9.575	-501742.866
BTUHWUSM	.228	.011	-.182	1.000
	523015369492.03	112379.285	-501742.866	796159524766.82

Page 6 Building 1667 - Heating - 6th Regressions 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUHTUSM

Beginning Block Number 1. Method: Enter OATAV TALLUAV BTUHWUSM

Variable(s) Entered on Step Number 1.. BTUHWUSM
2.. OATAV
3.. TALLUAV

Multiple R	.88180		
R Square	.77757	R Square Change	.77757
Adjusted R Square	.77425	F Change	234.21419
Standard Error	1223887.3612	Signif F Change	.0000

F = 234.21419 Signif F = .0000

------------------------------------ Variables in the Equation ------------------------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUHWUSM	.42047	.10107	.22117	.61977	.14565	.90277	4.160	.0000
OATAV	-93877.51186	12371.93374	-118272.9432	-69482.08050	-.42800	.34782	-7.588	.0000
TALLUAV	-396227.5174	47746.16046	-490375.1426	-302079.8923	-.47599	.33638	-8.299	.0000
(Constant)	44087963.335	3329244.476	37523237.337	50652689.334			13.243	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 1667 - Heating - 6th Regressions 11/22/88

This procedure was completed at 14:57:36

Variable Names for Motor Vehicle Repair Shops

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
EL1SM	kWh	Daily electricity consumption.
GAS1SM	Btu	Daily gas consumption.
ST1AV	°F	Daily average temperature, south zone (bay area).
NT1AV	°F	Daily average temperature, north zone (office area).
EL1N	None	Number of hourly values included in EL1SM.
GAS1N	None	Number of hourly values included in GAS1SM.
COUNT	None	Count of hourly data points included in daily total.
OATAV	°F	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.

The variable names listed above are those used for building 633. Buildings 634, 635 and 636 used similar names, except that the 1 in the names was replaced with a 2, 3, or 4 for buildings 534, 635 and 636, respectively.

Data Included If: Gas > 50,000 Btu, and
Daily Average Outdoor Air Temperature < 70 °F, and > 25 °F.

```
The SPSS/PC+ system file is read from
    file g:\k\sys\kbase.sys
The file was created on  7/13/88 at  3:14:12
and is titled Motor Pool - Replaced Data
The SPSS/PC+ system file contains
    225 cases, each consisting of
     37 variables (including system variables).
     37 variables will be used in this session.
```



```
This procedure was completed at 14:09:52
The raw data or transformation pass is proceeding
    74 cases are written to the uncompressed active file.
```


Number of Valid Observations (Listwise) = 74.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31849.62	43.44	31612.00	31908.00	74	
EL1SM	56.97	22.09	.03	111.61	74	
GAS1SM	5673073.6	2449983.20	58366.67	9833868	74	
ST1AV	68.88	3.71	60.18	78.20	74	
NT1AV	78.18	6.14	70.02	107.48	74	
EL1N	24.00	.00	24.00	24.00	74	
GAS1N	24.00	.00	24.00	24.00	74	
COUNT	23.74	.44	23	24	74	
OATAV	44.69	10.50	25.44	66.01	74	
OATN	23.74	.44	23	24	74	

This procedure was completed at 14:10:02

Page 5 Motor Repair Shops - 6th Regression - Bldg. 633 Heating 11/22/88

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 74

Correlation, Covariance:

	GAS1SM	OATAV	ST1AV	EL1SM
GAS1SM	1.000 6002417670111.4	-.814 -20948216.547	-.583 -5306516.233	-.175 -9465338.970
OATAV	-.814 -20948216.547	1.000 110.305	.767 29.917	.255 59.080
ST1AV	-.583 -5306516.233	.767 29.917	1.000 13.799	.166 13.660
EL1SM	-.175 -9465338.970	.255 59.080	.166 13.660	1.000 487.903

Page 6 Motor Repair Shops - 6th Regression - Bldg. 633 Heating 11/22/88

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. GAS1SM

Beginning Block Number 1. Method: Enter OATAV ST1AV EL1SM

Variable(s) Entered on Step Number 1.. EL1SM
2.. ST1AV
3.. OATAV

Multiple R	.81746		
R Square	.66824	R Square Change	.66824
Adjusted R Square	.65403	F Change	46.99950
Standard Error	1441069.2461	Signif F Change	.0000

F = 46.99950 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
EL1SM	4196.66770	7904.70593	-11568.77200	19962.10739	.03784	.93313	.531	.5972
ST1AV	67716.30486	70814.44248	-73518.65477	208951.26448	.10267	.41110	.956	.3422
OATAV	-210525.8306	25539.28292	-261462.3270	-159589.3342	-.90248	.39540	-8.243	.0000
(Constant)	10178663.433	4106347.672	1988810.8080	18368516.059			2.479	.0156

End Block Number 1 All requested variables entered.

Page 7 Motor Repair Shops - 6th Regression - Bldg. 633 Heating 11/22/88

This procedure was completed at 14:10:14
The SPSS/PC+ system file is read from
file g:\k\sys\kbase.sys
The file was created on 7/13/88 at 3:14:12
and is titled Motor Pool - Replaced Data
The SPSS/PC+ system file contains
225 cases, each consisting of
37 variables (including system variables).
37 variables will be used in this session.

Page 8 Motor Repair Shops - 6th Regression - Bldg. 634 Heating 11/22/88

This procedure was completed at 14:10:17
The raw data or transformation pass is proceeding
120 cases are written to the uncompressed active file.

Page 9 Motor Repair Shops - 6th Regression - Bldg. 634 Heating 11/22/88

Number of Valid Observations (Listwise) = 120.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31810.63	64.38	31612.00	31908.00	120	
EL2SM	72.58	35.17	18.93	162.56	120	
GAS2SM	8216387.5	3841052.34	58366.67	12743031	120	
ST2AV	62.65	6.13	43.96	75.44	120	
NT2AV	73.35	10.06	59.54	122.88	120	
EL2N	24.00	.00	24.00	24.00	120	
GAS2N	24.00	.00	24.00	24.00	120	
COUNT	23.83	.46	23	26	120	
OATAV	42.62	9.94	25.44	66.01	120	
OATN	23.83	.46	23	26	120	

Page 10 Motor Repair Shops - 6th Regression - Bldg. 634 Heating 11/22/88

This procedure was completed at 14:10:29

**** M U L T I P L E   R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 120

Correlation, Covariance:

	GAS2SM	OATAV	ST2AV	EL2SM
GAS2SM	1.000 14753683051059	-.812 -31003571.419	-.495 -11659721.871	.157 21263224.489
OATAV	-.812 -31003571.419	1.000 98.739	.783 47.693	-.025 -8.695
ST2AV	-.495 -11659721.871	.783 47.693	1.000 37.550	-.074 -16.028
EL2SM	.157 21263224.489	-.025 -8.695	-.074 -16.028	1.000 1236.724

**** M U L T I P L E   R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. GAS2SM

Beginning Block Number 1. Method: Enter OATAV ST2AV EL2SM

Variable(s) Entered on Step Number 1.. EL2SM
2.. OATAV
3.. ST2AV

Multiple R	.85796		
R Square	.73610	R Square Change	.73610
Adjusted R Square	.72927	F Change	107.85217
Standard Error	1998556.1257	Signif F Change	.0000

F = 107.85217 Signif F = .0000

Variables in the Equation

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
EL2SM	17316.23901	5231.68078	6954.23547	27678.24255	.15854	.99159	3.310	.0012
OATAV	-429630.5888	29699.21508	-488453.6295	-370807.5481	-1.11145	.38540	-14.466	.0000
ST2AV	242555.56866	48278.33036	146934.24718	338176.89014	.38696	.38350	5.024	.0000
(Constant)	10075874.383	2253208.603	5613110.6011	14538638.164			4.472	.0000

End Block Number 1 All requested variables entered.

Page 13 Motor Repair Shops - 6th Regression - Bldg. 634 Heating 11/22/88

This procedure was completed at 14:10:37
The SPSS/PC+ system file is read from
file g:\k\sys\kbase.sys
The file was created on 7/13/88 at 3:14:12
and is titled Motor Pool - Replaced Data
The SPSS/PC+ system file contains
225 cases, each consisting of
37 variables (including system variables).
37 variables will be used in this session.

Page 14 Motor Repair Shops - 6th Regression - Bldg. 635 Heating 11/22/88

This procedure was completed at 14:10:39
The raw data or transformation pass is proceeding
96 cases are written to the uncompressed active file.

Page 15 Motor Repair Shops - 6th Regression - Bldg. 635 Heating 11/22/88

Number of Valid Observations (Listwise) = 96.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31789.68	55.10	31612.00	31875.00	96	
EL3SM	10.36	13.12	.00	75.24	96	
GAS3SM	8718779.2	2983257.04	58366.67	14973339	96	
ST3AV	66.07	6.22	22.83	76.84	96	
NT3AV	72.88	15.21	43.62	107.72	96	
EL3N	24.00	.00	24.00	24.00	96	
GAS3N	24.00	.00	24.00	24.00	96	
COUNT	23.81	.49	23	26	96	
OATAV	39.74	7.32	26.77	66.01	96	
OATN	23.81	.49	23	26	96	

Page 16 Motor Repair Shops - 6th Regression - Bldg. 635 Heating 11/22/88

This procedure was completed at 14:10:53

Page 17 Motor Repair Shops - 6th Regression - Bldg. 635 Heating 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 96

Correlation, Covariance:

	GAS3SM	OATAV	ST3AV	EL3SM
GAS3SM	1.000	-.516	.046	.125
	8899822565438.0	-11252480.967	862142.572	4883650.058
OATAV	-.516	1.000	.342	.071
	-11252480.967	53.528	15.577	6.845
ST3AV	.046	.342	1.000	.089
	862142.572	15.577	38.672	7.303
EL3SM	.125	.071	.089	1.000
	4883650.058	6.845	7.303	172.203

Page 18 Motor Repair Shops - 6th Regression - Bldg. 635 Heating 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. GAS3SM

Beginning Block Number 1. Method: Enter OATAV ST3AV EL3SM

Variable(s) Entered on Step Number 1.. EL3SM
2.. OATAV
3.. ST3AV

Multiple R	.58597		
R Square	.34336	R Square Change	.34336
Adjusted R Square	.32195	F Change	16.03574
Standard Error	2456530.9545	Signif F Change	.0000

F = 16.03574 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
EL3SM	33308.12360	19301.73787	-5026.79487	71643.04208	.14651	.99012	1.726	.0878
OATAV	-248227.8693	36698.75026	-321114.7569	-175340.9816	-.60877	.88112	-6.764	.0000
ST3AV	115988.00684	43239.80776	30110.01407	201865.99961	.24178	.87853	2.682	.0087
(Constant)	10575672.139	2732925.505	5147846.0466	16003498.232			3.870	.0002

End Block Number 1 All requested variables entered.

Page 19 Motor Repair Shops - 6th Regression - Bldg. 635 Heating 11/22/88

This procedure was completed at 14:10:58
The SPSS/PC+ system file is read from
file g:\k\sys\kbase.sys
The file was created on 7/13/88 at 3:14:12
and is titled Motor Pool - Replaced Data
The SPSS/PC+ system file contains
225 cases, each consisting of
37 variables (including system variables).
37 variables will be used in this session.

Page 20 Motor Repair Shops - 6th Regression - Bldg. 636 Heating 11/22/88

This procedure was completed at 14:11:00
The raw data or transformation pass is proceeding
121 cases are written to the uncompressed active file.

Page 21 Motor Repair Shops - 6th Regression - Bldg. 636 Heating 11/22/88

Number of Valid Observations (Listwise) = 121.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31809.17	60.48	31689.00	31908.00	121	
EL4SM	41.80	21.10	3.86	125.74	121	
GAS4SM	10138063	4527190.77	1648143	20241903	121	
ST4AV	69.55	5.87	53.24	83.76	121	
NT4AV	83.25	6.60	68.79	121.62	121	
EL4N	24.00	.00	24.00	24.00	121	
GAS4N	24.00	.00	24.00	24.00	121	
COUNT	23.83	.46	23	26	121	
OATAV	41.49	9.50	25.44	64.24	121	
OATN	23.83	.46	23	26	121	

Page 22 Motor Repair Shops - 6th Regression - Bldg. 636 Heating 11/22/88

This procedure was completed at 14:11:13

Page 23 Motor Repair Shops - 6th Regression - Bldg. 636 Heating 11/22/88

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

N of Cases = 121

Correlation, Covariance:

	GAS4SM	OATAV	ST4AV	EL4SM
GAS4SM	1.000 20495456268509	-.773 -33269870.315	.150 3985980.628	.639 61046494.948
OATAV	-.773 -33269870.315	1.000 90.292	.273 15.220	-.386 -77.426
ST4AV	.150 3985980.628	.273 15.220	1.000 34.450	.022 2.673
EL4SM	.639 61046494.948	-.386 -77.426	.022 2.673	1.000 445.111

Page 24 Motor Repair Shops - 6th Regression - Bldg. 636 Heating 11/22/88

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. GAS4SM

Beginning Block Number 1. Method: Enter OATAV ST4AV EL4SM

Variable(s) Entered on Step Number 1.. EL4SM
2.. ST4AV
3.. OATAV

Multiple R	.91680		
R Square	.84053	R Square Change	.84053
Adjusted R Square	.83644	F Change	205.55824
Standard Error	1830912.7140	Signif F Change	.0000

F = 205.55824 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
EL4SM	74901.43137	8677.85358	57715.39665	92087.46610	.34906	.83341	8.631	.0000
ST4AV	263964.96463	29907.52868	204734.66975	323195.25952	.34223	.90657	8.826	.0000
OATAV	-348735.7101	20022.84283	-388389.9021	-309081.5181	-.73197	.77171	-17.417	.0000
(Constant)	3118149.3507	2037590.553	-917192.0712	7153490.7727			1.530	.1286

End Block Number 1 All requested variables entered.

Page 25 Motor Repair Shops - 6th Regression - Bldg. 636 Heating 11/22/88

This procedure was completed at 14:11:18

Dining Halls

Variable Names for Dining Halls

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
TEMPAV	^oF	Daily average space temperature.
ELPSM	kWh	Daily electricity consumption.
GASPSM	Btu	Daily gas consumption, used for cooking.
BTUHTPS	Btu	Daily heating hot water energy consumption.
BTUSTPS	Btu	Daily steam energy consumption, used for warming tables.
BTUHWPS	Btu	Daily domestic hot water energy consumption.
ELPN	None	Number of hourly values included in ELPSM.
GASPN	None	Number of hourly values included in GASPSM.
BTUHTPN	None	Number of hourly values included in BTUHTPS.
BTUSTPN	None	Number of hourly values included in BTUSTPS.
BTUHWPN	None	Number of hourly values included in BTUHWPS.
COUNT	None	Count of hourly data points included in daily total.
OATAV	^oF	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
MOATAV	^oF	Daily average outdoor air temperature, building 811, from outdoor air temperature file.
NOATAV	^oF	Daily average outdoor air temperature, building 812, from outdoor air temperature file.
OOATAV	^oF	Daily average outdoor air temperature, building 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.
MOATN	None	Number of hourly values included in MOATAV.
NOATN	None	Number of hourly values included in NOATAV.
OOATN	None	Number of hourly values included in OOATAV.
LDATE	None	Date plus Time in Lotus Symphony format.
O1361	None	Daily meals served, building 1361.
O1369	None	Daily meals served, building 1369.
O1669	None	Daily meals served, building 1669.

The variable names listed above are those used for building 1361. Buildings 1369, 1669 used similar names, except that the P in the names was replaced with an R or V for buildings 1369 and 1669, respectively.

Data Included If: For building 1361, date not 6/11-13/86,
For building 1369, date not before 3/8/86, 5/3-8/86, 6/2/86,
8/4/86-10/1/86, or 7/18-29/87, and
For building 1669, date not 8/30/86-9/1/86.

NOTE: The SPSS output on the following pages is formatted differently from that for the preceding building sets. The L-shaped barracks, rolling-pin barracks, and motor vehicle repair shop output is generated using the REGRESSION command in SPSS. For the dining halls, no regression models were found. Therefore, the correlation/convariance matrices were generated using the CORRELATION command. The data set described is the entire data set for these buildings, whereas for the preceding building sets it was only the data used in the regressions.

Page 14 Building 1361 - Data Set Descriptives 9/14/88

This procedure was completed at 16:13:29
The raw data or transformation pass is proceeding
468 cases are written to the uncompressed active file.

Page 15 Building 1361 - Data Set Descriptives 9/14/88

Number of Valid Observations (Listwise) = 187.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31741.84	162.84	31441.00	32015.00	468	
TEMPAV	71.84	5.33	52.08	84.63	468	
ELPSM	19.34	18.62	.00	74.28	468	
GASPSM	785481.89	3177582.88	319.30	17348633	468	
BTUHTPSM	598362.42	785410.66	-264818	3551667	468	
BTUSTPSM	210056839	2517407809	.00	3.46E+10	468	
BTUHWPSM	55253544	635409054	-2175625	8.65E+09	468	
ELPN	24.00	.00	24.00	24.00	468	
GASPN	24.00	.00	24.00	24.00	468	
BTUHTPN	24.00	.00	24.00	24.00	468	
BTUSTPN	24.00	.00	24.00	24.00	468	
BTUHWPN	24.00	.00	24.00	24.00	468	
COUNT	23.82	.43	21	24	468	
OATAV	51.79	15.75	7.38	80.71	468	
MOATAV	50.53	16.09	7.38	85.17	437	
NOATAV	53.07	15.34	11.60	84.50	433	
OOATAV	51.34	15.42	11.15	85.20	410	
OATN	23.81	.49	20	24	468	
MOATN	21.06	6.77	0	24	468	
NOATN	21.09	6.76	0	24	468	
OOATN	19.55	8.36	0	24	468	
LDATE	31741.84	162.84	31441.00	32015.00	468	
01361	.38	.05	.00	.43	257	
01369	.00	.04	.00	.38	285	
01669	.41	.07	.27	.53	257	

Page 16 Building 1361 - Data Set Descriptives 9/14/88

This procedure was completed at 16:13:57

The SPSS/PC+ system file is read from
file d:\p\sys\pbas2.sys
The file was created on 9/14/88 at 16:06:50
and is titled Dining Halls - P - Adding Occupancy Data
The SPSS/PC+ system file contains
471 cases, each consisting of
28 variables (including system variables).
28 variables will be used in this session.

Page 2 Building 1361 - Correlation/Covariance Matrix 9/14/88

This procedure was completed at 18:03:30
The raw data or transformation pass is proceeding
468 cases are written to the uncompressed active file.

Page 3 Building 1361 - Correlation/Covariance Matrix 9/14/88

Variables		Cases	Cross-Prod Dev	Variance-Covar	Variables		Cases	Cross-Prod Dev	Variance-Covar
NDATE	BTUHTPSM	468	-2580696796.930	-5526117.3382	NDATE	ELPSM	468	463313.3929	992.1058
NDATE	GASPSM	468	-93779740680.60	-200813149.2090	NDATE	BTUSTPSM	468	-5466622534562	-11705829838.46
NDATE	OATAV	468	185692.1388	397.6277	NDATE	TEMPAV	468	60412.3200	129.3626
NDATE	BTUHWPSM	468	-1664279501635	-3563767669.455	BTUHTPSM	ELPSM	468	1197480930.8647	2564198.9954
BTUHTPSM	GASPSM	468	337101104248503	721843906313.71	BTUHTPSM	BTUSTPSM	468	-5.61771613E+16	-1.20293707E+14
BTUHTPSM	OATAV	468	-3076617021.452	-6588045.0138	BTUHTPSM	TEMPAV	468	-409248255.3353	-876334.5939
BTUHTPSM	BTUHWPSM	468	-1.47020595E+16	-31481926222205	ELPSM	GASPSM	468	-277530098.0815	-594282.8653
ELPSM	BTUSTPSM	468	459820066169.37	984625409.3563	ELPSM	OATAV	468	-45085.1071	-96.5420
ELPSM	TEMPAV	468	-6138.4736	-13.1445	ELPSM	BTUHWPSM	468	94205536247.234	201724917.0176
GASPSM	BTUSTPSM	468	9.651001190E+17	2.066595544E+15	GASPSM	OATAV	468	-5887114966.626	-12606241.8986
GASPSM	TEMPAV	468	-722119800.4657	-1546295.0759	GASPSM	BTUHWPSM	468	2.476586157E+17	530318234831708
BTUSTPSM	OATAV	468	182468734253.99	390725341.0150	BTUSTPSM	TEMPAV	468	-105111806152.2	-225078814.0304
BTUSTPSM	BTUHWPSM	468	7.406690799E+20	1.586015160E+18	OATAV	TEMPAV	468	27450.8342	58.7812
OATAV	BTUHWPSM	468	44269222288.821	94794908.5414	TEMPAV	BTUHWPSM	468	-21929184494.21	-46957568.5101

Page 4 Building 1361 - Correlation/Covariance Matrix 9/14/88

Correlations:	NDATE	BTUHTPSM	ELPSM	GASPSM	BTUSTPSM	OATAV	TEMPAV	BTUHWPSM
NDATE	1.0000	-.0432	.3272**	-.3881**	-.0286	.1551**	.1490**	-.0344
BTUHTPSM	-.0432	1.0000	.1754**	.2892**	-.0608	-.5327**	-.2092**	-.0631
ELPSM	.3272**	.1754**	1.0000	-.0100	.0210	-.3293**	-.1324*	.0171
GASPSM	-.3881**	.2892**	-.0100	1.0000	.2583**	-.2519**	-.0913	.2627**
BTUSTPSM	-.0286	-.0608	.0210	.2583**	1.0000	.0099	-.0168	.9915**
OATAV	.1551**	-.5327**	-.3293**	-.2519**	.0099	1.0000	.7000**	.0095
TEMPAV	.1490**	-.2092**	-.1324*	-.0913	-.0168	.7000**	1.0000	-.0139
BTUHWPSM	-.0344	-.0631	.0171	.2627**	.9915**	.0095	-.0139	1.0000

N of cases: 468 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Page 5 Building 1361 - Correlation/Covariance Matrix 9/14/88

This procedure was completed at 18:03:54
The SPSS/PC+ system file is read from
file d:\p\sys\pbas2.sys
The file was created on 9/14/88 at 16:06:50
and is titled Dining Halls - P - Adding Occupancy Data
The SPSS/PC+ system file contains
471 cases, each consisting of
28 variables (including system variables).
28 variables will be used in this session.

Page 6 Building 1361 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

This procedure was completed at 18:03:56
The raw data or transformation pass is proceeding
468 cases are written to the uncompressed active file.

Page 7 Building 1361 - Correlation/Covariance Matrix w/ Occ. 9/14/88

Variables		Cases	Cross-Prod Dev	Variance-Covar	Variables		Cases	Cross-Prod Dev	Variance-Covar
NDATE	BTUHTPSM	257	-10836473026.6[illegible]	-42329972.7602	NDATE	ELPSM	257	183865.0207	718.2227
NDATE	GASPSM	257	-48221864152.46	-188366656.8455	NDATE	BTUSTPSM	257	6401581712148.5	25006178563.080
NDATE	OATAV	257	-61474.6583	-240.1354	NDATE	TEMPAV	257	-29590.7073	-115.5887
NDATE	BTUHWPSM	257	1549749936653.5	6053710690.0527	NDATE	01361	257	69.0474	.2697
BTUHTPSM	ELPSM	257	-386963483.3155	-1511576.1067	BTUHTPSM	GASPSM	257	423522471218910	1654384653198.9
BTUHTPSM	BTUSTPSM	257	-3.46197458E+16	-1.35233382E+14	BTUHTPSM	OATAV	257	-949551455.0787	-3709185.3714
BTUHTPSM	TEMPAV	257	-173139843.5064	-676327.5137	BTUHTPSM	BTUHWPSM	257	-8.52555063E+15	-33302932159034
BTUHTPSM	01361	257	28744.5743	112.2835	ELPSM	GASPSM	257	1566149942.3563	6117773.2123
ELPSM	BTUSTPSM	257	929365947847.11	3630335733.7778	ELPSM	OATAV	257	-32104.8555	-125.4096
ELPSM	TEMPAV	257	-8034.9359	-31.3865	ELPSM	BTUHWPSM	257	224332676315.17	876299516.8561
ELPSM	01361	257	-20.6491	-.0807	GASPSM	BTUSTPSM	257	9.045932963E+17	3.533567564E+15
GASPSM	OATAV	257	-5685329042.520	-22208316.5723	GASPSM	TEMPAV	257	-479578860.8132	-1873354.9251
GASPSM	BTUHWPSM	257	2.311853291E+17	903067691965788	GASPSM	01361	257	3564278.2839	13922.9620
BTUSTPSM	OATAV	257	251385223077.49	981973527.6464	BTUSTPSM	TEMPAV	257	-39102532222.28	-152744266.4933
BTUSTPSM	BTUHWPSM	257	7.364057807E+20	2.876585081E+18	BTUSTPSM	01361	257	-526255454.4436	-2055685.3689
OATAV	TEMPAV	257	13265.3804	51.8179	OATAV	BTUHWPSM	257	58611040626.457	228949377.4471
OATAV	01361	257	21.6386	.0845	TEMPAV	BTUHWPSM	257	-4581314038.834	-17895757.9642
TEMPAV	01361	257	10.0933	.0394	BTUHWPSM	01361	257	-126098908.4173	-492573.8610

Page 8 Building 1361 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

Correlations:	NDATE	BTUHTPSM	ELPSM	GASPSM	BTUSTPSM	OATAV	TEMPAV	BTUHWPSM	01361
NDATE	1.0000	-.6196**	.4366**	-.4555**	.0746	-.1635*	-.2378**	.0716	.0580
BTUHTPSM	-.6196**	1.0000	-.1314	.5721**	-.0577	-.3613**	-.1990**	-.0563	.0035
ELPSM	.4366**	-.1314	1.0000	.0879	.0643	-.5073**	-.3835**	.0615	-.1031
GASPSM	-.4555**	.5721**	.0879	1.0000	.2490**	-.3573**	-.0911	.2523**	.0708
BTUSTPSM	.0746	-.0577	.0643	.2490**	1.0000	.0195	-.0092	.9915**	-.0129
OATAV	-.1635*	-.3613**	-.5073**	-.3573**	.0195	1.0000	.7094**	.0180	.1210
TEMPAV	-.2378**	-.1990**	-.3835**	-.0911	-.0092	.7094**	1.0000	-.0043	.1705*
BTUHWPSM	.0716	-.0563	.0615	.2523**	.9915**	.0180	-.0043	1.0000	-.0122
01361	.0580	.0035	-.1031	.0708	-.0129	.1210	.1705*	-.0122	1.0000

N of cases: 257 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Page 9 Building 1361 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

This procedure was completed at 18:04:18

This procedure was completed at 16:23:19
The raw data or transformation pass is proceeding
309 cases are written to the uncompressed active file.

Number of Valid Observations (Listwise) = 130.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31747.09	143.33	31479.00	31999.00	309	
TEMRAV	74.56	5.61	52.49	88.55	309	
ELRSM	33.76	30.73	.00	106.70	309	
GASRSM	18447.12	82667.39	.00	428480.0	309	
BTUHTRSM	1753595.4	1621519.01	.00	7979695	309	
BTUSTRSM	1460417.0	1803214.13	.00	6318246	309	
BTUHWRSM	282144.21	352825.46	.00	2658593	309	
ELRN	24.00	.00	24.00	24.00	309	
GASRN	24.00	.00	24.00	24.00	309	
BTUHTRN	24.00	.00	24.00	24.00	309	
BTUSTRN	24.00	.00	24.00	24.00	309	
BTUHWRN	24.00	.00	24.00	24.00	309	
COUNT	23.82	.42	21	24	309	
OATAV	50.30	13.74	11.50	78.40	309	
MOATAV	49.90	14.35	11.09	77.91	295	
NOATAV	50.18	13.68	11.60	84.50	289	
OOATAV	48.97	13.76	11.80	81.34	284	
OATN	23.82	.43	21	24	309	
MOATN	21.71	5.89	0	24	309	
NOATN	21.22	6.65	0	24	309	
OOATN	20.48	7.35	0	24	309	
LDATE	31747.09	143.33	31479.00	31999.00	309	
01361	.38	.02	.34	.43	166	
01369	.00	.00	.00	.00	185	
01669	.39	.07	.27	.49	166	

This procedure was completed at 16:23:41

```
The SPSS/PC+ system file is read from
    file d:\r\sys\rbas2.sys
The file was created on  9/14/88 at 16:19:17
and is titled Dining Halls - R - Adding Occupancy Data
The SPSS/PC+ system file contains
    355 cases, each consisting of
     28 variables (including system variables).
     28 variables will be used in this session.
```

Page 2 Building 1369 - Correlation/Covariance Matrix 9/14/88

```
This procedure was completed at 18:06:59
The raw data or transformation pass is proceeding
    309 cases are written to the uncompressed active file.
```

Page 3 Building 1369 - Correlation/Covariance Matrix 9/14/88

Variables		Cases	Cross-Prod Dev	Variance-Covar
NDATE	BTUHTRSM	309	-4964467450.217	-16118400.8124
NDATE	GASRSM	309	-1423933610.446	-4623161.0729
NDATE	OATAV	309	-19340.6358	-62.7943
NDATE	BTUHWRSM	309	-7698185665.518	-24994109.3036
BTUHTRSM	GASRSM	309	24442207951797	79357818025.316
BTUHTRSM	OATAV	309	-2201068487.316	-7146326.2575
BTUHTRSM	BTUHWRSM	309	73088530271980	237300422960.97
ELRSM	BTUSTRSM	309	-7865674830.029	-25537905.2923
ELRSM	TEMRAV	309	684.6629	2.2229
GASRSM	BTUSTRSM	309	5517180255951.7	17912922908.934
GASRSM	TEMRAV	309	-12962009.8826	-42084.4477
BTUSTRSM	OATAV	309	-2179489751.329	-7076265.4264
BTUSTRSM	BTUHWRSM	309	23866473645927	77488550798.464
OATAV	BTUHWRSM	309	-214991903.8212	-698025.6618
NDATE	ELRSM	309	660462.1136	2144.3575
NDATE	BTUSTRSM	309	-33574209406.68	-109007173.3983
NDATE	TEMRAV	309	47300.6768	153.5736
BTUHTRSM	ELRSM	309	3387500775.7975	10998379.1422
BTUHTRSM	BTUSTRSM	309	-25000280097049	-81169740574.83
BTUHTRSM	TEMRAV	309	-51381931.6114	-166824.4533
ELRSM	GASRSM	309	25063947.0713	81376.4515
ELRSM	OATAV	309	-26229.2109	-85.1598
ELRSM	BTUHWRSM	309	-255232020.5511	-828675.3914
GASRSM	OATAV	309	-15579999.9458	-50584.4154
GASRSM	BTUHWRSM	309	4854121174717.7	15760133684.148
BTUSTRSM	TEMRAV	309	-909698962.6810	-2953568.0607
OATAV	TEMRAV	309	8408.1437	27.2992
TEMRAV	BTUHWRSM	309	11262439.0035	36566.3604

Page 4 Building 1369 - Correlation/Covariance Matrix 9/14/88

Correlations:	NDATE	BTUHTRSM	ELRSM	GASRSM	BTUSTRSM	OATAV	TEMRAV	BTUHWRSM
NDATE	1.0000	-.0694	.4868**	-.3902**	-.4218**	-.0319	.1912**	-.4942**
BTUHTRSM	-.0694	1.0000	.2207**	.5920**	-.0278	-.3208**	-.0184	.4148**
ELRSM	.4868**	.2207**	1.0000	.0320	-.4608**	-.2017**	.0129	-.0764
GASRSM	-.3902**	.5920**	.0320	1.0000	.1202	-.0445	-.0908	.5403**
BTUSTRSM	-.4218**	-.0278	-.4608**	.1202	1.0000	-.2857**	-.2922**	.1218
OATAV	-.0319	-.3208**	-.2017**	-.0445	-.2857**	1.0000	.3546**	-.1440*
TEMRAV	.1912**	-.0184	.0129	-.0908	-.2922**	.3546**	1.0000	.0185
BTUHWRSM	-.4942**	.4148**	-.0764	.5403**	.1218	-.1440*	.0185	1.0000

N of cases: 309 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Page 5 Building 1369 - Correlation/Covariance Matrix 9/14/88

This procedure was completed at 18:07:17
The SPSS/PC+ system file is read from
file d:\r\sys\rbas2.sys
The file was created on 9/14/88 at 16:19:17
and is titled Dining Halls - R - Adding Occupancy Data
The SPSS/PC+ system file contains
355 cases, each consisting of
28 variables (including system variables).
28 variables will be used in this session.

Page 6 Building 1369 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

This procedure was completed at 18:07:18
The raw data or transformation pass is proceeding
309 cases are written to the uncompressed active file.

Page 7 Building 1369 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

Variables		Cases	Cross-Prod Dev	Variance-Covar	Variables		Cases	Cross-Prod Dev	Variance-Covar
NDATE	BTUHTRSM	185	-11013621716.66	-59856639.7644	NDATE	ELRSM	185	60533.3793	328.9858
NDATE	GASRSM	185	-904115126.9148	-4913669.1680	NDATE	BTUSTRSM	185	4756872633.6521	25852568.6612
NDATE	OATAV	185	-114062.9510	-619.9073	NDATE	TEMRAV	185	-3315.4556	-18.0188
NDATE	BTUHWRSM	185	-4876498875.584	-26502711.2803	NDATE	01369	185	.0000	.0000
BTUHTRSM	ELRSM	185	365463011.4706	1986212.0189	BTUHTRSM	GASRSM	185	25654799249230	139428256789.29
BTUHTRSM	BTUSTRSM	185	46833306181688	254528837943.96	BTUHTRSM	OATAV	185	-1511483453.725	-8214583.9876
BTUHTRSM	TEMRAV	185	-10304038.2148	-56000.2077	BTUHTRSM	BTUHWRSM	185	66896619220747	363568582721.45
BTUHTRSM	01369	185	.0000	.0000	ELRSM	GASRSM	185	114690396.5744	623317.3727
ELRSM	BTUSTRSM	185	-1787834057.406	-9716489.4424	ELRSM	OATAV	185	1989.6577	10.8134
ELRSM	TEMRAV	185	-1771.8287	-9.6295	ELRSM	BTUHWRSM	185	-111220107.9535	-604457.1084
ELRSM	01369	185	.0000	.0000	GASRSM	BTUSTRSM	185	853147798751.61	4636672819.3023
GASRSM	OATAV	185	-12391945.0204	-67347.5273	GASRSM	TEMRAV	185	-6387152.9224	-34712.7876
GASRSM	BTUHWRSM	185	4585500705653.1	24921199487.245	GASRSM	01369	185	.0000	.0000
BTUSTRSM	OATAV	185	-1725432828.320	-9377352.3278	BTUSTRSM	TEMRAV	185	-425870007.6165	-2314510.9110
BTUSTRSM	BTUHWRSM	185	1798482724306.7	9774362632.1016	BTUSTRSM	01369	185	.0000	.0000
OATAV	TEMRAV	185	6246.7175	33.9496	OATAV	BTUHWRSM	185	-36273268.5241	-197137.3289
OATAV	01369	185	.0000	.0000	TEMRAV	BTUHWRSM	185	22192364.5734	120610.6770
TEMRAV	01369	185	.0000	.0000	BTUHWRSM	01369	185	.0000	.0000

Page 8 Building 1369 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

Correlations:	NDATE	BTUHTRSM	ELRSM	GASRSM	BTUSTRSM	OATAV	TEMRAV	BTUHWRSM	01369
NDATE	1.0000	-.3356**	.1701	-.4639**	.1398	-.4473**	-.0341	-.6494**	.
BTUHTRSM	-.3356**	1.0000	.0583	.7470**	.0781	-.3363**	-.0060	.5055**	.
ELRSM	.1701	.0583	1.0000	.3080**	-.2750**	.0408	-.0953	-.0775	.
GASRSM	-.4639**	.7470**	.3080**	1.0000	.0240	-.0464	-.0627	.5835**	.
BTUSTRSM	.1398	.0781	-.2750**	.0240	1.0000	-.3704**	-.2395**	.0131	.
OATAV	-.4473**	-.3363**	.0408	-.0464	-.3704**	1.0000	.4687**	-.0353	.
TEMRAV	-.0341	-.0060	-.0953	-.0627	-.2395**	.4687**	1.0000	.0565	.
BTUHWRSM	-.6494**	.5055**	-.0775	.5835**	.0131	-.0353	.0565	1.0000	.
01369	.	.	.	.	.	.	.	.	1.0000

N of cases: 185 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Page 9 Building 1369 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

This procedure was completed at 18:07:36

Page 18 Building 1669 - Data Set Descriptives 9/14/88

This procedure was completed at 16:30:27
The raw data or transformation pass is proceeding
398 cases are written to the uncompressed active file.

Page 19 Building 1669 - Data Set Descriptives 9/14/88

Number of Valid Observations (Listwise) = 156.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31750.91	164.34	31456.00	32015.00	398	
TEMVAV	74.59	6.28	40.04	86.90	398	
ELVSM	19.07	20.43	.00	92.95	398	
GASVSM	139717.47	657112.27	181.28	4444793	398	
BTUHTVSM	1705308.6	3920651.61	-2673.40	18664357	398	
BTUSTVSM	6564117.7	8199880.22	.00	39435112	398	
BTUHWVSM	.00	.00	.00	.00	398	
ELVN	24.00	.00	24.00	24.00	398	
GASVN	24.00	.00	24.00	24.00	398	
BTUHTVN	24.00	.00	24.00	24.00	398	
BTUSTVN	24.00	.00	24.00	24.00	398	
BTUHWVN	24.00	.00	24.00	24.00	398	
COUNT	23.83	.45	20	24	398	
OATAV	54.97	14.85	11.50	80.71	398	
MOATAV	54.02	15.17	10.65	85.17	372	
NOATAV	55.57	15.24	11.60	84.50	374	
OOATAV	53.74	15.16	11.15	85.20	353	
OATN	23.82	.48	20	24	398	
MOATN	21.00	6.86	0	24	398	
NOATN	21.20	6.49	0	24	398	
OOATN	19.62	8.28	0	24	398	
LDATE	31750.91	164.34	31456.00	32015.00	398	
01361	.38	.03	.34	.43	212	
01369	.00	.00	.00	.00	231	
01669	.40	.07	.27	.53	212	

Page 20 Building 1669 - Data Set Descriptives 9/14/88

This procedure was completed at 16:30:51

The SPSS/PC+ system file is read from
file d:\v\sys\vbas2.sys
The file was created on 9/14/88 at 16:24:45
and is titled Dining Halls - V - Adding Occupancy Data
The SPSS/PC+ system file contains
400 cases, each consisting of
28 variables (including system variables).
28 variables will be used in this session.

Page 2 Building 1669 - Correlation/Covariance Matrix 9/14/88

This procedure was completed at 18:07:53
The raw data or transformation pass is proceeding
398 cases are written to the uncompressed active file.

Page 3 Building 1669 - Correlation/Covariance Matrix 9/14/88

Variables		Cases	Cross-Prod Dev	Variance-Covar	Variables		Cases	Cross-Prod Dev	Variance-Covar
NDATE	BTUHTVSM	398	-124312953778.0	-313130865.9394	NDATE	ELVSM	398	387954.5933	977.2156
NDATE	GASVSM	398	-14291178803.09	-35997931.4939	NDATE	BTUSTVSM	398	-118618683509.4	-298787615.8926
NDATE	OATAV	398	73354.5794	184.7722	NDATE	TEMVAV	398	-29196.1564	-73.5420
NDATE	BTUHWVSM	398	.0000	.0000	BTUHTVSM	ELVSM	398	10000737341.242	25190774.1593
BTUHTVSM	GASVSM	398	734612118298451	1850408358434.4	BTUHTVSM	BTUSTVSM	398	6.800864189E+15	17130640274094
BTUHTVSM	OATAV	398	-4604455716.554	-11598125.2306	BTUHTVSM	TEMVAV	398	168293346.4786	423912.7115
BTUHTVSM	BTUHWVSM	398	.0000	.0000	ELVSM	GASVSM	398	2151965427.8812	5420567.8284
ELVSM	BTUSTVSM	398	3868738987.5330	9744934.4774	ELVSM	OATAV	398	23866.6274	60.1174
ELVSM	TEMVAV	398	-503.9231	-1.2693	ELVSM	BTUHWVSM	398	.0000	.0000
GASVSM	BTUSTVSM	398	1.061049979E+15	2672669971345.5	GASVSM	OATAV	398	-346884277.5360	-873763.9233
GASVSM	TEMVAV	398	-163443151.6905	-411695.5962	GASVSM	BTUHWVSM	398	.0000	.0000
BTUSTVSM	OATAV	398	-18324399769.17	-46157178.2599	BTUSTVSM	TEMVAV	398	-4069939492.054	-10251736.7558
BTUSTVSM	BTUHWVSM	398	.0000	.0000	OATAV	TEMVAV	398	15417.6872	38.8355
OATAV	BTUHWVSM	398	.0000	.0000	TEMVAV	BTUHWVSM	398	.0000	.0000

Page 4 Building 1669 - Correlation/Covariance Matrix 9/14/88

Correlations:	NDATE	BTUHTVSM	ELVSM	GASVSM	BTUSTVSM	OATAV	TEMVAV	BTUHWVSM
NDATE	1.0000	-.4860**	.2910**	-.3334**	-.2217**	.0757	-.0713	.
BTUHTVSM	-.4860**	1.0000	.3144**	.7182**	.5329**	-.1992**	.0172	.
ELVSM	.2910**	.3144**	1.0000	.4037**	.0582	.1981**	-.0099	.
GASVSM	-.3334**	.7182**	.4037**	1.0000	.4960**	-.0895	-.0998	.
BTUSTVSM	-.2217**	.5329**	.0582	.4960**	1.0000	-.3790**	-.1992**	.
OATAV	.0757	-.1992**	.1981**	-.0895	-.3790**	1.0000	.4166**	.
TEMVAV	-.0713	.0172	-.0099	-.0998	-.1992**	.4166**	1.0000	.
BTUHWVSM	.	.	.	.	.	.	.	1.0000

N of cases: 398 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Page 5 Building 1669 - Correlation/Covariance Matrix 9/14/88

This procedure was completed at 18:08:14
The SPSS/PC+ system file is read from
file d:\v\sys\vbas2.sys
The file was created on 9/14/88 at 16:24:45
and is titled Dining Halls - V - Adding Occupancy Data
The SPSS/PC+ system file contains
400 cases, each consisting of
28 variables (including system variables).
28 variables will be used in this session.

Page 6 Building 1669 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

This procedure was completed at 18:08:16
The raw data or transformation pass is proceeding
398 cases are written to the uncompressed active file.

Page 7 Building 1669 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

Variables		Cases	Cross-Prod Dev	Variance-Covar	Variables		Cases	Cross-Prod Dev	Variance-Covar
NDATE	BTUHTVSM	212	-53568058989.46	-253877056.8221	NDATE	ELVSM	212	-79720.7896	-377.8236
N' 'E	GASVSM	212	-6924090667.544	-32815595.5808	NDATE	BTUSTVSM	212	-90219555460.36	-427580831.5657
NDATE	OATAV	212	-86160.8111	-408.3451	NDATE	TEMVAV	212	-10133.1823	-48.0246
NDATE	BTUHWVSM	212	.0000	.0000	NDATE	01669	212	-812.2989	-3.8498
BTUHTVSM	ELVSM	212	13257027187.475	62829512.7368	BTUHTVSM	GASVSM	212	677607270812880	3211408866411.8
BTUHTVSM	BTUSTVSM	212	6.663087149E+15	31578612079089	BTUHTVSM	OATAV	212	-3304260657.838	-15660003.1177
BTUHTVSM	TEMVAV	212	-60154716.8874	-285093.4450	BTUHTVSM	BTUHWVSM	212	.0000	.0000
BTUHTVSM	01669	212	37551951.4393	177971.3338	ELVSM	GASVSM	212	2413187185.0800	11436906.0904
ELVSM	BTUSTVSM	212	17570552249.306	83272759.4754	ELVSM	OATAV	212	-9549.5370	-45.2585
ELVSM	TEMVAV	212	-8043.5292	-38.1210	ELVSM	BTUHWVSM	212	.0000	.0000
ELVSM	01669	212	69.7088	.3304	GASVSM	BTUSTVSM	212	1.103392575E+15	5229348698122.7
GASVSM	OATAV	212	-367146452.1320	-1740030.5788	GASVSM	TEMVAV	212	-203122365.6269	-962665.2399
GASVSM	BTUHWVSM	212	.0000	.0000	GASVSM	01669	212	4705752.5272	22302.1447
BTUSTVSM	OATAV	212	-1872798426.226	-8875821.9252	BTUSTVSM	TEMVAV	212	-394715060.4131	-1870687.4901
BTUSTVSM	BTUHWVSM	212	.0000	.0000	BTUSTVSM	01669	212	60301582.3861	285789.4900
OATAV	TEMVAV	212	4549.0164	21.5593	OATAV	BTUHWVSM	212	.0000	.0000
OATAV	01669	212	62.5757	.2966	TEMVAV	BTUHWVSM	212	.0000	.0000
TEMVAV	01669	212	8.2263	.0390	BTUHWVSM	01669	212	.0000	.0000

Page 8 Building 1669 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

Correlations:	NDATE	BTUHTVSM	ELVSM	GASVSM	BTUSTVSM	OATAV	TEMVAV	BTUHWVSM	01669
NDATE	1.0000	-.5688**	-.2302**	-.4244**	-.6031**	-.3474**	-.0882	.	-.6426**
BTUHTVSM	-.5688**	1.0000	.6566**	.7123**	.7639**	-.2285**	-.0090	.	.5095**
ELVSM	-.2302**	.6566**	1.0000	.6899**	.5479**	-.1796*	-.3267**	.	.2573**
GASVSM	-.4244**	.7123**	.6899**	1.0000	.7302**	-.1466	-.1751*	.	.3686**
BTUSTVSM	-.6031**	.7639**	.5479**	.7302**	1.0000	-.0815	-.0371	.	.5151**
OATAV	-.3474**	-.2285**	-.1796*	-.1466	-.0815	1.0000	.2580**	.	.3224**
TEMVAV	-.0882	-.0090	-.3267**	-.1751*	-.0371	.2580**	1.0000	.	.0915
BTUHWVSM	.	.	.	.	.	.	.	1.0000	.
01669	-.6426**	.5095**	.2573**	.3686**	.5151**	.3224**	.0915	.	1.0000

N of cases: 212 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Page 9 Building 1669 - Correlation/Covariance Matrix - w/ Occ. 9/14/88

This procedure was completed at 18:08:34

APPENDIX E:

ENERGY CONSUMPTION AND SAVINGS PREDICTIONS WITH PLOTS OF ACTUAL VS. PREDICTED ENERGY CONSUMPTION

Annual Gas Consumption Prediction
L-Shaped Barracks
Colorado Springs AFM Bin Data

	(MBtu)		Savings (MBtu)	Savings (%)	
811 (86/87) Expected:	5430	(AE)			(Retrofit)
Low:	5442	(AL)			
High:	5418	(AH)			
Average of 812 (86/7), 813 (86/7, 87/8) Expected:	7403	(BE)	**1973**	**26.7%**	(BE - AE)
High:	7420	(BH)	**2002**	**27.0%**	(BH - AL)
Low:	7386	(BL)	**1944**	**26.3%**	(BL - AH)

Regression equation parameters:

Building	Season	Constant	OAT*	TAll**	BTUDHW***	R^2
811	1986/87	-9327695	-589970	620333	3.984	0.860
	1987/88	-8625504	-488705	589370	1.049	0.821
812	1986/87	-92651150	-727207	1865736	4.630	0.799
813	1986/87	-62407438	-764174	1584589	1.900	0.784
	1987/88	-63614755	-761587	1544064	3.910	0.904

			Ave. Gas at Bin T (KBtuH)						Annual Gas (MBtu)					
			1986/87			1987/88			1986/87			1987/88		
Bin Temp	Annual Hours	Oct Thru May Hours	811	812	813	811	812	813	811	812	813	811	812	813
62	798	299	405	739	622	245	632	460	121	221	186	73	189	137
57	799	394	528	890	781	347	767	618	208	351	308	137	302	244
52	769	527	651	1042	940	449	902	777	343	549	495	236	475	409
47	737	627	774	1193	1099	550	1037	936	485	748	689	345	650	587
42	710	668	897	1345	1258	652	1172	1094	599	898	841	436	783	731
37	672	657	1020	1496	1418	754	1307	1253	670	983	931	495	859	823
32	678	672	1142	1648	1577	856	1443	1412	768	1107	1060	575	969	949
27	582	582	1265	1799	1736	958	1578	1570	736	1047	1010	557	918	914
22	438	438	1388	1951	1895	1060	1713	1729	608	854	830	464	750	757
17	242	242	1511	2102	2054	1161	1848	1888	366	509	497	281	447	457
12	137	137	1634	2254	2214	1263	1983	2046	224	309	303	173	272	280
7	80	80	1757	2405	2373	1365	2118	2205	141	192	190	109	169	176
2	46	46	1880	2557	2532	1467	2253	2364	86	118	116	67	104	109
-3	20	20	2003	2708	2691	1569	2389	2522	40	54	54	31	48	50
-8	11	11	2126	2860	2850	1670	2524	2681	23	31	31	18	28	29
-13	3	3	2249	3011	3010	1772	2659	2840	7	9	9	5	8	9
-18	2	2	2372	3163	3169	1874	2794	2998	5	6	6	4	6	6
-23	0	0	2494	3314	3328	1976	2929	3157	0	0	0	0	0	0
	6724	5405						Expected:	5430	7986	7556	4006	6977	6667
								High:	5442	8005	7573	4017	6991	6681
								Low:	5418	7967	7539	3995	6963	6653
								Percent Uncertainty:	0.228%	0.242%	0.229%	0.276%	0.206%	0.207%

* OAT is the outside air temperature. The energy consumption calculations above use the indicated bin temperatures

** TAll is the average of the 7 measured space temperatures: Mess Hall, and Zones 1 through 3, East and West. For the days included in the data sets used for the regressions, the average values of TAll were: 75.51°F, 77.46°F, 76.05°F, and 74.85°F, for buildings 811 (86/87), 812 (86/87), 813 (86/87), and 813 (87/88), respectively. These values were used in calculating the energy consumption figures above.

*** BTUDHW is the energy used for domestic hot water. For the days included in the data sets used for the regressions, the average values of BTUDHW were: 2,204,936; 2,365,053; 2,208,015; and 1,608,735 BTUs, for buildings 811 (86/87), 812 (86/87), 813 (86/87), and 813 (87/88), respectively. These values were used in calculating the energy consumption figures above.

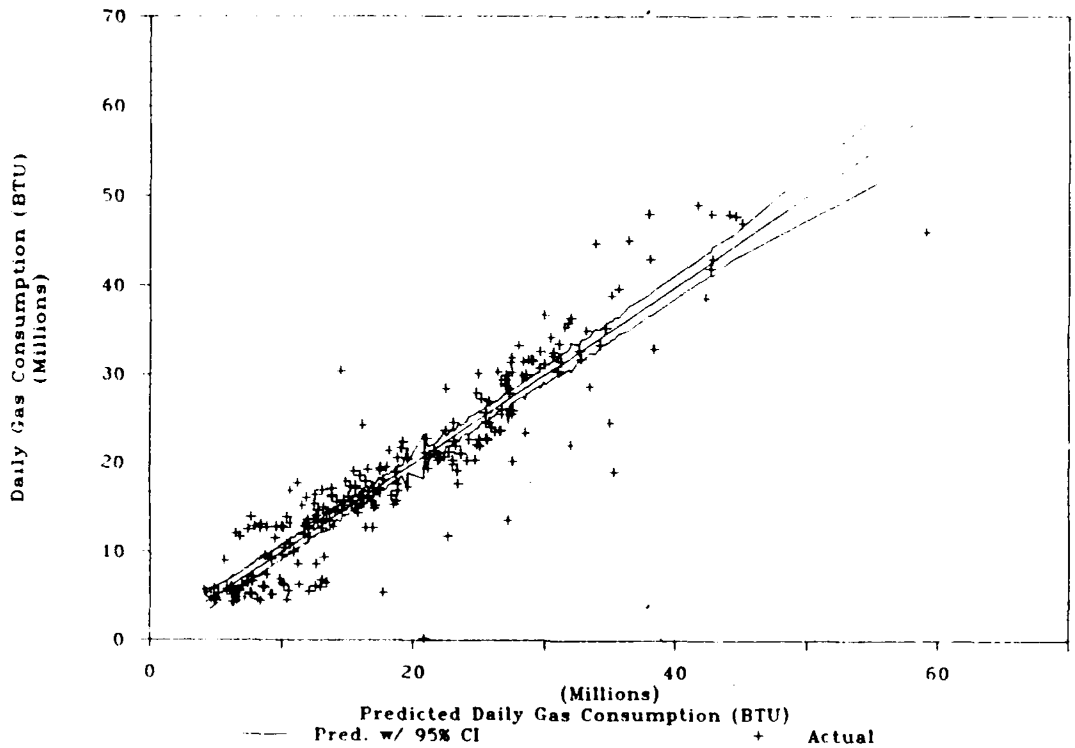

Figure E1. Actual vs. predicted gas consumption, L-shaped barracks, Bldg 811 (86/87).

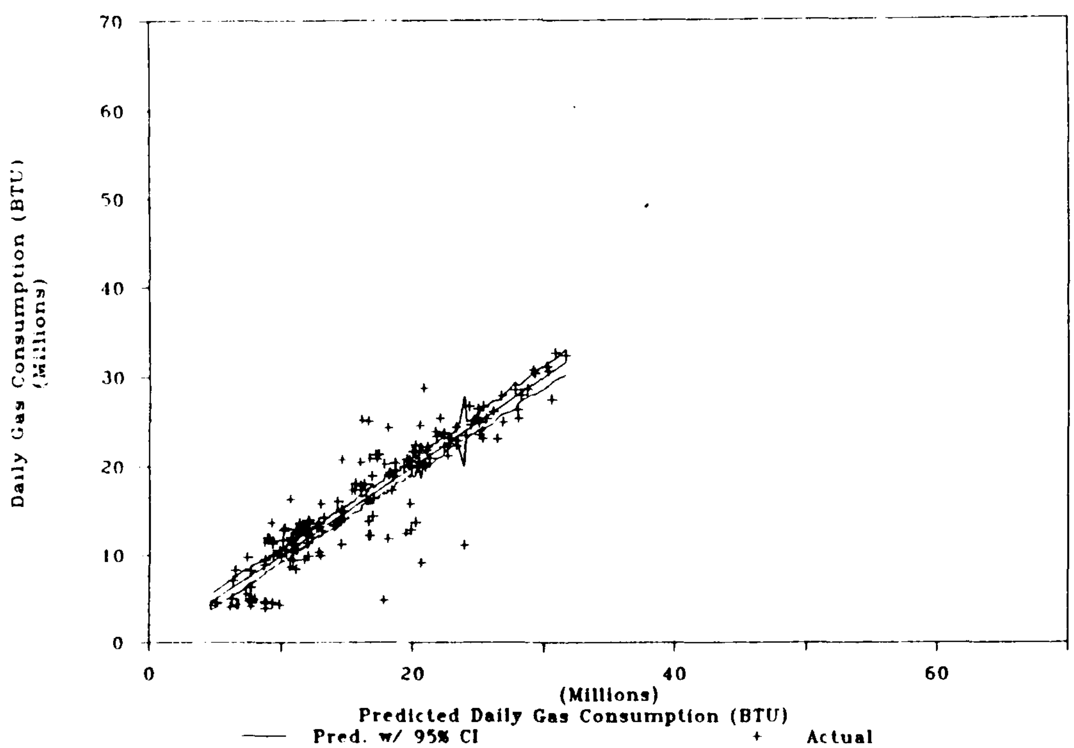

Figure E2. Actual vs. predicted gas consumption, L-shaped barracks, Bldg 811 (87/88).

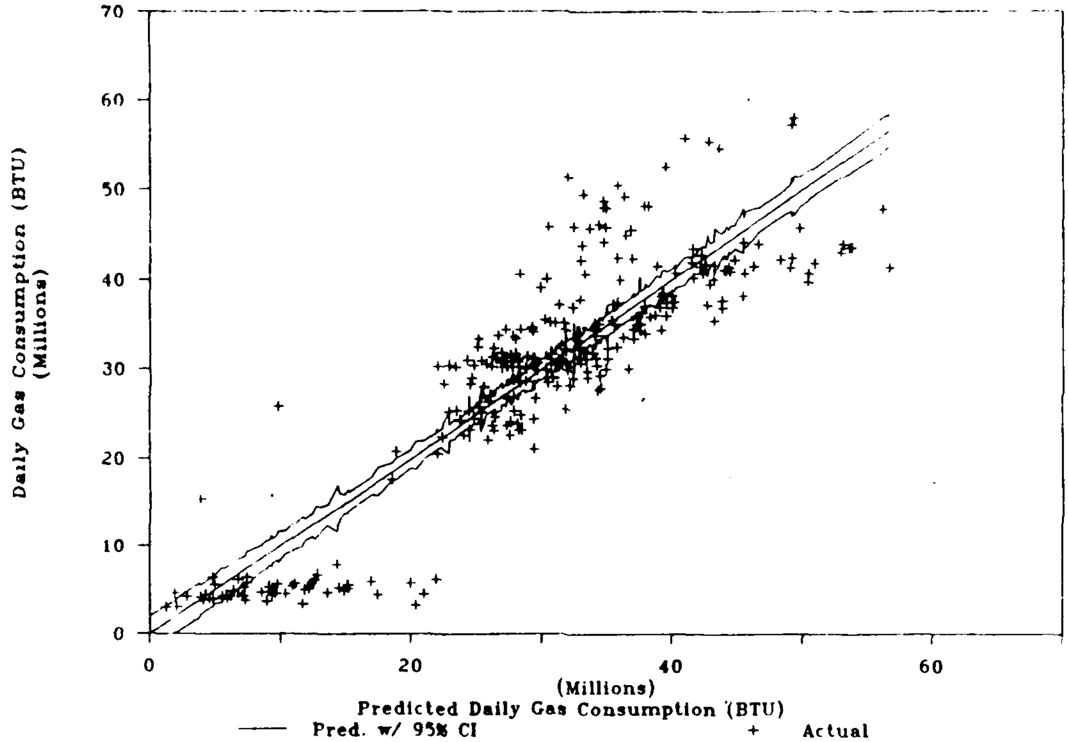

Figure E3. Actual vs. predicted gas consumption, L-shaped barracks, Bldg 812 (86/87).

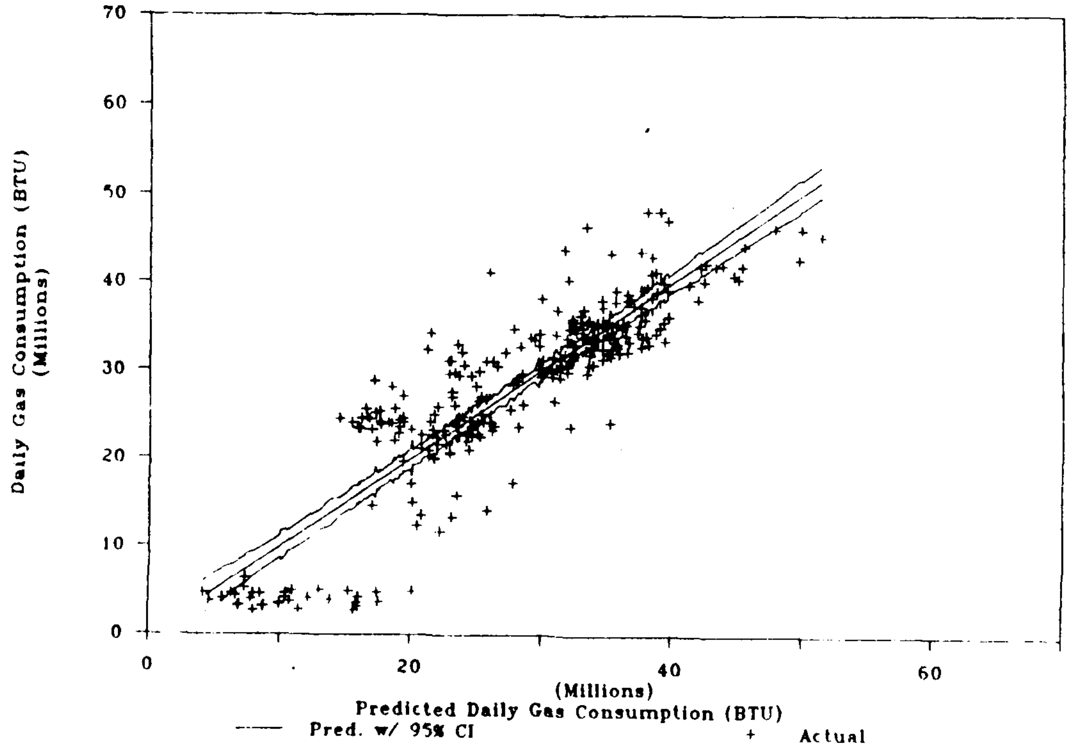

Figure E4. Actual vs. predicted gas consumption, L-shaped barracks, Bldg 813 (86/87).

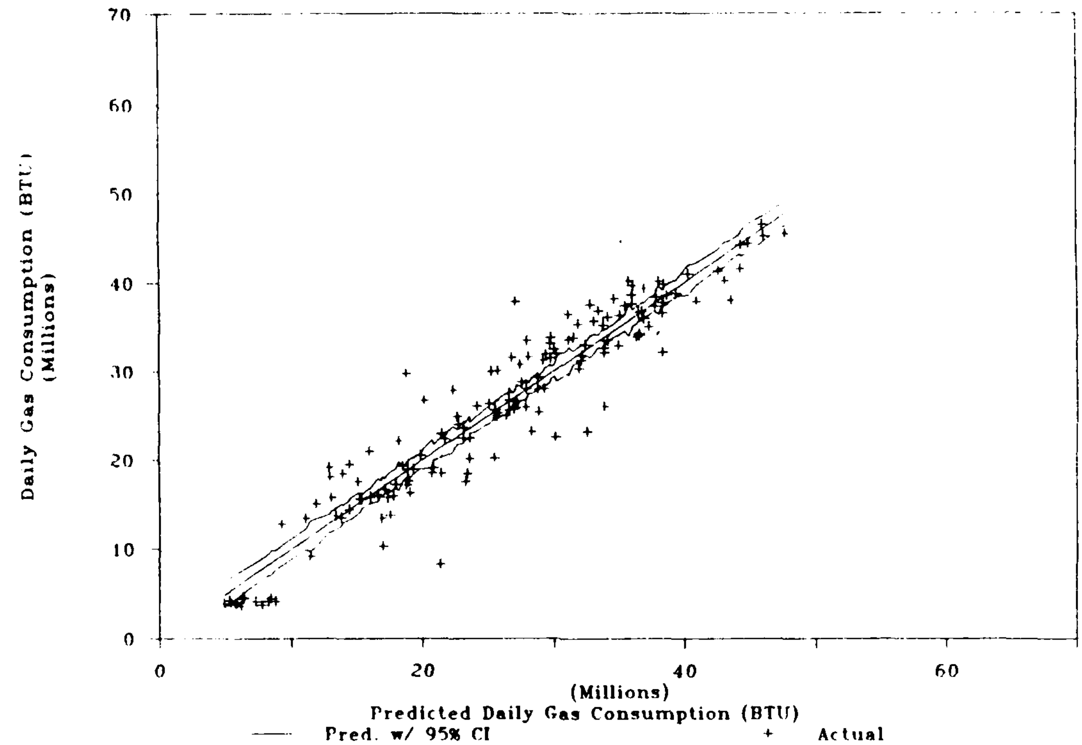

Figure E5. Actual vs. predicted gas consumption, L-shaped barracks, Bldg 813 (87/88).

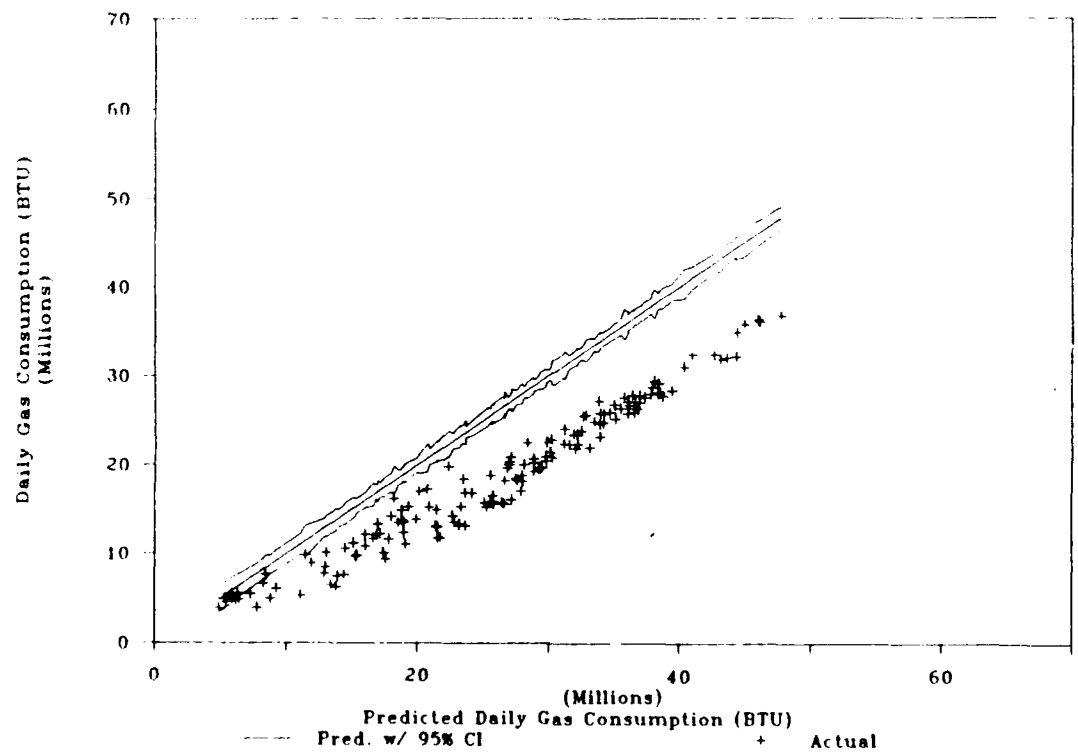

Figure E6. Bldg 811 (86/87) predicted using Bldg 813 (87/88) data.

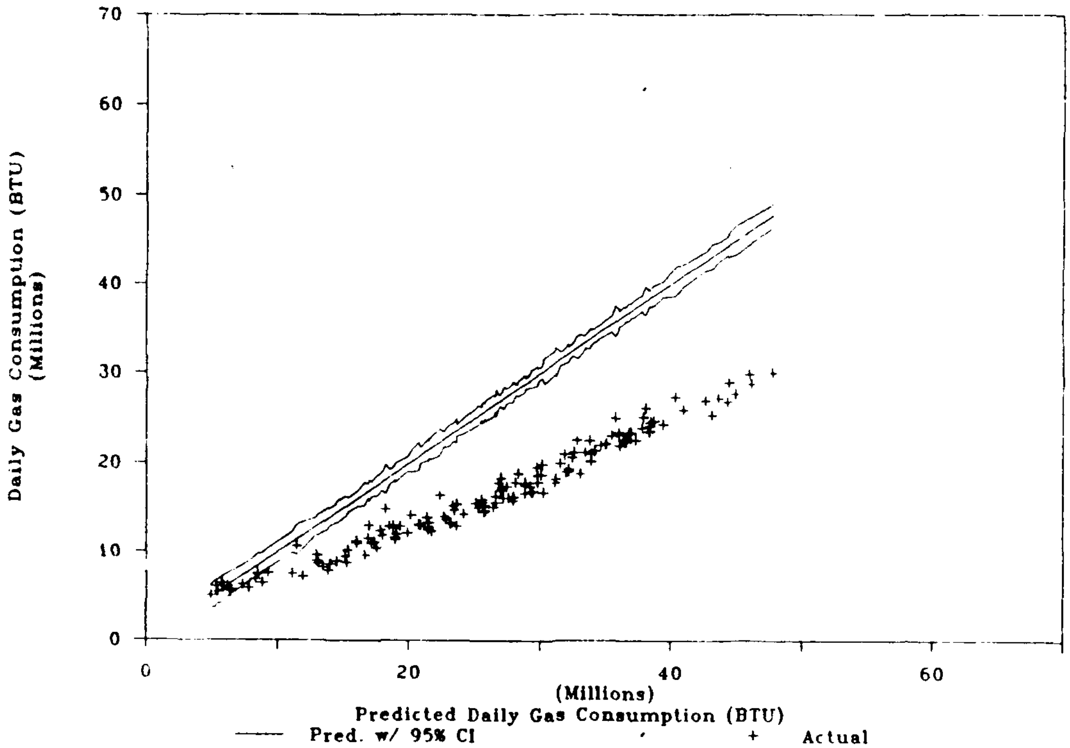

Figure E7. Bldg 811 (87/88) predicted using Bldg 813 (87/88) data.

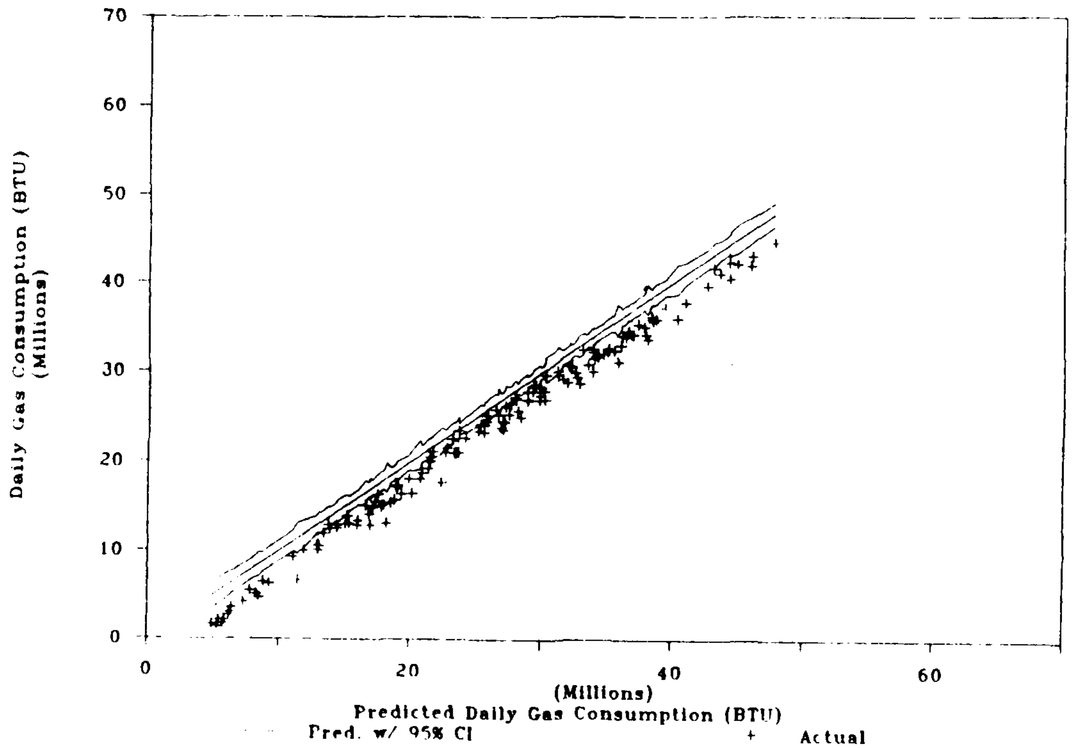

Figure E8. Bldg 812 (86/87) predicted using Bldg 813 (87/88) data.

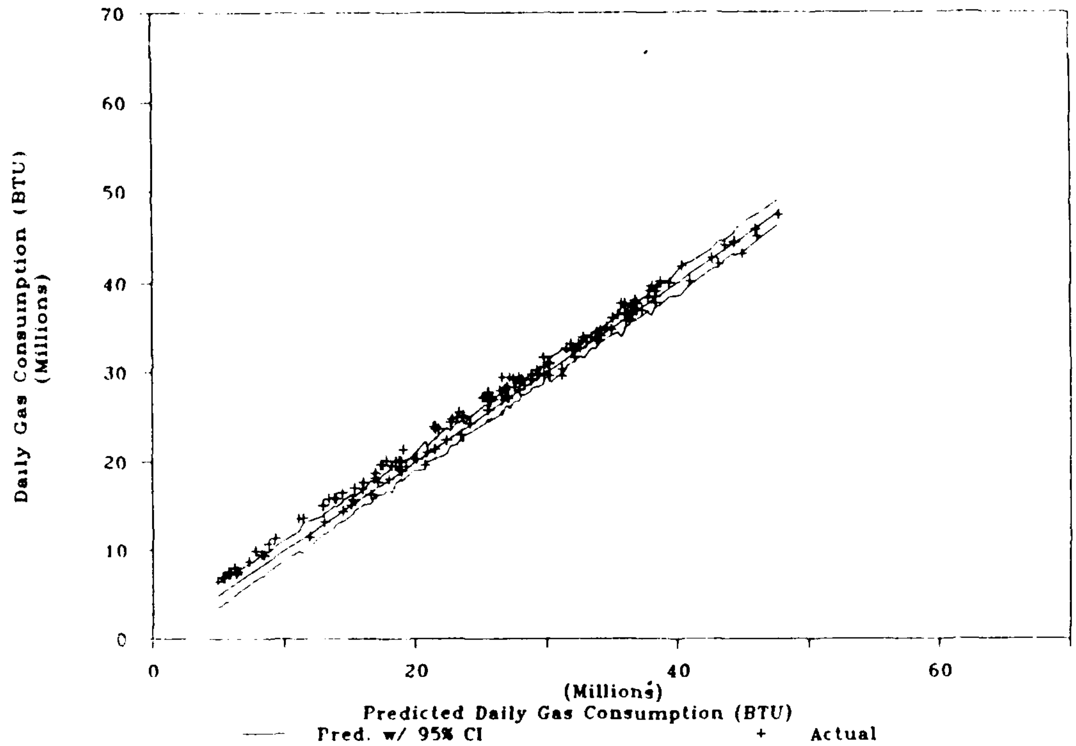

Figure E9. Bldg 813 (86/87) predicted using Bldg 813 (87/88) data.

L-Shaped Barracks-Heating

Annual Heating Energy Consumption Prediction
L-Shaped Barracks
Colorado Springs AFM Bin Data

	(MBtu)		Savings (MBtu)	Savings (%)	
811 (86/87) Expected:	1997	(AE)			(Retrofit)
Low:	2009	(AL)			
High:	1985	(AH)			
Average of 812 (86/7), 813 (86/7, 87/8) Expected:	2587	(BE)	590	22.8%	(BE - AE)
High:	2595	(BH)	610	23.5%	(BH - AL)
Low:	2579	(BL)	570	22.1%	(BL - AH)

Regression equation parameters:

Building	Season	Constant	OAT*	TAll**	BTUDHW***	R^2
811	1986/87	-5751443	-356983	363148	0.053	0.821
	1987/88	-9014913	-225372	313087	-0.034	0.834
812	1986/87	-27302473	-408236	719930	0.069	0.821
813	1986/87	-20014694	-374145	591011	0.143	0.787
	1987/88	-34180655	-373474	750659	1.091	0.833

Bin Temp	Annual Hours	Oct Thru May Hours	Ave. Heating at Bin T (KBtuH) 1986/87 811	1986/87 812	1986/87 813	1987/88 811	1987/88 812	1987/88 813	Annual Heating (MBtu) 1986/87 811	1986/87 812	1986/87 813	1987/88 811	1987/88 812	1987/88 813
62	798	299	7	130	94	-11	87	37	2	39	28	0	26	11
57	799	394	81	215	171	36	179	115	32	85	68	14	71	45
52	769	527	155	300	249	83	272	193	82	158	131	44	143	102
47	737	627	230	385	327	130	365	271	144	241	205	81	229	170
42	710	668	304	470	405	177	458	348	203	314	271	118	306	233
37	672	657	379	555	483	223	551	426	249	365	318	147	362	280
32	678	672	453	640	561	270	643	504	304	430	377	182	432	339
27	582	582	527	725	639	317	736	582	307	422	372	185	429	339
22	438	438	602	810	717	364	829	660	264	355	314	160	363	289
17	242	242	676	895	795	411	922	737	164	217	192	100	223	178
12	137	137	750	980	873	458	1015	815	103	134	120	63	139	112
7	80	80	825	1065	951	505	1107	893	66	85	76	40	89	71
2	46	46	899	1150	1029	552	1200	971	41	53	47	25	55	45
-3	20	20	973	1235	1107	599	1293	1049	19	25	22	12	26	21
-8	11	11	1048	1321	1185	646	1386	1126	12	15	13	7	15	12
-13	3	3	1122	1406	1263	693	1479	1204	3	4	4	2	4	4
-18	2	2	1197	1491	1341	740	1571	1282	2	3	3	1	3	3
-23	0	0	1271	1576	1419	787	1664	1360	0	0	0	0	0	0
	6724	5405						Expected:	1997	2945	2561	1181	2915	2254
								High:	2009	2953	2569	1186	2928	2262
								Low:	1985	2937	2553	1176	2902	2246
								Percent Uncertainty:	0.602%	0.28[illegible]%	0.307%	0.448%	0.446%	0.369%

* OAT is the outside air temperature. The energy consumption calculations above use the indicated bin temperatures

** TAll is the average of the 7 measured space temperatures: Mess Hall, and Zones 1 through 3, East and West. For the days included in the data sets used for the regressions, the average values of TAll were: 76.90°F, 77.16°F, 76.29°F, and 75.10°F, for buildings 811 (86/87), 812 (86/87), 813 (86/87), and 813 (87/88), respectively. These values were used in calculating the energy consumption figures above.

*** BTUDHW is the energy used for domestic hot water. For the days included in the data sets used for the regressions, the average values of BTUDHW were: 2,316,305, 2,579,943, 2,571,336, and 1,696,767 BTUs, for buildings 811 (86/87), 812 (86/87), 813 (86/87), and 813 (87/88), respectively. These values were used in calculating the energy consumption figures above.

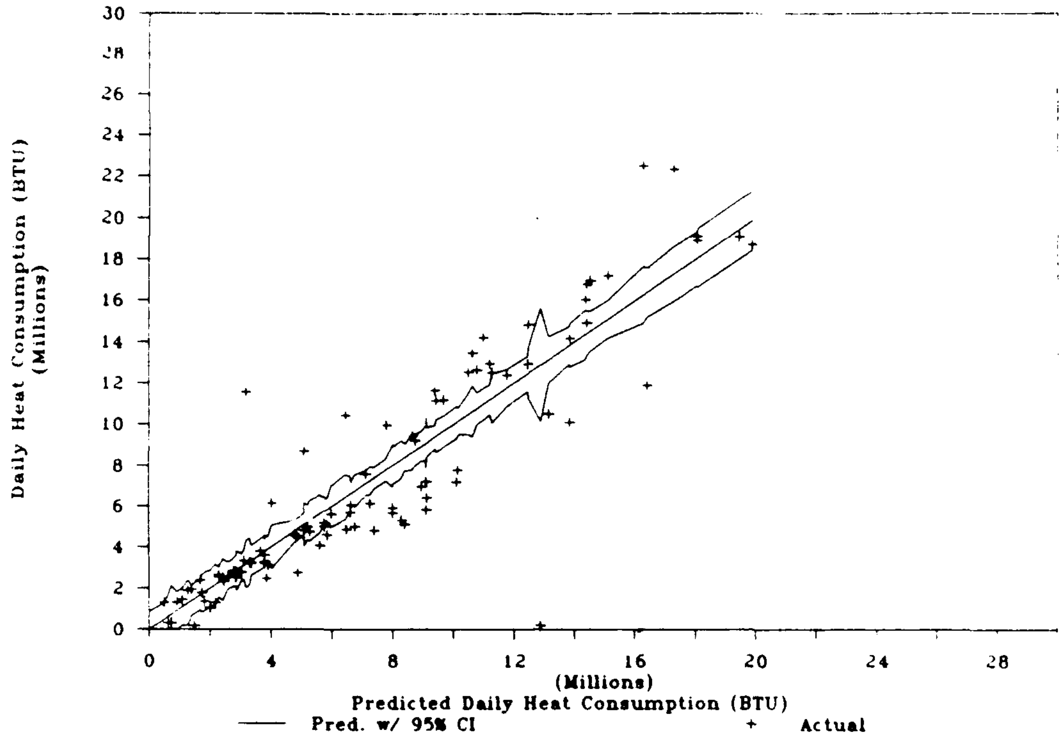

Figure E10. Actual vs. predicted heating use, L-shaped barracks, Bldg 811 (86/87).

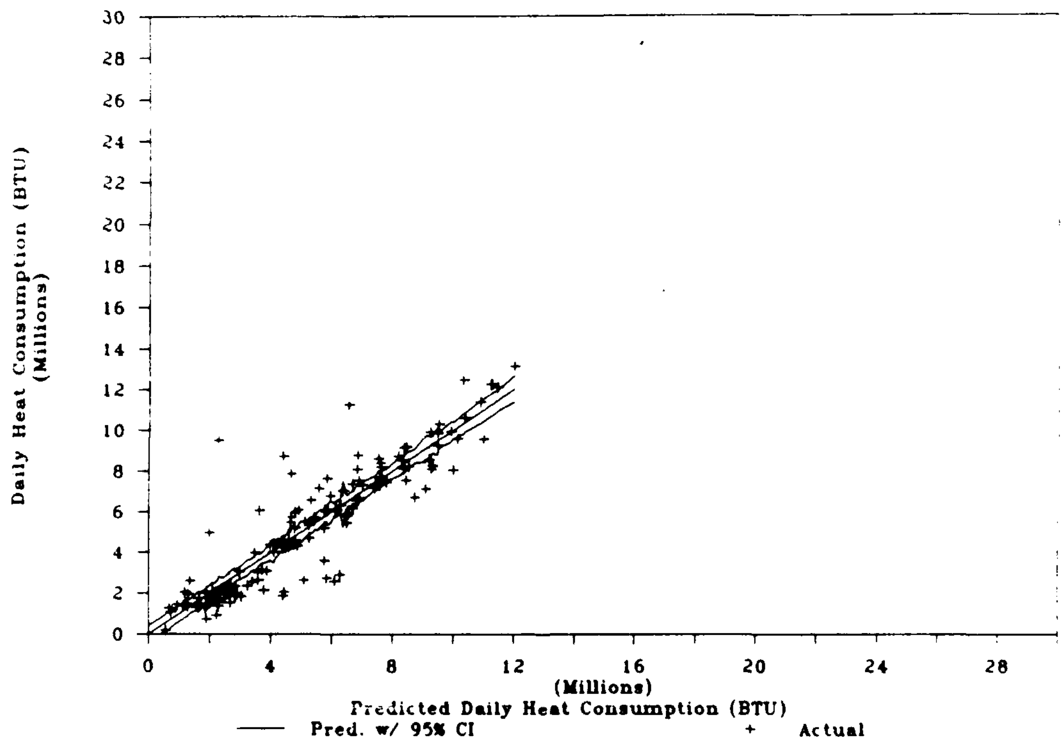

Figure E11. Actual vs. predicted heating use, L-shaped barracks, Bldg 811 (87/88).

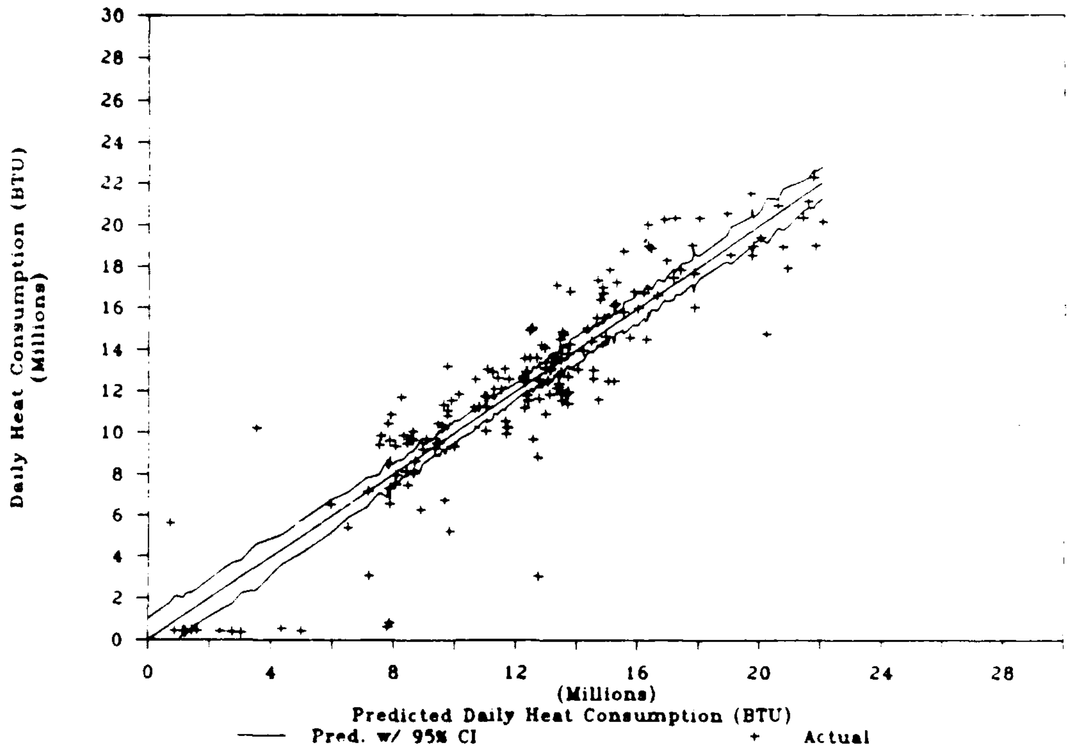

Figure E12. Actual vs. predicted heating use, L-shaped barracks, Bldg 812 (86/87).

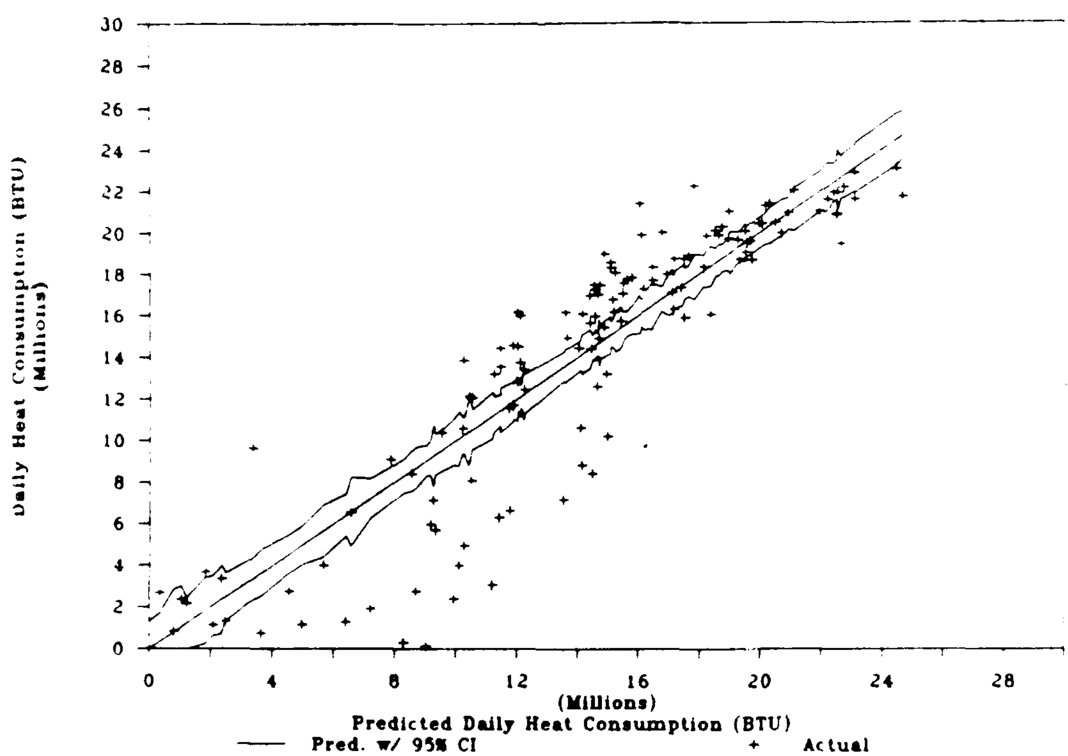

Figure E13. Actual vs. predicted heating use, L-shaped barracks, Bldg 812 (87/88).

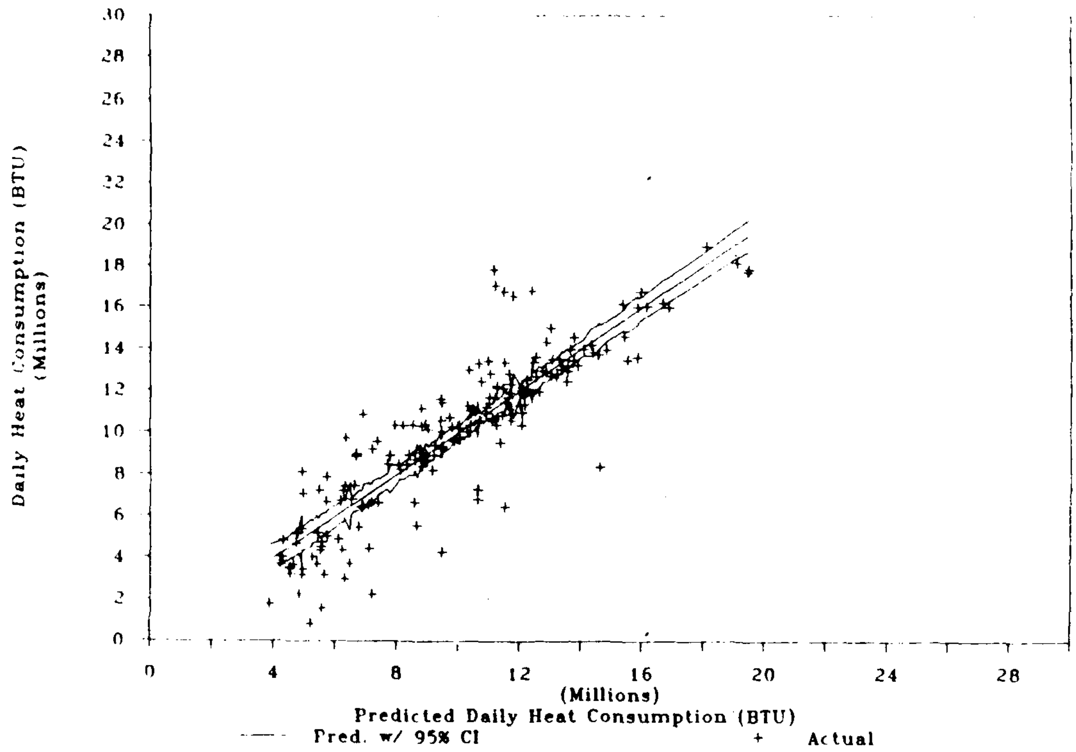

Figure E14. Actual vs. predicted heating use, L-shaped barracks, Bldg 813 (86/87).

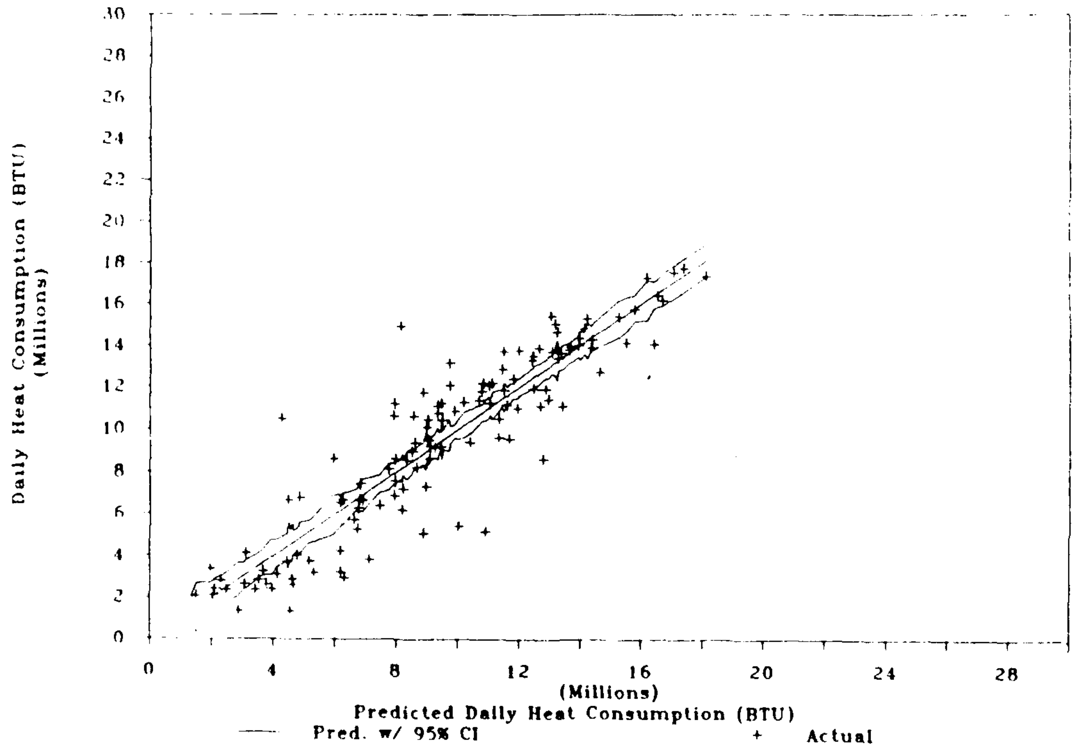

Figure E15. Actual vs. predicted heating use, L-shaped barracks, Bldg 813 (87/88).

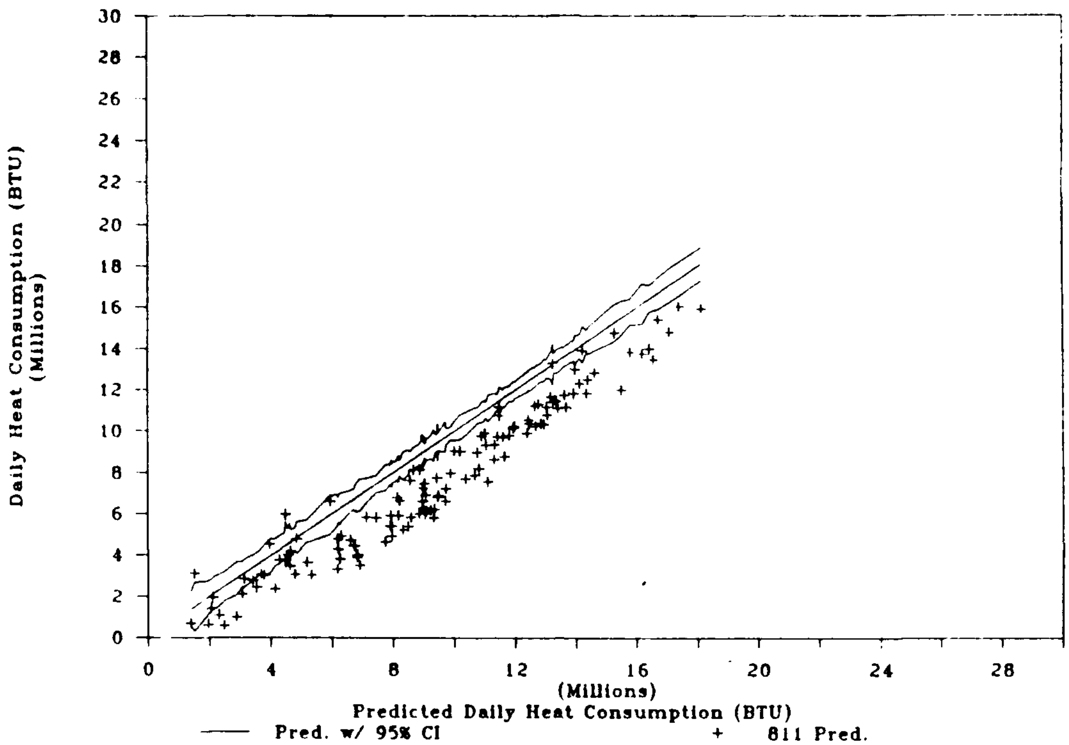

Figure E16. Bldg 811 (86/87) predicted using Bldg 813 (87/88) data.

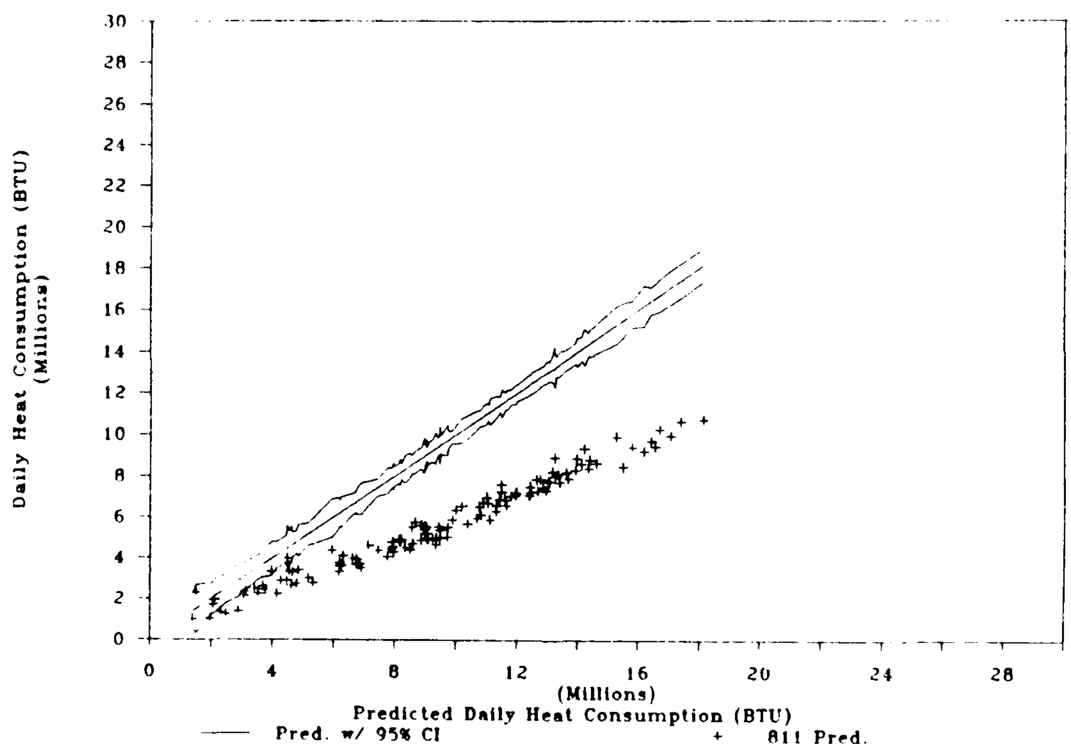

Figure E17. Bldg 811 (87/88) predicted using Bldg 813 (87/88) data.

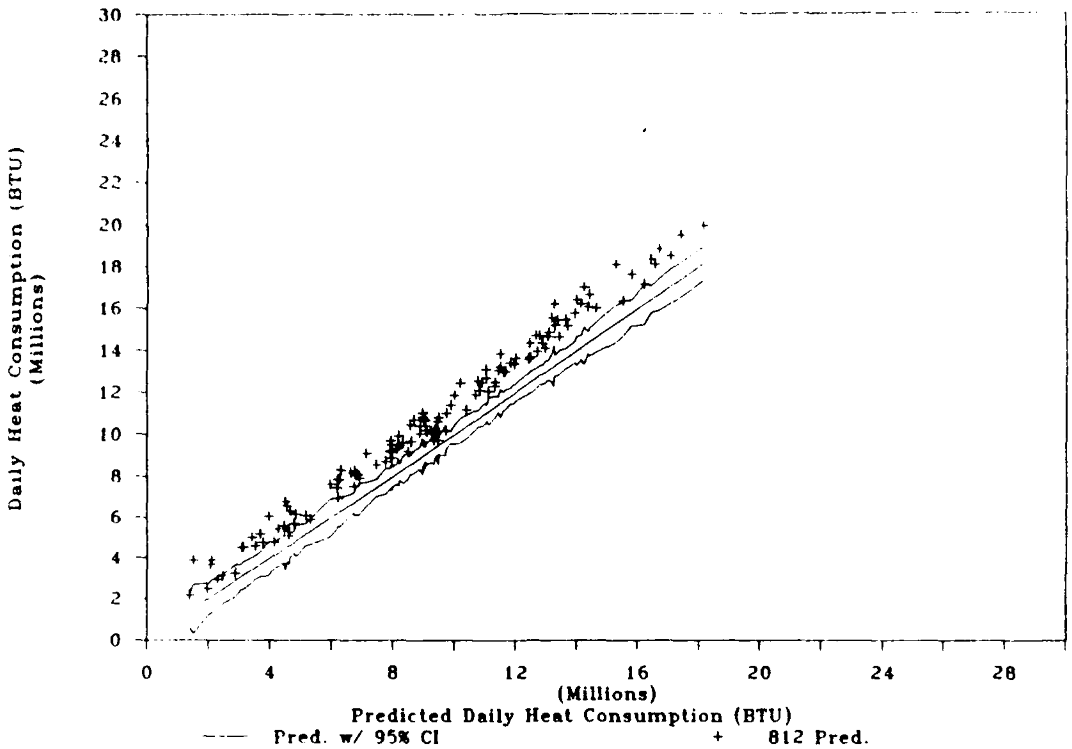

Figure E18. Bldg 812 (86/87) predicted using Bldg 813 (87/88) data.

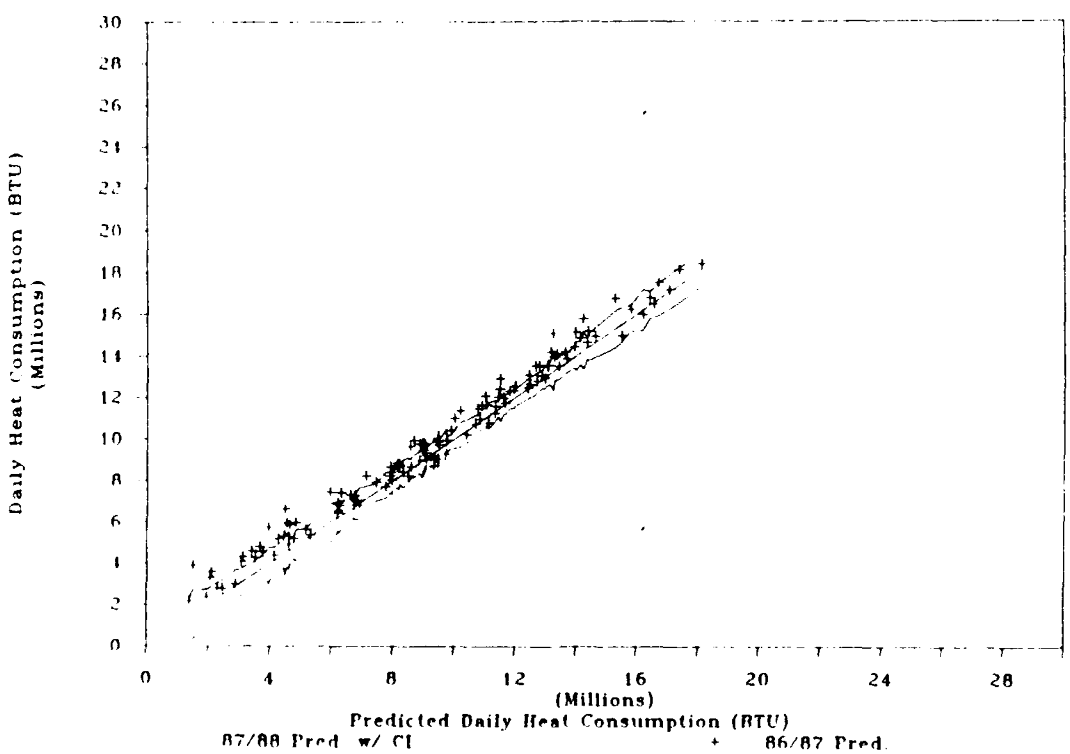

Figure E19. Bldg 813 (86/87) predicted using Bldg 813 (87/88) data.

Rolling-Pin Barracks

Annual Heating Energy Consumption Prediction
Rolling-Pin Barracks
Colorado Springs AFM Bin Data

		(MBtu)		Savings (MBtu)	Savings (%)	
Building 1363	Expected:	1545	(AE)			(Retrofit)
	Low:	1550	(AL)			
	High:	1540	(AH)			
Average of 1663, 1666, and 1667	Expected:	2611	(BE)	**1066**	**40.8%**	(BE - AE)
	High:	2618	(BH)	**1078**	**41.2%**	(BH - AL)
	Low:	2605	(BL)	**1055**	**40.5%**	(BL - AH)

Regression Equation Parameters:

Building	Constant	OAT*	TAll**	BTUHW***	R^2
1363	10998625	-254382	83651	-1.126	0.792
1663	32145206	-271148	-134688	0.921	0.929
1666	27817445	-58271	-171558	-0.376	0.241
1667	44087963	-93878	-396278	0.420	0.778

Bin Temp	Annual Hours	Oct Thru May Hours	Ave. Heating at Bin T (KBtuH) 1363	1663	1666	1667	Annual Heating (MBtu) 1363	1663	1666	1667
62	798	299	27	246	434	340	8	73	130	102
57	799	394	80	302	446	360	32	119	176	142
52	769	527	133	359	458	379	70	189	242	200
47	737	627	186	415	471	399	117	260	295	250
42	710	668	239	472	483	418	160	315	322	279
37	672	657	292	528	495	438	192	347	325	288
32	678	672	345	584	507	457	232	393	341	307
27	582	582	398	641	519	477	232	373	302	278
22	438	438	451	697	531	496	198	305	233	217
17	242	242	504	754	543	516	122	182	131	125
12	137	137	557	810	556	536	76	111	76	73
7	80	80	610	867	568	555	49	69	45	44
2	46	46	663	923	580	575	31	42	27	26
-3	20	20	716	980	592	594	14	20	12	12
-8	11	11	769	1036	604	614	8	11	7	7
-13	3	3	822	1093	616	633	2	3	2	2
-18	2	2	875	1149	628	653	2	2	1	1
-23	0	0	928	1206	640	672	0	0	0	0
	6724	5405				Expected:	1545	2814	2667	2353
						High:	1550	2818	2677	2359
						Low:	1540	2810	2657	2347
						Percent Uncertainty:	0.340%	0.152%	0.359%	0.251%

* OAT is the outside air temperature. The energy consumption calculations above use the indicated bin temperatures

** TAll is the daily average of the space temperatures on the three floors of the barracks. For the days included in the data sets used for the regressions, the average values of TAll were: 73.84°F, 71.90°F, 76.45°F, and 77.24°F, for buildings 1363, 1663, 1666 and 1667, respectively. These values were used in calculating the energy consumption figures above.

*** BTUHW is the energy used for domestic hot water. For the days included in the data sets used for the regressions, the average values of BTUHW were: 661,637, 264,447, 1,780,563, and 1,179,286 BTUs, for buildings 1363, 1663, 1666, and 1667, respectively. These values were used in calculating the energy consumption figures above.

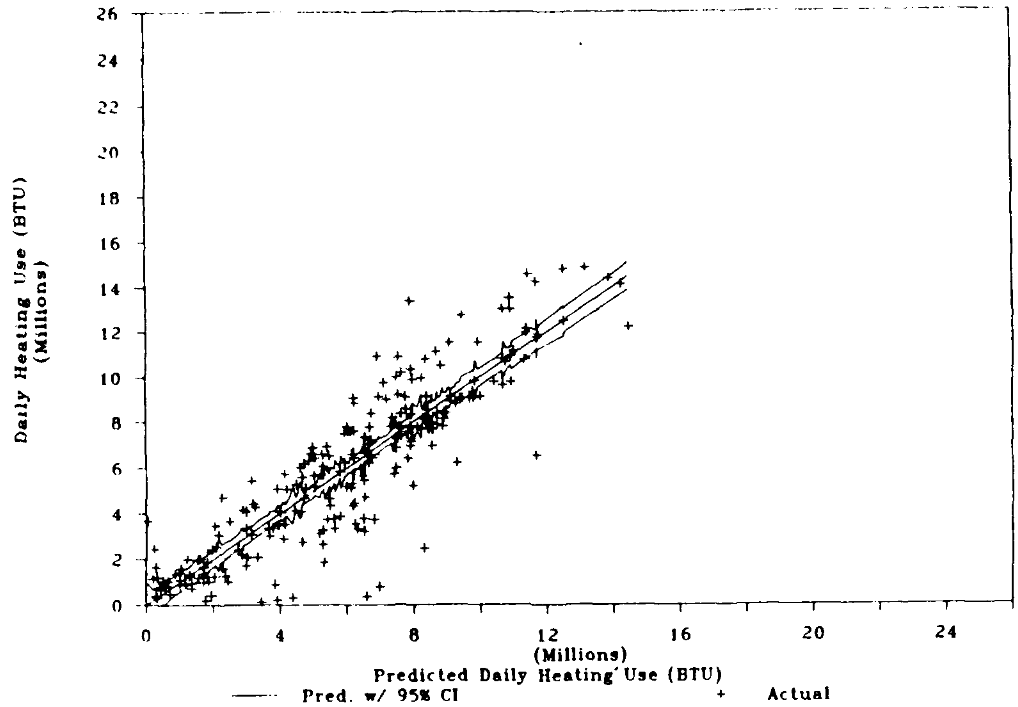

Figure E20. Actual vs. predicted heating use, rolling-pin barracks, Bldg 1363.

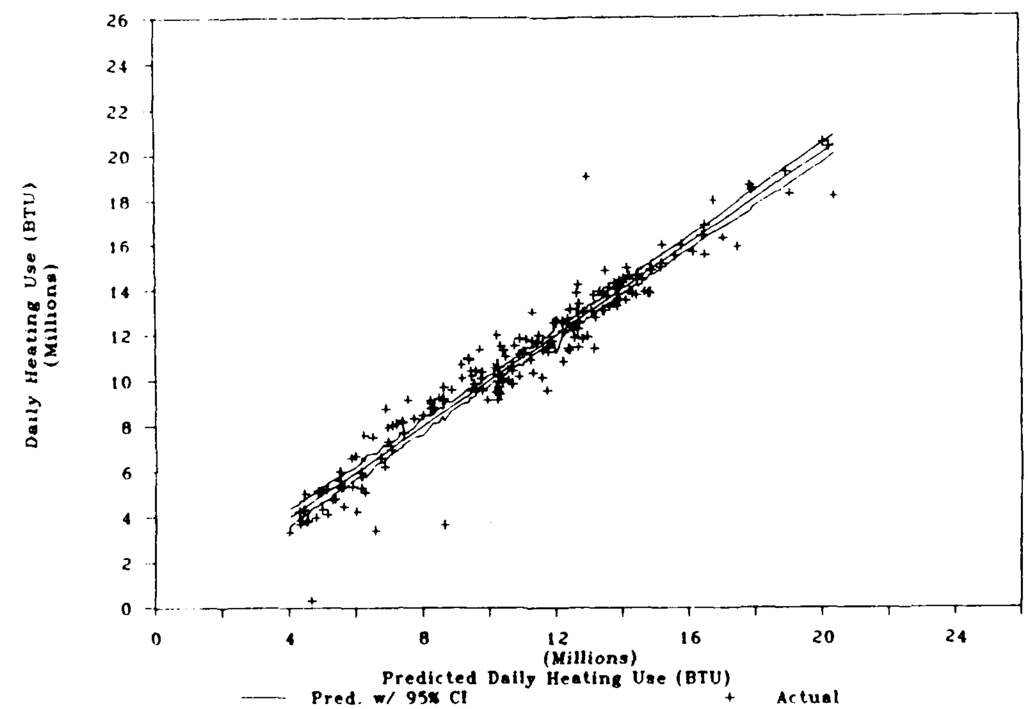

Figure E21. Actual vs. predicted heating use, rolling-pin barracks, Bldg 1663.

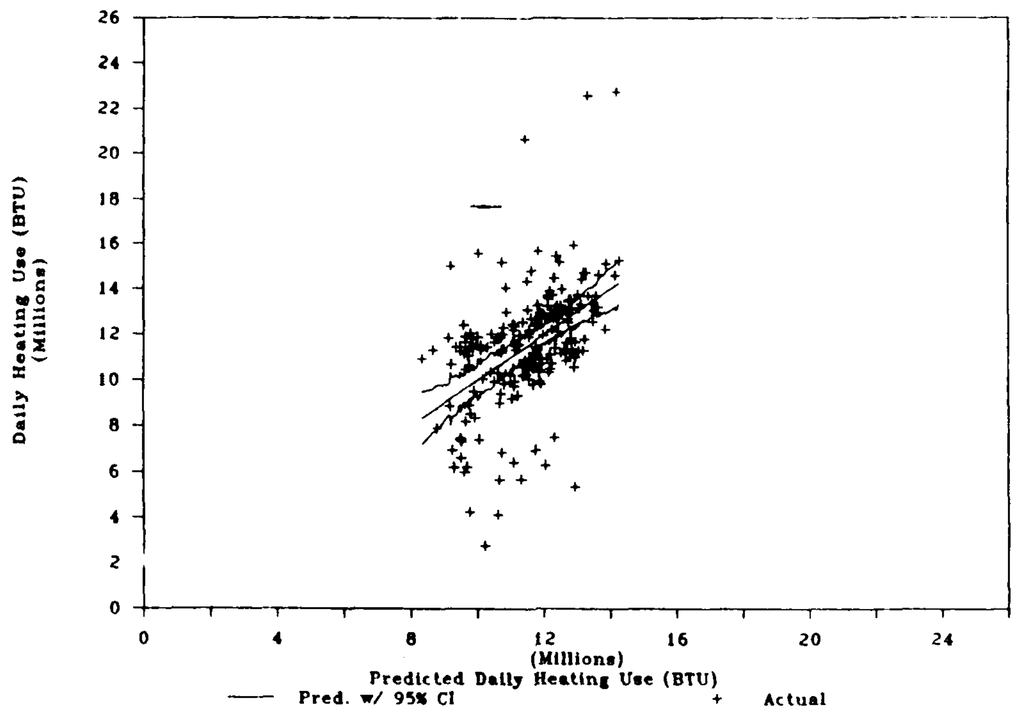

Figure E22. Actual vs. predicted heating use, rolling-pin barracks, Bldg 1666.

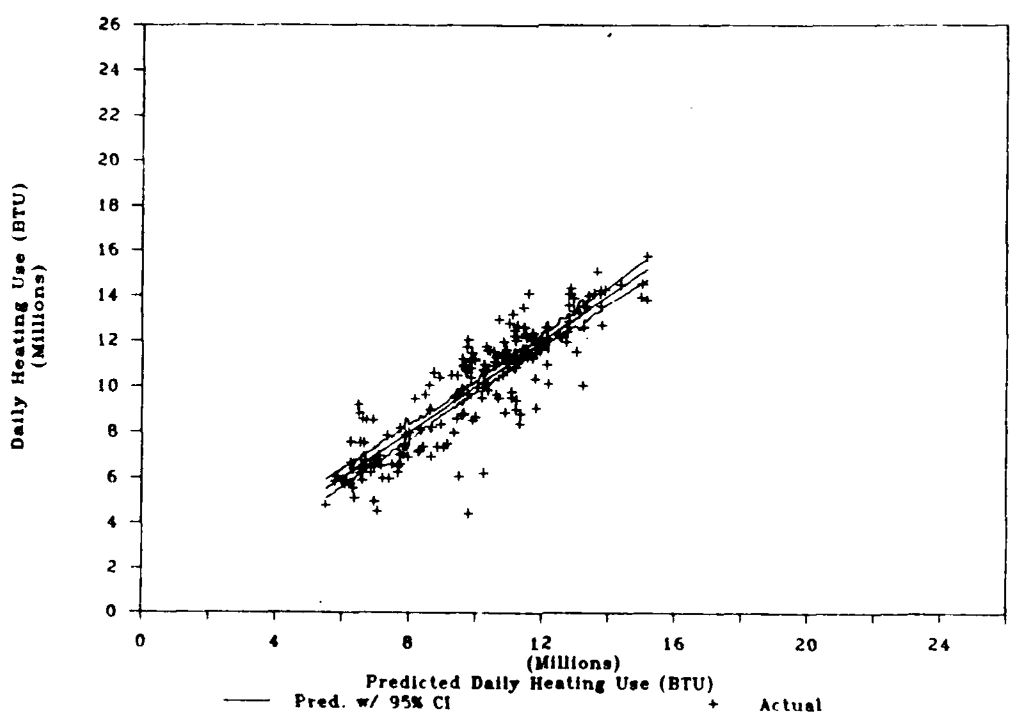

Figure E23. Actual vs. predicted heating use, rolling-pin barracks, Bldg 1667.

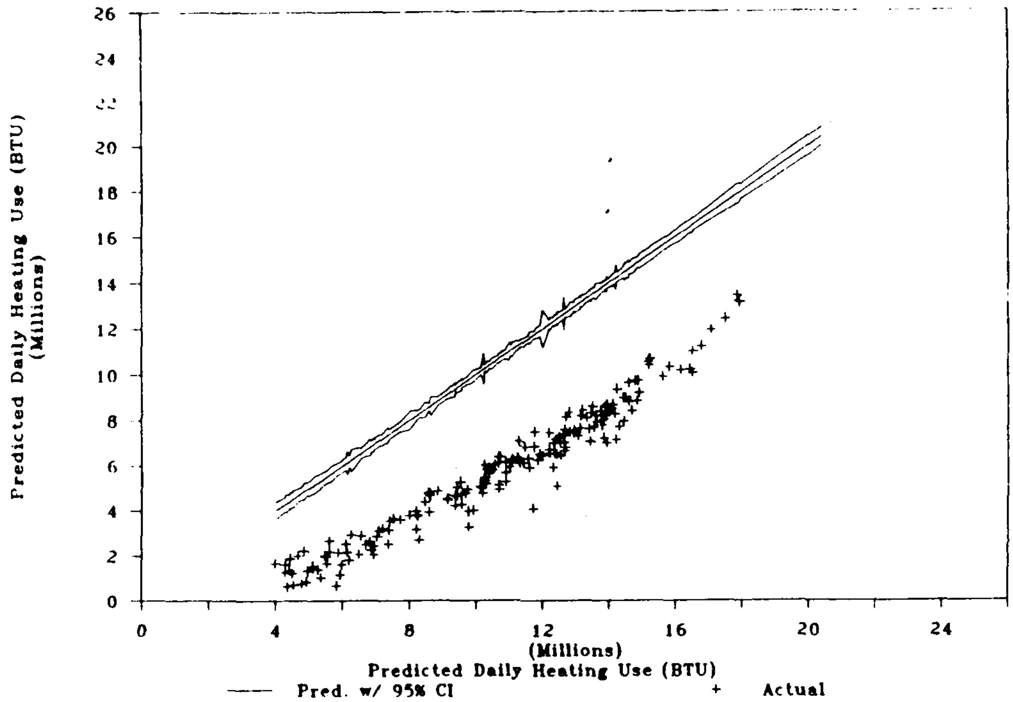

Figure E24. Bldg 1363 predicted heating use using Bldg 1663 actual data.

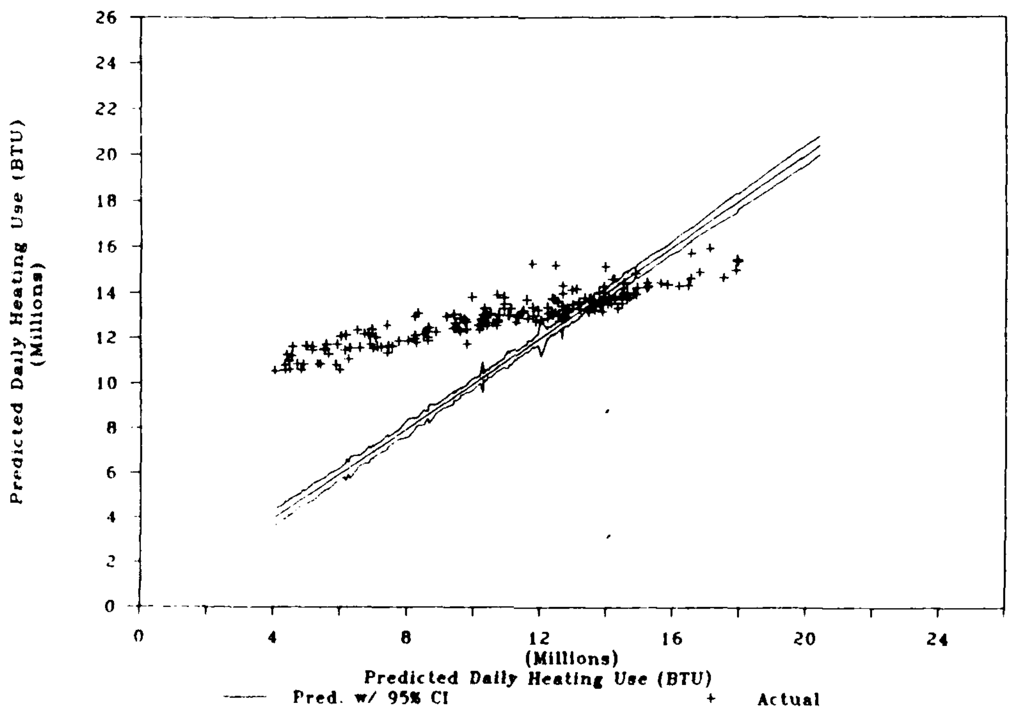

Figure E25. Bldg 1666 predicted heating use using Bldg 1663 actual data.

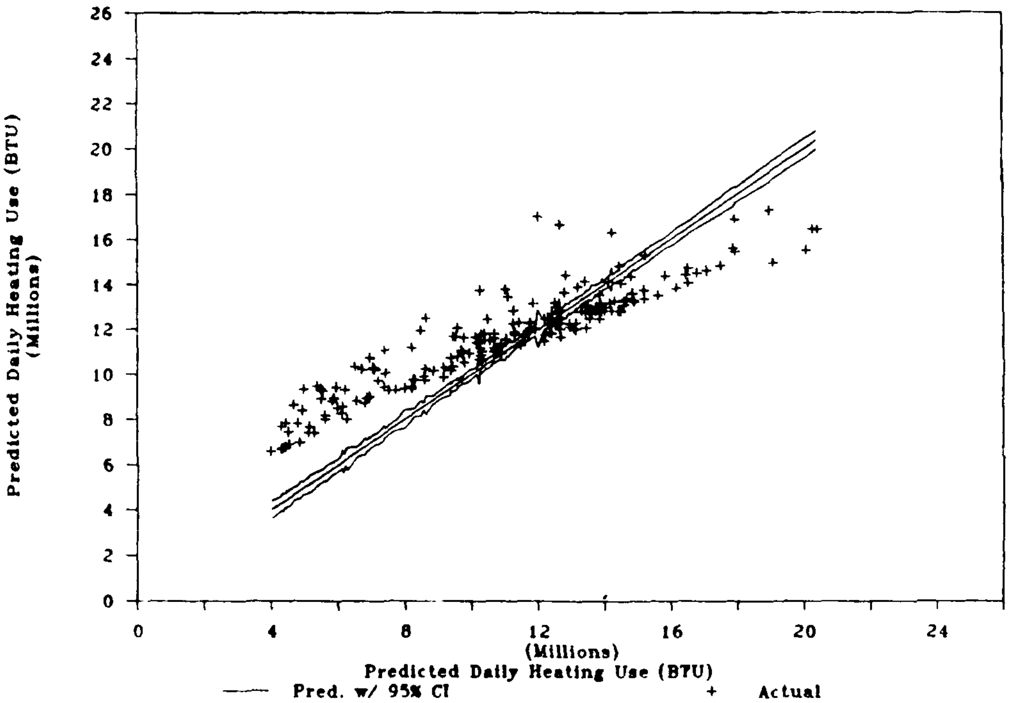

Figure E26. Bldg 1667 predicted heating use using Bldg 1663 actual data.

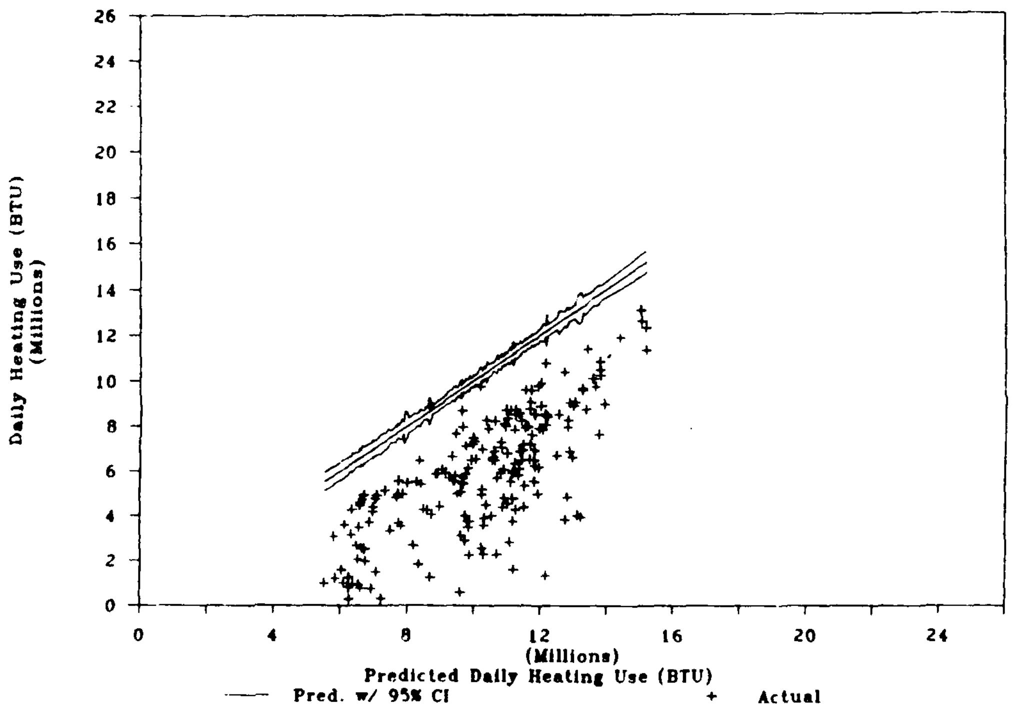

Figure E27. Bldg 1363 predicted heating use using Bldg 1667 actual data.

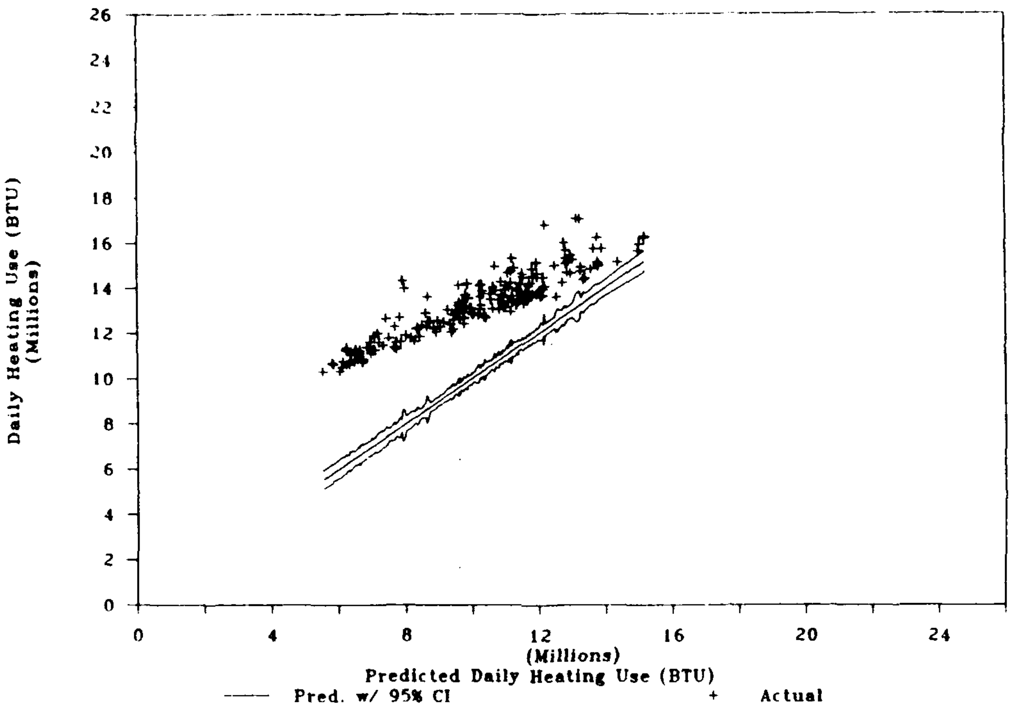

Figure E28. Bldg 1666 predicted heating use using Bldg 1667 actual data.

Motor Repair Shops

Annual Gas Consumption Prediction
Motor Repair Shops
Colorado Springs AFM Bin Data

		(MBtu)		Savings (MBtu)	Savings (%)	
Building 633	Expected:	1592	(AE)			(Retrofit)
	Low:	1579	(AL)			
	High:	1605	(AH)			
Average of 634 and 636	Expected:	2336	(BE)	744	31.9%	(BE - AE)
	High:	2350	(BH)	771	32.8%	(BH - AL)
	Low:	2323	(BL)	718	30.9%	(BL - AH)

Regression Equation Parameters:

Building	Constant	OAT*	Bay Temperature**	Electric Consumption***	R^2
633	10178663	-210526	67716	4197	0.668
634	10075874	-429631	242556	17316	0.736
635	10575672	-248228	115988	33308	0.343
636	3118149	-348736	263965	74901	0.841

Bin Temp	Annual Hours	Oct Thru May Hours	Ave. Gas at Bin T (KBtuH) 633	634	635	636	Annual Gas (MBtu) 633	634	635	636
62	798	299	4	-5	133	124	1	0	40	37
57	799	394	128	85	185	197	51	33	73	78
52	769	527	172	175	237	270	91	92	125	142
47	737	627	216	264	288	342	136	166	181	215
42	710	668	260	354	340	415	174	236	227	277
37	672	657	304	443	392	488	200	291	257	320
32	678	672	348	533	443	560	234	358	298	377
27	582	582	392	622	495	633	228	362	288	368
22	438	438	435	712	547	706	191	312	239	309
17	242	242	479	801	599	778	116	194	145	188
12	137	137	523	891	650	851	72	122	89	117
7	80	80	567	980	702	924	45	78	56	74
2	46	46	611	1070	754	996	28	49	35	46
-3	20	20	655	1159	805	1069	13	23	16	21
-8	11	11	699	1249	857	1142	8	14	9	13
-13	3	3	742	1338	909	1214	2	4	3	4
-18	2	2	786	1428	961	1287	2	3	2	3
-23	0	0	830	1517	1012	1360	0	0	0	0
	8747	5823				Expected:	1592	2337	2083	2589
						High:	1605	2351	2100	2599
						Low:	1579	2323	2066	2579
						Percent Uncertainty:	0.812%	0.582%	0.825%	0.385%

* OAT is the outside air temperature. The energy consumption calculations above use the indicated bin temperatures

** Bay Temperature is the temperature in the work area of the shop. For the days included in the data sets used for the regressions, the average values of Bay Temperature were: 68.88°F, 62.65°F, 66.07°F, and 69.55°F, for buildings 633, 634, 635 and 636, respectively. These values were used in calculating the energy consumption figures above.

*** Electricity Consumption is the daily consumption for the building. For the days included in the data set used for the regressions, the average values of Electricity Consumption were: 56.97, 72.58, 10.36, and 41.80 KWH, for buildings 633, 634, 635 and 636, respectively. These values were used in calculating the energy consumption figures above.

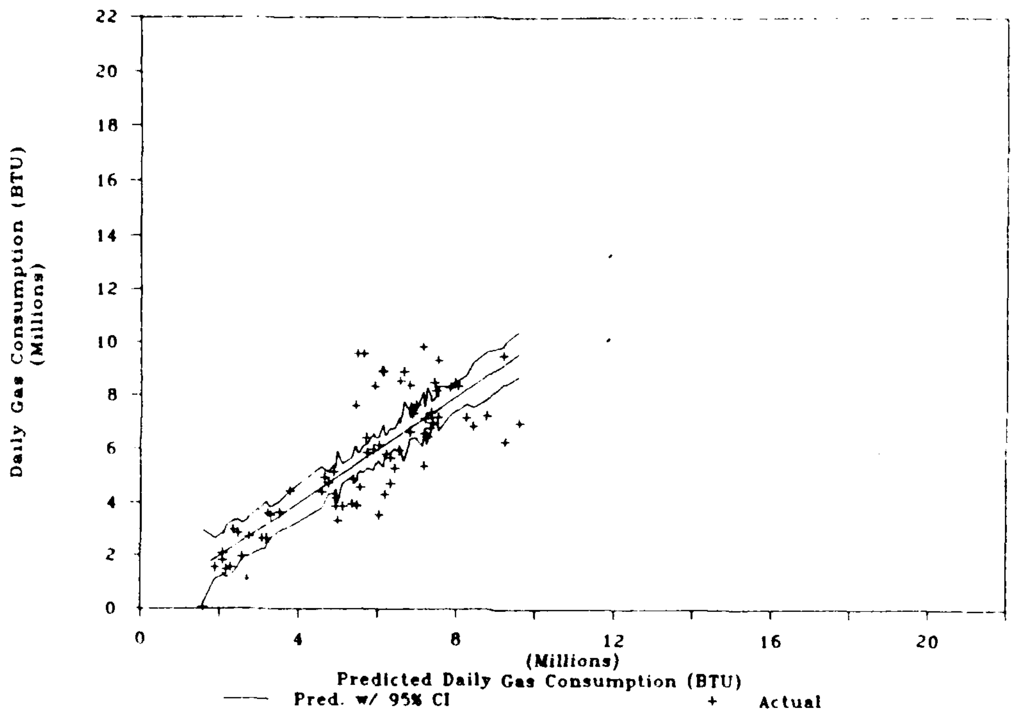

Figure E29. Actual vs. predicted gas consumption, motor repair shop, Bldg 633.

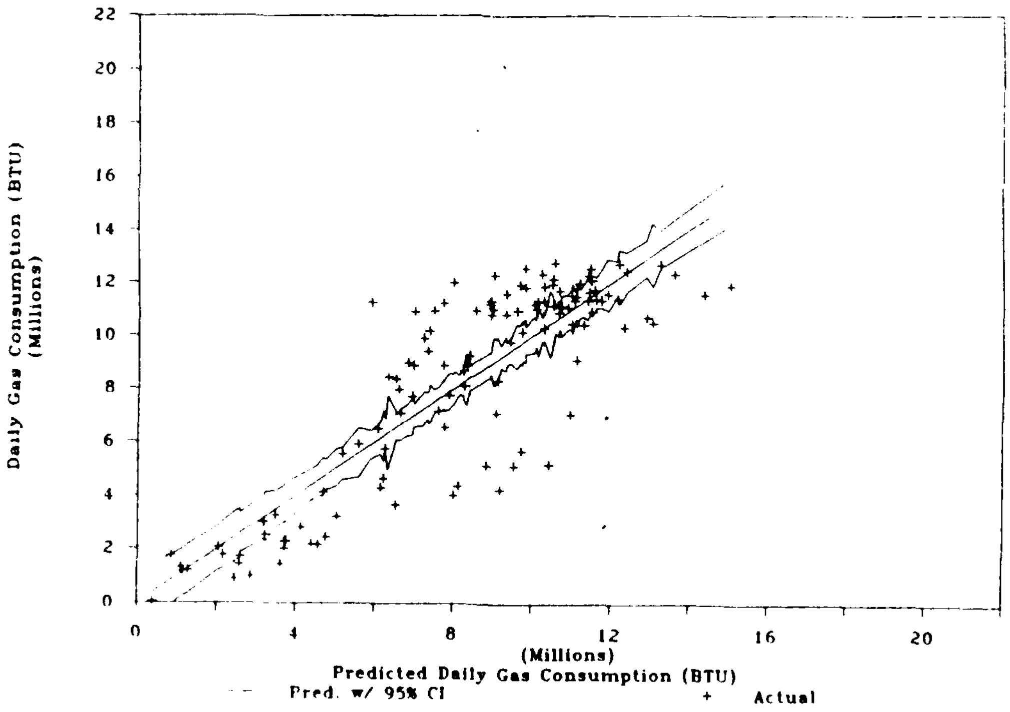

Figure E30. Actual vs. predicted gas consumption, motor repair shop, Bldg 634.

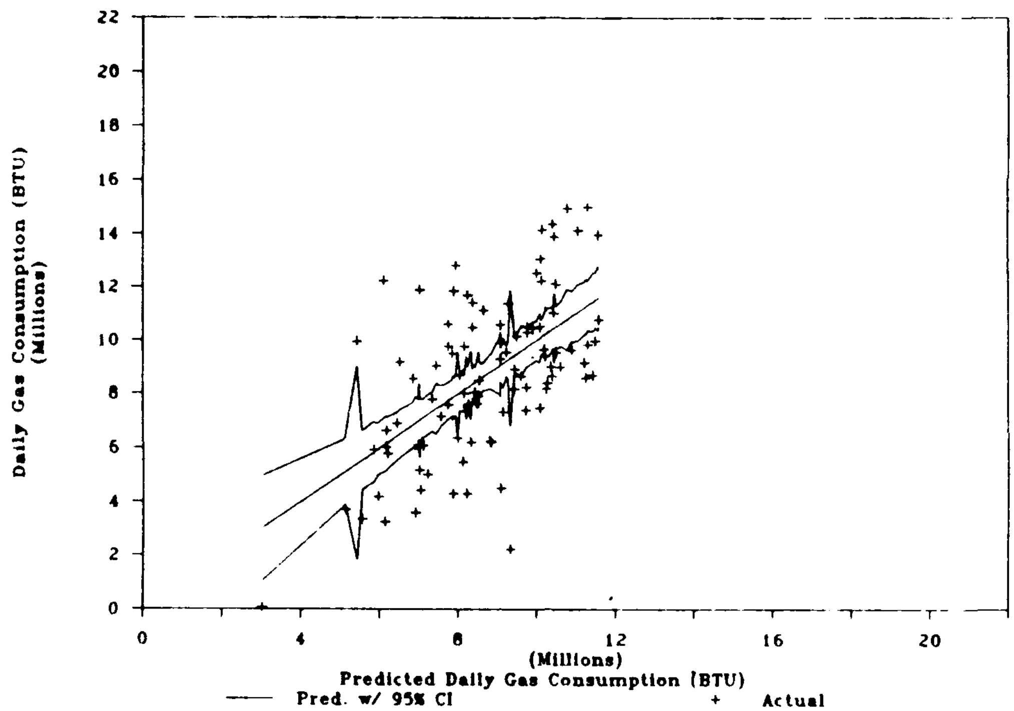

Figure E31. Actual vs. predicted gas consumption, motor repair shop, Bldg 635.

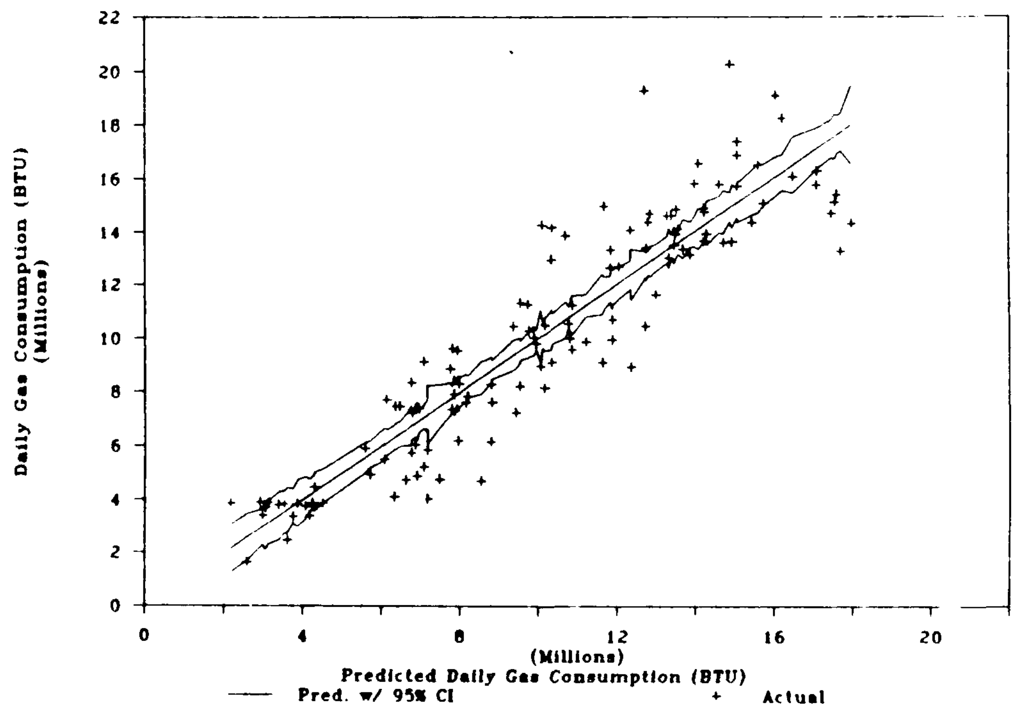

Figure E32. Actual vs. predicted gas consumption, motor repair shop, Bldg 636.

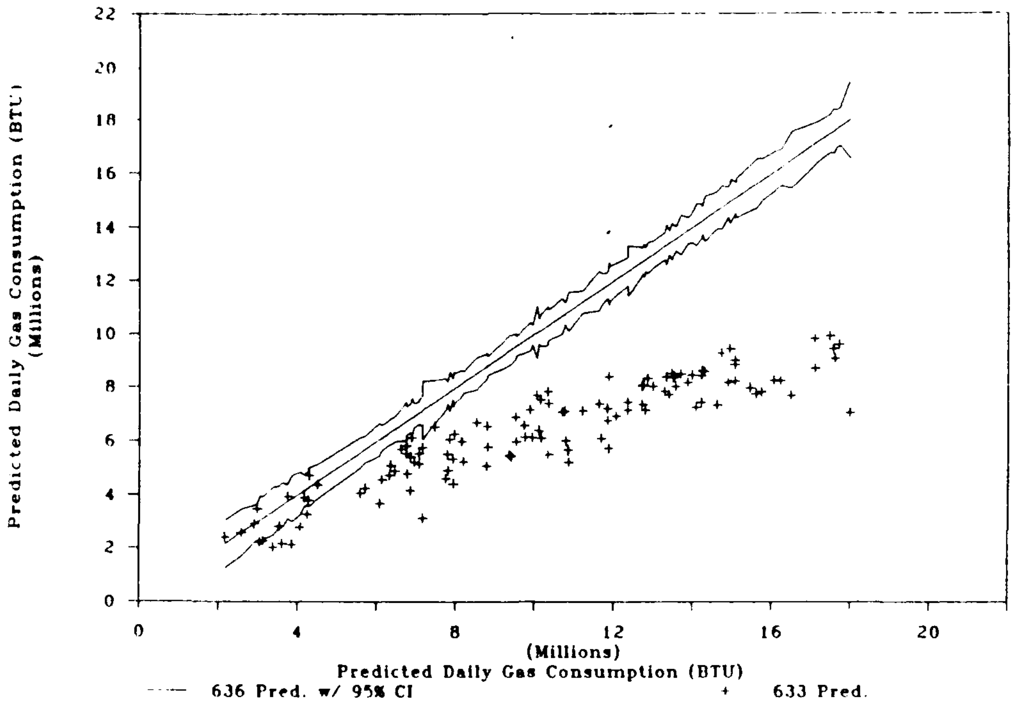

Figure E33. Bldg 633 predicted gas consumption using Bldg 636 data.

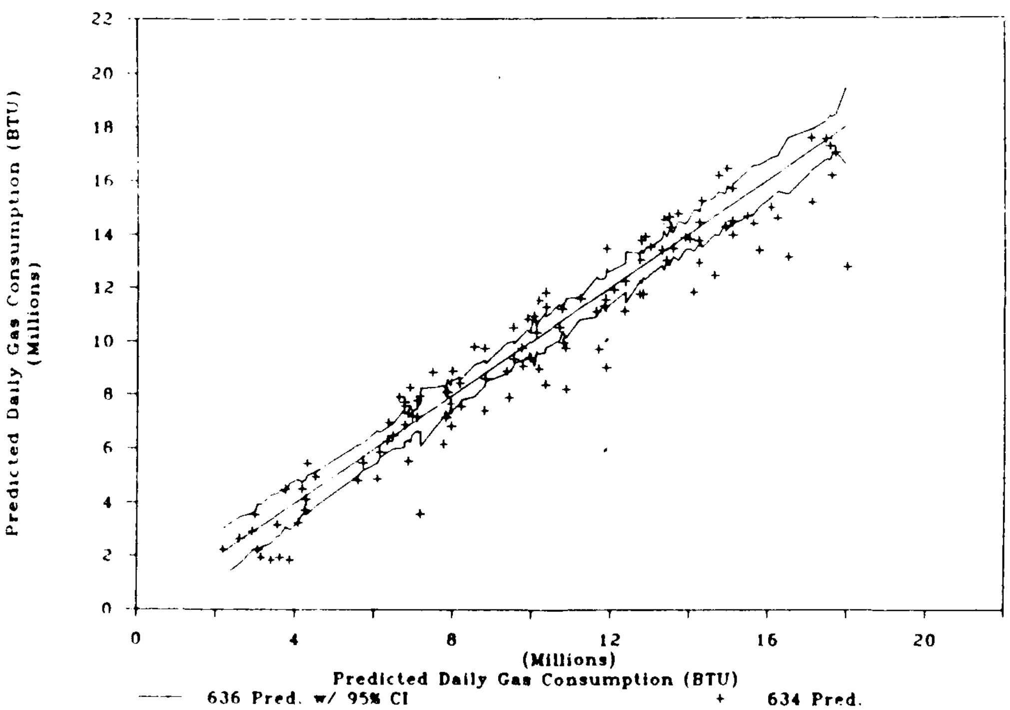

Figure E34. Bldg 634 predicted gas consumption using Bldg 636 data.

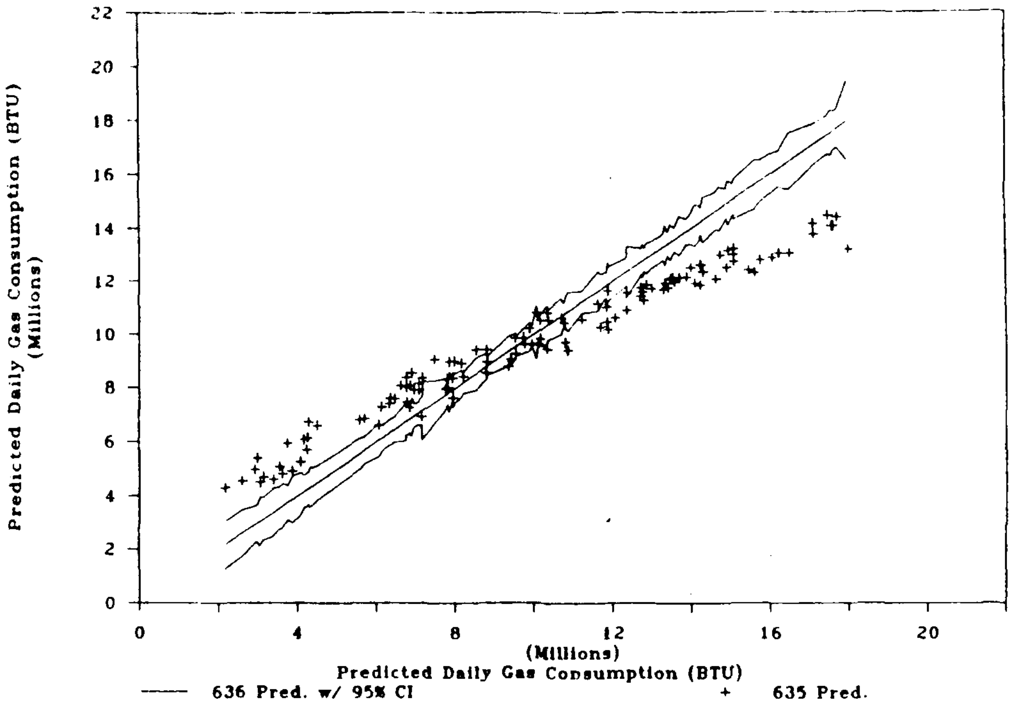

Figure E35. Bldg 635 predicted gas consumption using Bldg 636 data.

APPENDIX F:

GRAPHS OF OCCUPANCY DATA

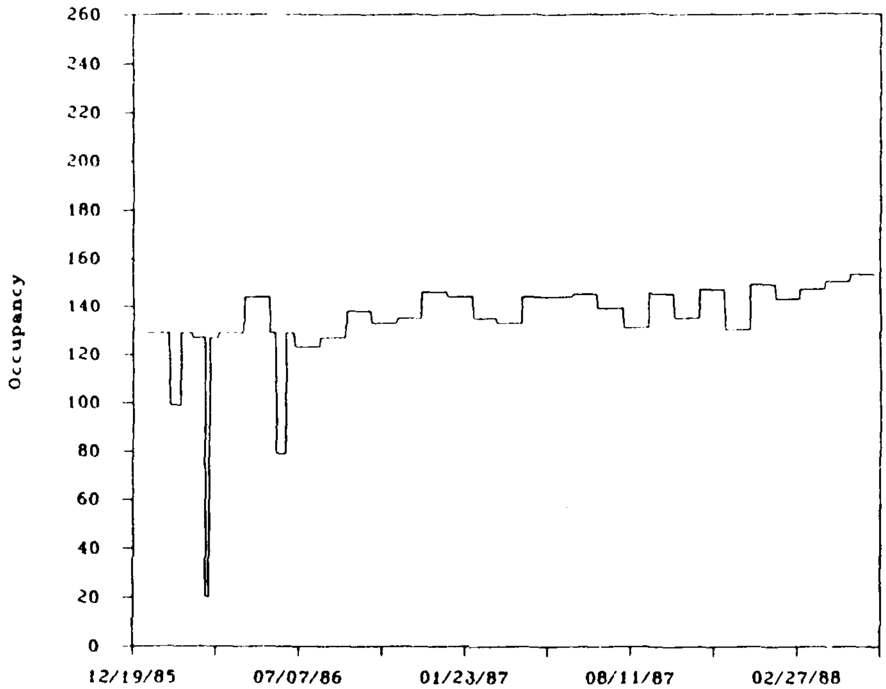

Figure F1. Building occupancy data for L-shaped barracks, Bldg 811.

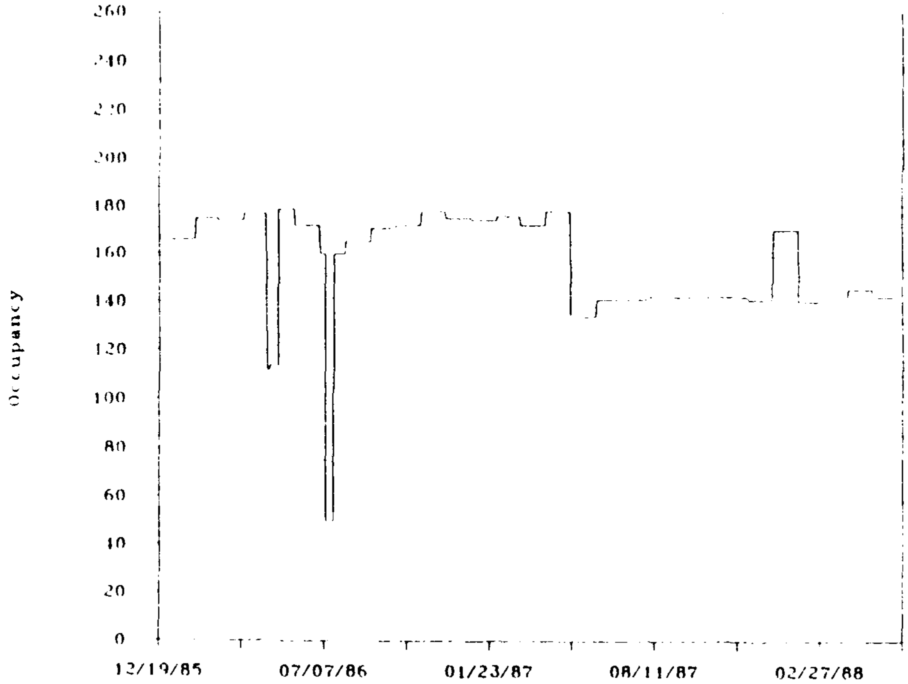

Figure F2. Building occupancy data for L-shaped barracks, Bldg 812.

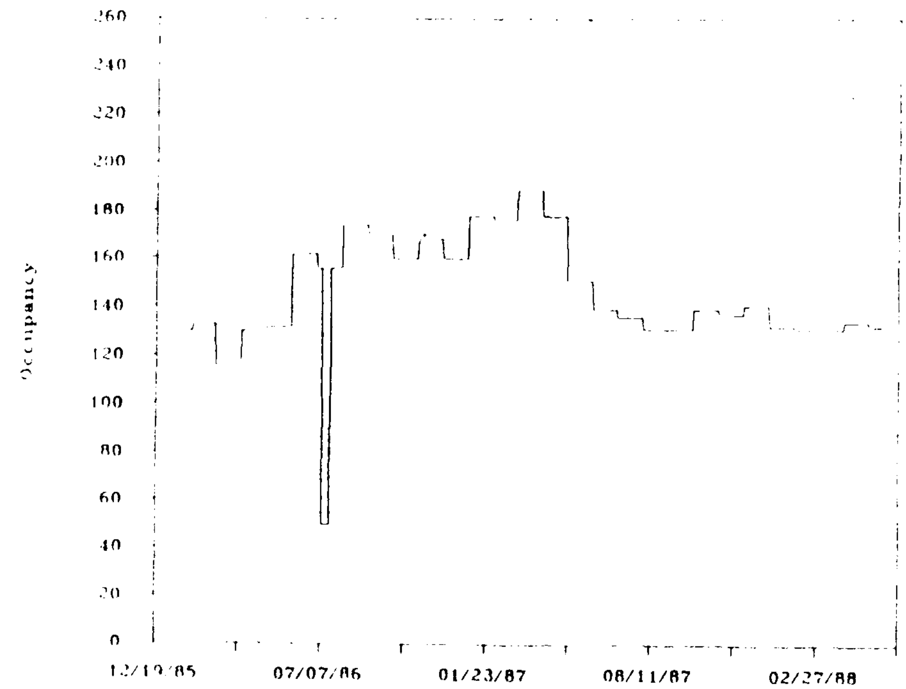

Figure F3. Building occupancy data for L-shaped barracks, Bldg 813.

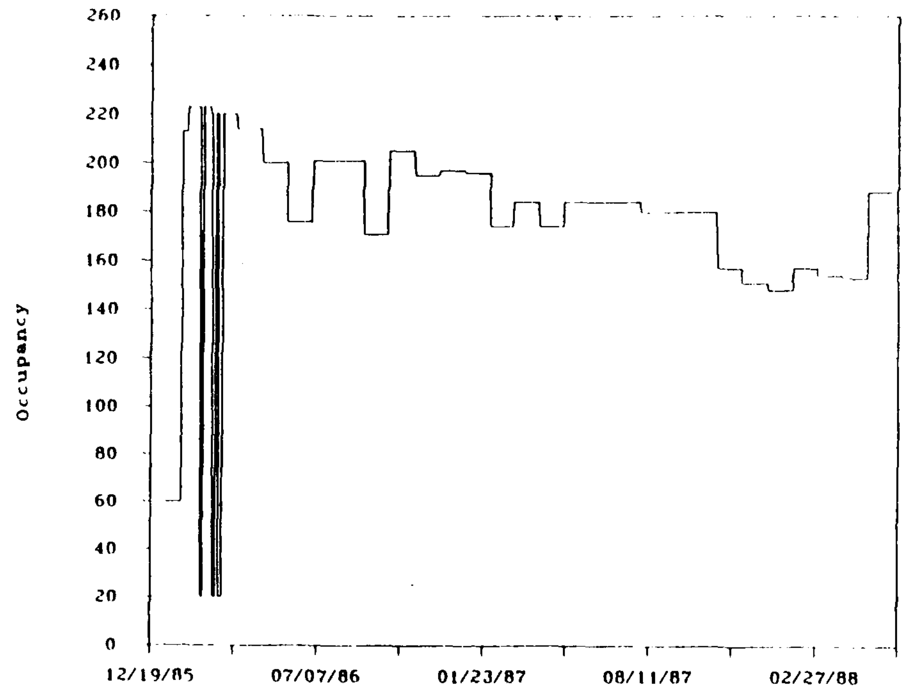

Figure F4. Building occupancy data for rolling-pin barracks, Bldg 1363.

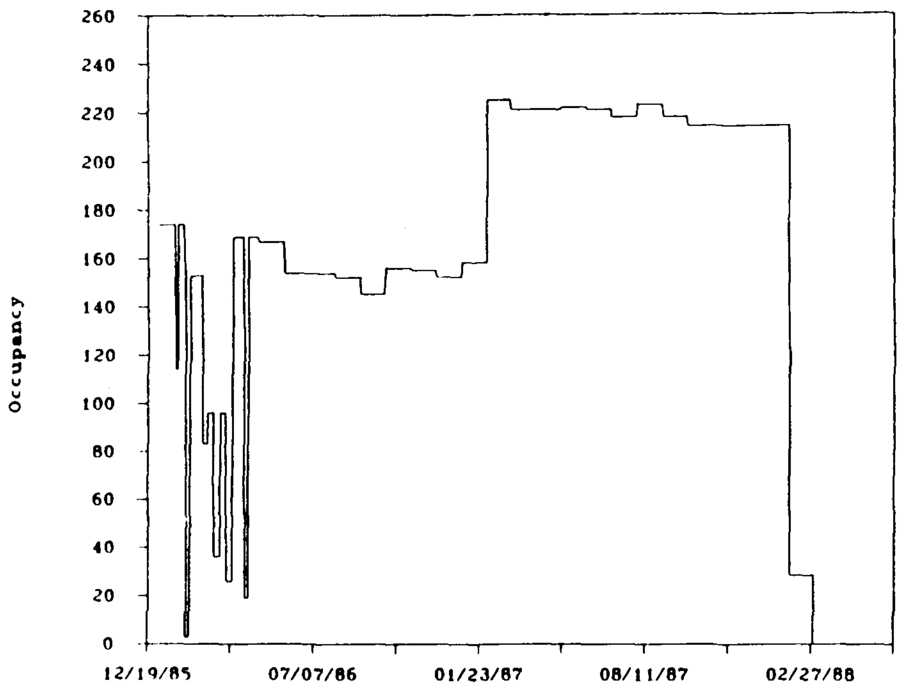

Figure F5. Building occupancy data for rolling-pin barracks, Bldg 1663.

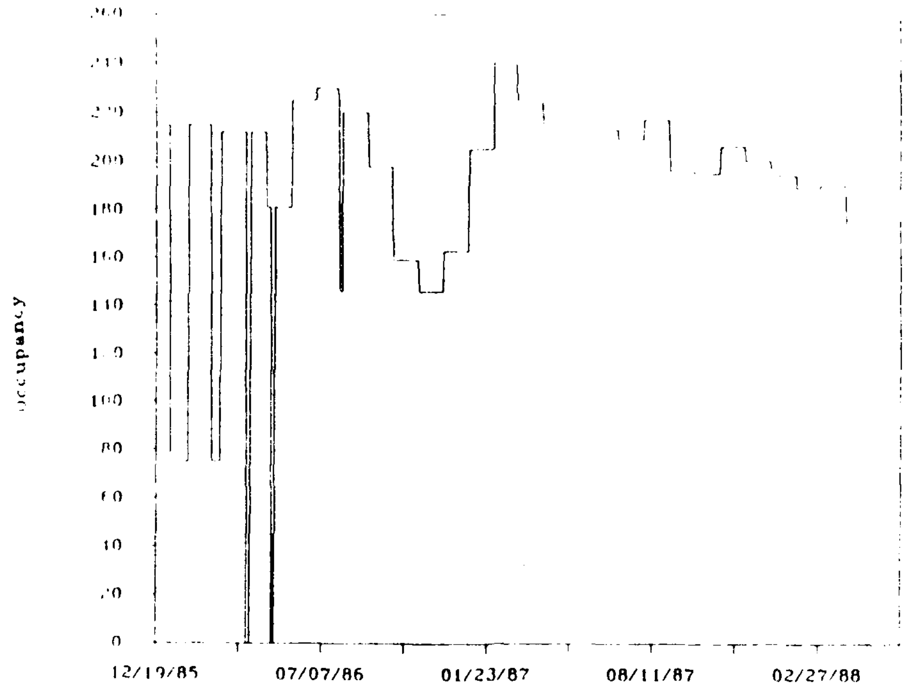

Figure F6. Building occupancy data for rolling-pin barracks, Bldg 1666.

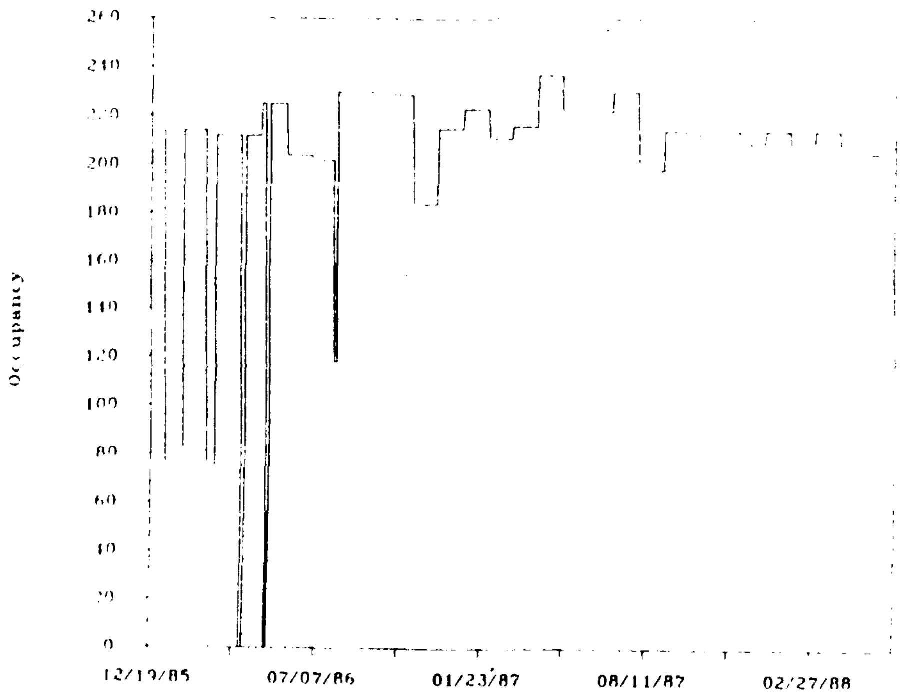

Figure F7. Building occupancy data for rolling-pin barracks, Bldg 1667.

APPENDIX G:

REGRESSION RESULTS FOR OTHER DEPENDENT VARIABLES

The first regression step was to run multiple regressions for all dependent variables, allowing SPSS to select the best independent variables to include in the regression equation. Addition of a variable was one step in a multistep process. The tables below show the dependent variables, other than those for which models were developed, with the independent variables selected by SPSS. Below each independent variable is the R^2 value for the equation, using the independent variable listed to that point. In other words, the R^2 for the first variable listed applies to the one-variable equation developed using that variable alone. The R^2 under the second variable applies to the two-variable model using both the first and second independent variables, and so on down the list. To proceed with development of models for a building type, it is necessary to identify variables that have good predictive power for all buildings of the type being studied. Good predictive power for some buildings of a type, but poor power for others, is inadequate for good model development.

L-SHAPED BARRACKS

Building 811

Cooling:	DHW	T3E
	.749	.859

Building 812

Cooling:	DHW
	.541

Building 813

Cooling:	T2E
	.409

DHW is domestic hot water energy consumption.
T2E, T3E are space temperatures on the east side of the 2nd and 3rd floors.

ROLLING-PIN BARRACKS

Building 1363

Cooling:	OAT .471	Occ .678	T2 .699			
Electricity:	OAT .493	T3 .553	T1 .670	T2 .701	Occ .706	Delete T3 .705
DHW	OAT .061	T3 .115				
Occ	DHW .009					

Building 1663

Cooling:	Occ .086			
Electricity:	Occ .490	OAT .631	DHW .643	T1 .654
DHW	Occ .256	OAT .308	T3 .327	
Occ	DHW .256	T2 .290	OAT .314	

Building 1666

Cooling:	Occ .466			
Electricity:	OAT .064	DHW .140		
DHW	OAT .163	Occ .184		
Occ	T3 .067	TAll .145	OAT .160	DHW .181

Building 1667

Cooling:	Occ	OAT		
	.197	.297		
Electricity:	T3	OAT	TA11	DHW
	.403	.470	.488	.502
DHW	OAT	TA11	Occ	
	.170	.215	.244	
Occ	T1	DHW	OAT	
	.119	.142	.153	

OAT is outside air temperature.
Occ is occupancy.
DHW is domestic hot water energy consumption.
T1, T2, T3 are space temperatures on the 1st, 2nd, and 3rd floors.
TAll is the average of T1, T2, and T3.

MOTOR VEHICLE REPAIR SHOPS

Building 633

Electricity:	Date	OAT
	.550	.564

Building 634

Electricity:	OAT	Date	ST
	.202	.289	.306

Building 635

Electricity:	Date
	.173

Building 636

Electricity:	OAT	Date	NT
	.363	.388	.409

OAT is outside air temperature.
Date is the date, represented as a serial number starting at 1/1/1900.
ST is the south space temperature (vehicle bays).
NT is the north space temperature (office area).

DINING HALLS

Building 1361

Heating Btus:	OAT .338	DHW .363
Electricity:	OAT .093	Temp .104
Gas (Cooking):	OAT .074	DHW .150
Steam Btus:	DHW .983	

Building 1369

Heating Btus:	Elec .061	DHW .114	OAT .140	Temp .167
Electricity:	Steam .240	OAT .3331	DHW .346	
Gas (Cooking):	Steam .311			
Steam Btus:	OAT .327	Elec 427	DHW .518	

Building 1669

Heating Btus:	Elec .395	Temp .449	Steam .506
Electricity:	OAT .046	Steam .073	
Gas (Cooking):	Steam .547	OAT .625	
Steam Btus:	OAT .208	Elec .248	Temp .265

OAT is outside air temperature.
DHW is domestic hot water energy consumption.
Temp is space temperature.
Steam is Steam Btus, used for warming tables.
Elec is electricity consumption.

APPENDIX H:

EXAMPLE CALCULATION OF SAVINGS RANGE

Calculation of Range on Predicted Energy Consumption

This is an example calculation of the high and low estimates of predicted energy consumption as used in Appendix E. The data below are from Building 633, motor repair shop. OAT and BayT are the daily average outdoor air and bay area temperatures. Eicc is the daily total consumption of electricity. Pred Gas and Gas SE are the predicted gas value and the standard error for each data point, as calculated by SPSS. The bin data used in the calculation of annual energy consumption were added to the actual building data set supplied to SPSS. Because the bin data points did not have gas consumption values, they were not used in the calculation of the regression line. SPSS did, however, include them in the calculation of predicted gas consumption and standard error of the estimate values for each data point. These values are shown below as Pred Gas and Gas SE.

The calculation of a range on the annual total consumption uses the square root of the sum of the squares of the Standard Errors. For the bin data set, each hour at the given bin temperature is treated as an individual case. For each temperature, the Pred Gas value is multiplied by the October through May hours at that temperature (Annual Consump). Also, standard error (Gas SE) is squared (SE Sqrd), then multiplied by the number of hours at that temperature (Ann SE^2). All the Annual Consump and Ann SE^2 values are summed. The sum of the Annual Consump values is divided by 1000 for readability. The square root of the sum of the Ann SE^2 values is found, multiplied by the T statistic, and also divided by 1000 for consistency.

The value of the T statistic is a function of the percentage confidence desired and the number of cases used in the regression. The T statistic used is 1.96, and is for an infinite sample size and 97.5 percent (one-tailed) probability (to find the 95 percent two-tailed confidence limit).

The annual consumption prediction of 1589 MBtu is shown in line 1 on the next page. The uncertainty value of 12.9 MBtu is shown in line 3. Thus, the annual consumption will be between 1576 and 1601 MBtu. The uncertainty is 0.08 percent of the predicted value.

1. Sum of Annual Predicted Gas Consumption Values, divided by 1000: 1589262

2. Sum of squares of standard errors, times annual hours: 4.3E+13

3. Square root of line 2, divided by 1000, multiplied by T-statistics: 12912

Due to differences in rounding procedure, these numbers are slightly different from those found in Appendix E.

OAT	BayT	Elec	Pred Gas	Gas SE	SE Sqrd	Oct thru May Hours	Annual Consump	Ann SE^2	
62	68.88	56.97	84560.21	472564.1	2.2E+11	299	1053479.	2.8E+12	
57	68.88	56.97	3082074.	356049.8	1.3E+11	394	50597386	2.1E+12	
52	68.88	56.97	4134703.	250676.8	6.3E+10	527	90791197	1.4E+12	
47	68.88	56.97	5187332.	177536.0	3.2E+10	627	1.4E+08	8.2E+11	
42	68.88	56.97	6239961.	181140.6	3.3E+10	668	1.7E+08	9.1E+11	
37	68.88	56.97	7292590.	258297.4	6.7E+10	657	2.0E+08	1.8E+12	
32	68.88	56.97	8345220.	365015.0	1.3E+11	672	2.3E+08	3.7E+12	
27	68.88	56.97	9397849.	482044.7	2.3E+11	582	2.3E+08	5.6E+12	
22	68.88	56.97	10450478	603416.0	3.6E+11	438	1.9E+08	6.6E+12	
17	68.88	56.97	11503107	726957.7	5.3E+11	242	1.2E+08	5.3E+12	
12	68.88	56.97	12555736	851725.8	7.3E+11	137	71672330	4.1E+12	
7	68.88	56.97	13608365	977250.7	9.6E+11	80	45361219	3.2E+12	
2	68.88	56.97	14660995	1103274.	1.2E+12	46	28100240	2.3E+12	
-3	68.88	56.97	15713624	1229642.	1.5E+12	20	13094686	1.3E+12	
-8	68.88	56.97	16766253	1356260.	1.8E+12	11	7684532.	8.4E+11	
-13	68.88	56.97	17818882	1483062.	2.2E+12	3	2227360.	2.7E+11	
-18	68.88	56.97	18871511	1610006.	2.6E+12	2	1572625.	2.2E+11	
-23	68.88	56.97	19924140	1737060.	3.0E+12	0	0	0	
-28	68.88	56.97	20976769	1864202.	3.5E+12	0	0	0	
							1.6E+09	4.3E+13	
							1589262.	12911.76	0.008124

APPENDIX I:

RESULTS OF ANALYSIS USING T-TESTS

Analysis of the various dependent variables was attempted by using the t-test. This is a test which can show that differences in energy consumption by different buildings are statistically significant. A finding of statistically significant differences would support claims that the retrofit packages are effective in reducing energy consumption, and that the differences are not due to random variations in energy consumption.

Before performing a t-test, it must be shown that the variances of the populations being compared are not different. This is done by using the Independent-Samples Test, which calculates the F value, testing homogeneity of variance and its probability. The probability value included in the tables is the probability that the variances are homogeneous. If the probability is less than 0.05, then there is a 95 percent or greater probability that they are different. In this case, the t-test is invalid, and the t-test results are not included in the tables below.

For the pairs of buildings found to have acceptable homogeneous variances, the t-test then tests the hypothesis that the data came from the same populations. The two-tailed probability value shows the probability that the populations are the same. A value of less than 0.05 indicates a greater than 95 percent probability that they are different, thus implying that the observed savings are statistically significant.

The tests being considered here require that the t-test be valid between most of the buildings in a group for any meaningful conclusion to be drawn. In particular, it would be expected that the various baeline buildings would not be found to differ from each other. A Scheffe's test could be used to show whether the baseline buildings were closer to each other than to the retrofit building, also demonstrating effectiveness of the retrofits. Unfortunately, the Independent-Samples test eliminated most building pairs from further analysis. In most cases, the number of remaining building pairs is too few to allow development of conclusion as to the effectiveness of the retrofit packages.

In the case of gas consumption by the L-shaped barracks, conclusions can be drawn. The first table below shows these results. Building 811 (1986/87), compared with two of the baseline buildings (813 86/87 and 813 87/88), has valid t-tests and shows zero probability of being the same. This means that there is a statistically significant difference between this building and two of the three baseline buildings. This difference is assumed to be due to the retrofit package, savings for which have been calculated in Appendix E, and included in Table 17. Results of the t-test analyses are shown below.

L-Shaped Barracks

Gas

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
811 (86/87) vs. 812 (86/87)	1.71	0		0
811 (86/87) vs. 813 (86/87)	1.10	0.413	-9.8(	0
811 (86/87) vs. 813 (87/88)	1.12	0.393	-7.6	
812 (86/87) vs. 813 (86/87)	1.55	0		
812 (86/87) vs. 813 (87/88)	1.52	0.003		
813 (86/87) vs. 813 (87/88)	1.02	0.878	0.68	0.498

86/87 inlcudes up to August 31, 1987; 87/88 includes September 1, 1987 and later.

Data included if: Gas > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F, and
For Bldg 811, date not 1/2/87.

L-Shaped Barracks

Heating

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
811 (86/87) vs. 812 (86/87)	1.22	0.238	-7.66	0
811 (86/87) vs. 813 (86/87)	2.09	0		
811 (86/87) vs. 813 (87/88)	2.00	0		
812 (86/87) vs. 813 (86/87)	1.71	0		
812 (86/87) vs. 813 (87/88)	2.44	0		
813 (86/87) vs. 813 (87/88)	4.19	0		

86/87 inlcudes up to August 31, 1987; 87/88 includes September 1, 1987 and later.

Data included if: Gas > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F, and
For Bldg 811, date not 1/2/87.

L-Shaped Barracks

Cooling

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
811 vs. 812	16.95	0		
811 vs. 813	4.35	0		
812 vs. 813	3.89	0		

Based on data for 1986 and 1987 cooling seasons, up to September 1, 1987.

Data included if: Gas > 50,000 Btu, and
For Bldg 811, date not 1/2/87.

L-Shaped Barracks

Electricity

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
811 (86/87) vs. 812 (86/87)	1.17	0.117	-15.03	0
811 (86/87) vs. 813 (86/87)	1.77	0		
811 (86/87) vs. 813 (87/88)	2.21	0		
812 (86/87) vs. 813 (86/87)	2.06	0		
812 (86/87) vs. 813 (87/88)	2.57	0		
813 (86/87) vs. 813 (87/88)	1.25	0.082	3.2[illegible]	0.001

86/87 inlcudes up to August 31, 1987; 87/88 includes September 1, 1987 and later.

Data included if: Electricity > 0 kWh, and
For Bldg 811, date not 1/2/87.

L-Shaped Barracks

Electricity During the Heating Season

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
811 (86/87) vs. 812 (86/87)	1.36	0.008		
811 (86/87) vs. 813 (86/87)	1.74	0		
811 (86/87) vs. 813 (87/88)	1.14	0.321	-9.5[illegible]	0
812 (86/87) vs. 813 (86/87)	2.37	0		
812 (86/87) vs. 813 (87/88)	1.56	0.001		
813 (86/87) vs. 813 (87/88)	1.52	0.001		

86/87 inlcudes up to August 31, 1987; 87/88 includes September 1, 1987 and later.

Data included if: Electricity > 0 kWh, and
Gas > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F, and
For Bldg 811, date not 1/2/87.

L-Shaped Barracks

Electricity During the Cooling Season

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
811 vs. 812	1.15	0.441	0.19	0.849
811 vs. 813	2.44	0		
812 vs. 813	2.81	0		

Based on data for 1986 and 1987 cooling seasons, up to September 1, 1987.

Data included if: Electricity > 0 kWh,
Cooling > 50,000 Btu, and
For Bldg 811, date not 1/2/87.

Rolling-Pin Barracks

Heating

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1363 (Retrofit) vs. 1663	1.08	0.569	-13.83	0
1363 (Retrofit) vs. 1666	1.60	0		
1363 (Retrofit) vs. 1667	1.12	0.382	-7.61	0
1663 vs. 1666	1.73	0		
1663 vs. 1667	1.04	0.798	6.61	0
1666 vs. 1667	1.79	0		

Data included if: Gas > 50,000 Btu,
Daily Average Outdoor Air Temperature ≤ 65 °F,
For Bldg 1363, date not 4/2-3/87, and
For Bldg 1667, date not 11/28/86-12/1/86.

Rolling-Pin Barracks

Electricity

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1363 (Retrofit) vs. 1663	8.74	0		
1363 (Retrofit) vs. 1666	155.16	0		
1363 (Retrofit) vs. 1667	1.31	0.003		
1663 vs. 1666	17.76	0		
1663 vs. 1667	6.66	0		
1666 vs. 1667	118.24	0		

Data included if: Electricity > 0 kWh,
For Bldg 1363, date not 4/2-3/87, and
For Bldg 1667, date not 11/28/86-12/1/86.

Rolling-Pin Barracks

Electricity During the Heating Season

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1363 (Retrofit) vs. 1663	6.22	0		
1363 (Retrofit) vs. 1666	32.26	0		
1363 (Retrofit) vs. 1667	1.23	0.113	-0.63	0.53
1663 vs. 1666	5.19	0		
1663 vs. 1667	7.62	0		
1666 vs. 1667	39.52	0		

Data included if: Electricity > 0 kWh,
Gas > 50,000 Btu,
Daily Average Outdoor Air Tempcature ≤ 65 °F,
For Bldg 1363, date not 4/2-3/87, and
For Bldg 1667, date not 11/28/86-12/1/86.

Rolling-Pin Barracks

Electricity During the Cooling Season

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1363 (Retrofit) vs. 1663	4.65	0		
1363 (Retrofit) vs. 1666	45.15	0		
1363 (Retrofit) vs. 1667	3.05	0		
1663 vs. 1666	9.71	0		
1663 vs. 1667	14.17	0		
1666 vs. 1667	137.65	0		

Data included if: Electricity > 0 kWh,
Cooling > 50,000 Btu,
For Bldg 1363, date not 4/2-3/87, and
For Bldg 1667, date not 11/28/86-12/1/86.

Rolling-Pin Barracks

Cooling

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1363 (Retrofit) vs. 1663	38.91	0		
1363 (Retrofit) vs. 1666	28.10	0		
1363 (Retrofit) vs. 1667	409.58	0		
1663 vs. 1666	1.38	0.064	-15.15	0
1663 vs. 1667	10.53	0		
1666 vs. 1667	14.57	0		

Data included if: Cooling > 50,000 Btu,
For Bldg 1363, date not 4/2-3/87, and
For Bldg 1667, date not 11/28/86-12/1/86.

Motor Vehicle Repair Shops

Gas

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
633 (Retrofit) vs. 634	2.46	0		
633 (Retrofit) vs. 635	1.48	0.079	-7.31	0
633 (Retrofit) vs. 636	3.41	0		
634 vs. 635	1.66	0.111	-3.55	0
634 vs. 636	1.39	0.074		
635 vs. 636	2.30	0		

Data covered June 1986 through June 1987.

Data included if: Gas > 50,000 Btu, and
Daily Average Outdoor Air temperature < 70 °F, and > 25 F.

Motor Vehicle Repair Shops

Electricity

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
633 (Retrofit) vs. 634	2.48	0		
633 (Retrofit) vs. 635	2.04	0		
633 (Retrofit) vs. 636	1.02	0.903	5.1[illegible]	0
634 vs. 635	5.06	0		
634 vs. 636	2.52	0		
635 vs. 636	2.01	0		

Data covered June 1986 through June 1987.

Data included if: Electricity > 0 kWh.

Dining Halls

Heating

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1361 (Retrofit) vs. 1369	5.05	0		
1361 (Retrofit) vs. 1669	72.83	0		
1369 vs. 1669	14.43	0		

Data included if: Heating > 50,000 Btu,
Daily Average Outdoor Air Temperature < 65 °F,
For Bldg 1361, date not 6/11-13/86,
For Bldg 1369, date not before 3/8/86, 5/3-8/86, 6/2/86, 8/4/86-10/1/86, or 7/18-29/87, and
For Bldg 1669, date not 8/30/86-9/1/86.

Dining Halls

Electricity

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1361 (Retrofit) vs. 1369	2.63	0		
1361 (Retrofit) vs. 1669	1.27	0.024		
1369 vs. 1669	2.08	0		

Data included if: Electricity > 0 kWh,
For Bldg 1361, date not 6/11-13/86,
For Bldg 1369, date not before 3/8/86, 5/3-8/86, 6/2/86, 8/4/86-10/1/86, or 7/18-29/87, and
For Bldg 1669, date not 8/30/86-9/1/86.

Dining Halls

Gas (Used for Cooking)

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1361 (Retrofit) vs. 1369	*****	0		
1361 (Retrofit) vs. 1669	16.05	0		
1369 vs. 1669	*****	0		

Stars (*) indicate that the values are so large that they did not fit into the field allocated to them by SPSS.

Data included if: Gas > 50,000 Btu,
For Bldg 1361, date not 6/11-13/86,
For Bldg 1369, date not before 3/8/86, 5/3-8/86, 6/2/86, 8/4/86-10/1/86, or 7/18-29/87, and
For Bldg 1669, date not 8/30/86-9/1/86.

Dining Halls

Steam (Used for Warming Tables)

	F Value	2-Tail Prob.	t Value	2-Tail Prob.
1361 (Retrofit) vs. 1369	*****	0		
1361 (Retrofit) vs. 1669	*****	0		
1369 vs. 1669	29.14	0		

Stars (*) indicate that the values are so large that they did not fit into the field allocated to them by SPSS.

Data included if: Steam > 50,000 Btu,
For Bldg 1361, date not 6/11-13/86,
For Bldg 1369, date not before 3/8/86, 5/3-8/86, 6/2/86, 8/4/86-10/1/86, or 7/18-29/87, and
For Bldg 1669, date not 8/30/86-9/1/86.

APPENDIX J:

CONTRACTOR'S LINE ITEM ESTIMATE

CONTRACT NO DACW88-85-C-0002
STARTING DATE 01/18/85
COMPLETION DATE 03/18/86
PURCHASE REQUEST NO CERL-ES-85-003
PROJECT NO DACW88-85-B-0002
ACTUAL STARTING DATE 04/01/85
ACTUAL COMPLETION DATE

COST AND PERCENTAGE BREAKDOWN OF PROGRESS CHART LINE ITEMS

PROJECT TITLE: Energy Conservation Retrofit, Ft. Carson, CO.

SUBMITTED BY
DATE: 03/07/85
CONTRACTOR (Name and Address): CHARLES MACE CONST., INC. 808 Van Buren Pueblo, CO 8 004
CONTRACTOR (Signature): George Mace

APPROVAL RECOMMENDED BY
DATE:
[illegible] ENGINEER (Signature):

APPROVED BY
DATE: 3/22/85
CONTRACTING OFFICER (Signature):

Line	Work Category	%		Building 633	Building 811	Building 1361	Building 1363	Item Totals
1	Mobilization & Bond	5.0	Item%	11.3	56	15	17.7	100
			$Cost	3061	15168	4063	4793	27085
3	Demolition	5.0	Item%	20.0	35	15	30	100
			$Cost	5417	9478	4063	8127	27085
5	Masonry	4.0	Item%		100			100
			$Cost		21668			21668
7	Carpentry	4.0	Item%	90		10		100
			$Cost	19501		2167		21668
9	Doors	5.3	Item%	80		20		100
			$Cost	22968		5742		28710
11	Aluminum Windows	21.2	Item%		60		40	100
			$Cost		68905		45963	114841
13	Insulation & Wall Systems	36.9	Item%	24	70	05	01	100
			$Cost	47974	139922	9994	1999	[illegible]
15	Painting	3.8	Item%	25	30	25	20	100
			$Cost	5142	6175	5146	4117	[illegible]
17	Mechanical	5.0	Item%		03	90	07	100
			$Cost		812	24376	1897	27085
19	Electrical	2.6	Item%	30	10	50	10	100
			$Cost	4226	1408	7042	1408	[illegible]
21	Controls	6.2	Item%	18	20	30	32	100
			$Cost	6048	6217	10075	10748	[illegible]
23	Final Inspection & Clean up	1.0	Item%	11.3	56	15	17.7	[illegible]
			$Cost	613	[illegible]	812	959	[illegible]

APPENDIX K:

CURRENT YEAR COST ESTIMATES*

BUILDING 633 COST ESTIMATE
CURRENT YEAR

DESCRIPTION	NUMBER OF UNITS	UNIT OF MEASURE	$/UNIT LABOR	REGION ADJUST	$/UNIT MATERIAL	REGION ADJUST	TOTAL COST
1. PLYWOOD WAINSCOT	273	SF	0.62	0.88	0.68	1.18	368.004
2. CAULK WAINSCOT	45.5	LF	0.97	0.88	0.18	1.18	48.503
3. '6 INCH COVE BASE	35.75	LF	0.27	1	0.69	1	34.32
4. 2X4WALL, WALL BD. 2SD AND 3 1/2 BATT INS	436	SF	1.69	0.88	0.97	1.18	1147.464
5. 2X4 WALL, WALL BD AND 3 1/2 BATT INS	301	SF	1.69	0.88	0.97	1.18	792.1718
6. 2X4 PLATE ANCHORS	188	LF	0.62	0.88	0.39	1.18	189.0904
7. 3X6-8X1 3/4 H.M.DOOR WITH FRAME	1	EA	102.33	0.88	229	1.18	360.2704
8. INT. WALL WINDOWS	2	EA	14.5	1	96	1	221
9.REM 20 IN CONC BLK	47	SF	0.52	1	0	1	24.44
10. REM 4FT CHN LNK FNC	28.25	LF	0.55	1	0	1	15.5375
11. REM 8FT CHN LNK FNC	4	LF	0.55	1	0	1	2.2
12. PAINT PRIM/2CTS	940	SF	0.39	0.88	0.1	1.18	433.528
13. PAINT DOOR/FRAME	56	SF	0.9	0.88	0.17	1.18	55.5856
14. PAINT WALL COLMNS	72	SF	0.17	0.88	0.08	1.18	17.568
15. O.H. DOORS STEEL INSUL 11'-10"X14'-2"	7	EA	317.19	0.88	1298	1.18	12675.37
16. REM OLD OH DOORS	7	EA	97.09	1	288	1	2695.63
17. PAINT OH DOORS PRIME	1173	SF	0.32	0.88	0.05	1.18	399.5238
18. PAINT OH DOORS	1173	SF	0.26	0.88	0.04	1.18	323.748
19. 6" RUBBER COVE BASE	134	LF	0.27	0.88	0.69	1.18	140.9412
20. 1/4" PORC. ENAML PNL	458	SF	3.71	0.88	11.47	1.18	7694.125
21 2X4WALL, WALL BD 1SD BATT INS. AND PAINT	1818	SF	1.35	0.88	0.74	1.18	3747.261
22. CAULK WINDOW FRAMES	510	LF	0.97	0.88	0.18	1.18	543.66
23. PAINT WINDOW FRAMES I	510	LF	0.17	0.88	0.12	1.18	148.512
							32078.45

*Source: Dodge System Unit Cost Data.

BUILDING 811 COST ESTIMATE
CURRENT YEAR

DESCRIPTION	NUMBER OF UNITS	UNIT OF MEASURE	$/UNIT LABOR	REGION ADJUST	$/UNIT MATERIAL	REGION ADJUST	TOTAL COST
1. WNDOW 2'6"X5'5" DBL GL DBL HUNG THERMAL	127	EA	77.98	0.88	263.81	1.18	48249.61
2.WNDOW 5'X5'5" DG,DH,T	56	EA	86.39	0.88	360.27	1.18	28063.94
3.WNDOW 10'X6'9" DG,DH,T	2	EA	176.35	0.88	987.42	1.18	2640.687
4.WNDOW 3'X8'9",DG,DH,T	10	EA	91.57	0.88	392.5	1.18	5437.316
5.WNDOW 3'4"X5'5",DG,DH,T	1	EA	86.39	0.88	293.71	1.18	422.601
6.REM EX. WND, 21'5"X5'5"	56	EA	99.76	1	93.94	1	10847.2
7.REM EX.WND.11'X5'5"	6	EA	51.24	1	57.47	1	652.26
8.REM EX.WND.18'X5'5"	2	EA	83.85	1	81.97	1	331.64
9.REM EX.WND.3'X5 5"	1	EA	19.07	1	29.47	1	48.54
10.REM EX.WND.14'3"X8'	3	EA	98.04	1	77.88	1	527.76
11.REM EX.WND.10'10"X7'	2	EA	65.22	1	62.24	1	254.92
12. 4' WYTHES CMU	281	SF	2.02	0.88	0.79	1.18	761.4538
13.6" CMU	4188	SF	2.29	0.88	0.9	1.18	12887.31
14. 1"RIGD INS.,3/8"NYLON MESH, 1/4"INSULCRETE 1/8" STUCCO FINISH	2558	SF	2.31	1	1.75	1	10385.48
15.1/4" CONC.,STUCCO FINISH COAT ON FLUE	363	SF	2.1	1	1.5	1	1306.8
16.2"RGD INS,3/8"NYLON MESH,1/4"INSULCRETE, 1/8" STUCCO FINISH	16400	SF	2.31	1	1.75	1	66584
17.PAINT GUTTERS	784	LF	0.56	0.88	0.15	1.18	525.1232
18. PAINT LOUVERS	193	SF	0.84	0.88	0.22	1.18	192.7684
19. PAINT DOORS	6	EA	37.8	0.88	7.14	1.18	250.1352
20. PAINT DOWNSPOUTS	341	LF	0.56	0.88	0.15	1.18	228.4018
21. PAINT INT. CMU	4256	SF	0.41	0.88	0.1	1.18	2037.772
22.COPPER FLASHING	316	SF	1.63	0.88	1.94	1.18	1176.657
23. EXPANSION JNTS IN CMU	690	LF	1.23	1	2.3	1	2435.7
24. CURT. RODS 2'6"WNDO	127	EA	5.14	1	12.65	1	2259.33
25. CURT. RODS 5' WNDO	56	EA	5.65	1	19.6	1	1414
							199921.4

BUILDING 1361 COST ESTIMATE
CURRENT YEAR

DESCRIPTION	NUMBER OF UNITS	UNIT OF MEASURE	$/UNIT LABOR	REGION ADJUST	$/UNIT MATERIAL	REGION ADJUST	TOTAL COST
1.PAINT NEW MTL TRIM	226.5	SF	0.9	0.88	0.17	1.18	224.8239
2.PAINT EXIST MTL TRIM	265	SF	0.9	0.88	0.17	1.18	263.039
3.PAINT EXIST H.M. DOORS	5	EA	37.8	0.88	7.14	1.18	208.446
4.PAINT GUTTRS/DOWNSPTS	626	LF	0.56	0.88	0.15	1.18	419.2948
5.PAINT LOUVERS	324	SF	0.9	0.88	0.17	1.18	321.6024
6.INST/PAINT 5/8" GYP BD	192	SF	0.77	0.88	0.31	1.18	200.3328
7.INST 1 1/2" RIGD INS	192	SF	0.44	0.88	0.61	1.18	212.544
8.1 1/2" MTL FURRING CHNL	104	LF	0.54	0.88	0.55	1.18	116.9168
9. J MTL SEALANT	64	LF	0.97	0.88	0.18	1.18	68.224
10.FLUOR. LIGHT FIXTRS	5	EA	38.84	0.88	79	1.18	636.996
11. DOORS 3'X6'8"	8	EA	66.06	0.88	153	1.18	1909.3824
12. BUTTS	24	EA	7.07	1	18.5	1	613.68
13. MORT. EXIT DEVICE	2	EA	27.25	0.88	146.64	1.18	394.0304
14. U.R. EXIT DEVICE	2	EA	27.25	0.88	436.8	1.18	1078.808
15. CLOSERS	8	EA	36.33	0.88	166.4	1.18	1826.5792
16. THRESHOLD	2	EA	28.26	1	60	1	176.52
17. ASTRIGAL	4	EA	10.9	0.88	39.31	1.18	223.9112
18. WEATHERSTRIP	2	SETS	54.5	0.88	21.82	1.18	147.4152
19. PUSH PLATE	4	EA	4.24	1	10	1	56.96
20. PULL PLATE	4	EA	4.24	1	10	1	56.96
21. INSUL DOOR FRAMES	20	SF	0.36	0.88	0.24	1.18	12
22.PATCH/PNT DOORS AT CEI	30	SF	1.23	1	0.2	1	42.9
23. REFL. FILM ON WINDOS	522	SF	2.62	0.88	5.53	1.18	4609.782
24. PORCLN MTL PNLS	522	SF	3.71	0.88	11.47	1.18	8769.2868
25. MOD SCREENS	41	EA	10.74	1		1	440.34
26.INS.STRIP/CALK MTLPNLS	73	LF	1.39	0.88	0.8	1.18	158.2056
							23188.9805

BUILDING 1363 COST ESTIMATE
CURRENT YEAR

DESCRIPTION	NUMBER OF UNITS	UNIT OF MEASURE	$/UNIT LABOR	REGION ADJUST	$/UNIT MATERIAL	REGION ADJUST	TOTAL COST
1.REM/REPL 2'8"X4'8"WNDO DG,DH,THERMAL	2	EA	85.74	0.88	207.25	1.18	640.0124
2.REM/REPL 7'8"X4'8" WNDO DG,DH,THERMAL	14	EA	122.34	0.88	417	1.18	8396.0688
3.REM/REPL 11'8"X4'8"WNDO DG,DH,THERMAL	24	EA	192.6	0.88	796.43	1.18	26622.6096
4.REM/REPL 15'8"X4'8"WNDO DG,DH,THERMAL	46	EA	252.22	0.88	834	1.18	55479.3856
5.PATCHING NEW WNDOS	10400	LF	0.54	1	0.13	1	6968
6.PREFIN.WOOD BLOCK	28	EA	1.27	1	1.54	1	78.68
7.PREFIN MTL TRIM	56	EA	18.79	1	16	1	1948.24
8.PAINT WALL ADJ WNDO	6927	SF	0.17	0.88	0.12	1.18	2017.1424
							102150.138

MECHANICAL SYSTEM ESTIMATE
BUILDING 633 CURRENT YEAR

	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
T-STATS, PROGMBLE	3	EA		103.58	0.88		99	1.18	623.9112
RELAYS W/SOCKETS SPST	1	EA		73.99	0.88		33	1.18	104.0512
RELAYS W/SOCKET SPDT	2	EA		73.99	0.88		35	1.18	212.8224
NEMA ENCL 6X6X4	3	EA		32.37	0.88		56.4	1.18	285.1128
COND 1/2"C(3#12)	150	LF			1		4.4	1.03	679.8
JCTN BOXES 4X4	7	EA		25.9	0.88		3.83	1.18	191.1798
COND 1/2"C(2#12)	40	LF			1		4.13	1.03	170.156
COND 3/4"C(5#12)	30	LF			1		5.63	1.03	173.967
JCA19 BOILER T CNTRLR	1	EA		216	0.88		500	1	690.08
COND 1/2:C(3#12)	30	LF			1		4.4	1.03	135.96
REM EXIST COND	220	LF			1		1.56	1.03	353.496
MANUAL MTR STARTRS	3	EA		255.72	0.88		134	1.18	1149.460
									4769.997

MECHANICAL SYSTEM ESTIMATE
BUILDING 811 CURRENT YEAR

	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
MINIMIZE OA AIR									
CUT 70X14 IN HOLE	1	EA	4	52.16	0.88				183.6032
DISC. DAMP. MTR ACU2	1	EA	3	54	0.88				142.56
LOCK DAMPER	1	EA	2	54	0.88		15	1	110.04
REMOVE CONDUCTORS	1	EA	2	32.37	0.88				56.9712
DISC DAMP MTR ACU1	1	EA	3	54	0.88				142.56
LOCK DAMPER	1	EA	2	54	0.88		15	1	110.04
REM FLEX CONNCTR	1	EA	2	54	0.88				95.04
FILL OA HSNG INSUL	1	EA	6	52.16	0.88				275.4048
INSUL BOARD	100	SF			1		1.29	1.03	132.87
20 GA GALV SHT	100	SF			1		1.2	1.03	123.6
SEALANT	40	LF			1		0.8	1.03	32.96
NEW HW CONTROLS									
REM EXIST OA CNTRLR	2	EA	4	54	0.88				380.16
REM EXIST HW CNTRLR	2	EA	4	54	0.88				380.16
REPAIR HW SYST	1	EA	24	54	0.88		1000	1	2140.48
NEW OA RESET CNTRLR	2	EA	10	54	0.88		1276	1	3502.4
NEW HW RESET CNTRLR	2	EA	10	54	0.88		1276	1	3502.4
8 INCH DA ACTUATOR	2	EA	3	54	0.88		162.85	1	610.82
1/4 COPPER TUBING	100	LF			1		4.73	1.03	487.19
									12409.25

MECHANICAL SYSTEM ESTIMATE
BUILDING 1361 CURRENT YEAR

	NO. UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
T-STATS/HW CNTRLR								
REM EXIST OA CONTRLR	1 EA	4	54	0.88			1.18	190.08
REM EXIST T-STATS	3 EA	1	54	0.88			1.18	142.56
REM EXIST HW CONTRLR	1 EA	4	54	0.88			1.18	190.08
REPAIR HW SYST.	1 EA	24	54	0.38		1000	1	2140.48
NEW T-STATS	3 EA	1	103.58	0.88		99	1.18	623.9112
NEW OA RESET CNTRLR	1 EA	8	54	0.88		1276	1	1656.16
NEW HW RESET CNTRLR	1 EA	8	54	0.88		1276	1	1656.16
ELEC-PNEU RELAY	1 EA	2	54	0.88		200	1	295.04
TIME CLOCK 7-DAY	1 EA	1	32.37	0.88		64.58	1.18	104.69
RELAYS SPDT	3 EA	1	73.99	0.88		35	1.18	319.2336
CNTRL CABNT 9X6X4	1 EA	1	32.37	0.88		87.2	1.18	131.3816
1/2 C(2#12)	60 LF			1		4.13	1.03	255.234
1/2 C(4#12)	50 LF			1		4.67	1.03	240.505
1/4 COPPER TUBE	260 LF			1		4.73	1.03	1266.694
KTCHN HOOD VENT UNIT								
REM EXIST 24X24 DUCT	1 EA	6	52.16	0.88			1.18	275.4048
CAP DUCT	1 EA	2	52.16	0.88			1.18	91.8016
CAP 16 GA 2(29X24)	9.67 SF			1		0.84	1.03	8.366484
REM EXIST 36X36 DUCT	1 EA	4	52.16	0.88			1.18	183.6032
REM EXHAUST FAN	1 EA	4	52.16	0.88			1.18	183.6032
REM EXIST 9X15 HOOD	1 EA	6	52.16	0.88			1.18	275.4048
REM WIRING AND COND	1 EA	2	54	0.88			1.18	95.04
NEW MAKEUP FURNACE	1 EA	12	140.56	0.88	276	11000	1	12760.31
NEW SS 9X15 HOOD	1 EA	12	111.78	0.88		10000	1	11180.39
WITH FIRE CONTROL								
GAS REGULATOR W/FITTIN	1 EA	3	54.75	0.88		350	1	494.54
ROOF FAN W/CURB+DMPER	1 EA	8	54	0.88		2296	1	2676.16
3/4 C(5#12)	20 LF			1		5.63	1.03	115.978
1/2 C(2#12)	70 LF			1		4.13	1.18	341.138
3/4 C(3#10)	85 LF			1		5.48	1.18	549.644
30 AMP DISC SW+FUSES	1 EA	1	90.64	0.88		98	1.18	195.4032
MISC MOUNTING HDWR								
16 GA GALV ST 4X4	16 SF			1		0.97	1.03	15.9856
ROOF FLASHING	10 SF			1		2.34	1.03	24.102
26 GA GALV 4X4 ST	16 SF			1		0.72	1.03	11.8656
20 GA SS. 4(1X9)	36 SF			1		5.06	1.03	187.6248
4-1/2 TIE RODS	16 LF			1		0.98	1.03	16.1504
								38894.73

MECHANICAL SYSTEM ESTIMATE
BUILDING 1363 CURRENT YEAR

ESTIMATE 1363	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MAT'LS PRICE	REGION ADJUST	TOTAL
HEATING SYST CONTRLR									
REM EXIST OA CNTRLR	1	EA	4	54	0.88			1	190.08
REM EXIST HW CTRLR	1	EA	4	54	0.88			1	190.08
REM EXIST 3X9 DMPERS	2	EA	8	52.16	0.88			1	734.4128
INSPECT REP AHU1 AHU2	1	EA	24	54	0.88		1000	1	2140.48
INSPECT REP HW SYST	1	EA	24	54	0.88		1000	1	2140.48
NEW OA CNTRLR	1	EA	10	54	0.88		1276	1	1751.2
NEW HW RESET CNTRLR	1	EA	10	54	0.88		1276	1	1751.2
1/4 COPPER TUBE	100	LF			1		4.73	1.03	487.19
NEW OA DAMPERS	2	EA	8	52.16	0.88		450	1	1634.412
									11019.53

APPENDIX L:

PROJECT YEAR COST ESTIMATE*

CONSTRUCTION COST ESTIMATE

RETROFIT MOTOR VEHICLE REPAIR SHOP (BLDG. 633) FEBRUARY 14, 1989
FORT CARSON, COLORADO

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
6'-0"X3/4" MDO PLYWOOD WAINSCOT W/1 COAT OF DEVOE PAINT	273	SF	0.98	268.88	1.18	322.14	591.02
CAULK BETWEEN WAINSCOAT & CONCRETE FLOOR	45.5	LF	0.72	32.98	0.19	8.65	41.63
6" RUBBER COVE BASE	35.75	LF	0.27	9.72	0.69	24.67	34.39
2X4 WALL 9'-7" HIGH, STUDS @ 16" OC W/3 1/2" BATT INSUL.	45.5	LF	5.51	250.74	7.59	345.35	596.09
2X4 WALL 8'-0" HIGH, STUDS @ 16" OC W/3 1/2" BATT INSUL.	37.67	LF	3.39	127.75	4.35	163.86	291.61
2X4 PLATE ANCHORS	188	LF	0.28	53.13	0.34	63.92	117.05
3'X6'-8"X1 3/4" H.M. DOOR/FRAME	1	EA	117.70	117.70	215.45	215.45	333.15
4'X4' INTERIOR WALL WINDOWS	2	EA	14.50	28.99	96.00	192.00	220.99
REMOVE 20" CONCRETE BLOCK CURB	28.25	LF	0.97	27.31	0.00	0.00	27.31
REMOVE 4' CHAIN LINK FENCE	28.25	LF	1.29	36.41	0.00	0.00	36.41
REMOVE 8' CHAIN LINK FENCE/GATE	4	LF	1.29	5.16	0.00	0.00	5.16
PAINT 1 COAT OF DEVOE PRIMER #50801 & 2 COATS OF #500XX	940	SF	0.28	264.52	0.07	65.80	330.32
PAINT NEW DOOR & FRAME	56	SF	1.69	94.55	0.08	4.48	99.03
PAINT 2 EXIST. W COLUMNS	72	SF	0.14	10.13	0.04	2.88	13.01
OVERHEAD DOORS BY CLOPAY MODEL MODEL 670; STEEL INSULATED	7	EA	214.80	1 503.60	1 165.20	8 156.40	9.660.00

*Sources: Basic—USACE Unit Price Data; Mechanical—Dodge System Unit Cost Data; Building 812—Dodge System Unit Cost Data.

CONSTRUCTION COST ESTIMATE

RETROFIT MOTOR VEHICLE REPAIR SHOP (BLDG. 633)
FORT CARSON, COLORADO

FEBRUARY 14, 1989

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
REMOVE OH DOORS, TRACK, AND PREPARE OPENING FOR NEW DOOR	7	EA	97.09	679.63	288.00	2,016.00	2,695.63
PAINT 1 COAT DEVOE	1173	SF	0.28	330.08	0.11	129.03	459.11
PAINT 1 COAT DEVOE PRIMER, CAULK PAINT TRIM - OH DOORS	7	EA	1.41	9.85	0.23	1.61	11.46
6" RUBBER COVE BASE	134	LF	0.27	36.42	0.69	92.46	128.88
REMOVAL OF GLAZING & REPLACE W/ 1/4" ALLIANCE PORCELAIN ENAMEL	458	SF	1.27	580.93	4.45	2,038.10	2,619.03
WALL 17'-6" HIGH, 2X4 STUDS @ 16" OC, BATT INSUL., 5/8" FIRE CODE GYP. BD., 1 COAT PRIMER	61.5	LF	15.83	973.27	11.32	696.18	1,669.45
WALL 2'-8" HIGH, 2X4 STUDS @ 16" OC, BATT INSUL., 5/8" FIRE CODE GYP. BD., 1 COAT PRIMER (UNDER WINDOWS, SERVICE AREA)	47.67	LF	3.39	161.66	1.90	90.57	252.23
WALL 2'-0" HIGH, 2X4 STUDS @ 16" OC, BATT INSUL., 5/8" FIRE CODE GYP. BD., 1 COAT PRIMER (OVER WINDOWS)	47.67	LF	2.83	134.72	1.48	70.55	205.27
WALL 1'-6" HIGH, 2X4 STUDS @ 16" OC, BATT INSUL., 5/8" FIRE CODE GYP. BD., 1 COAT PRIMER (UNDER WINDOWS IN OFFICE)	63.5	LF	2.40	152.53	1.16	73.66	226.19
WALL 10'-6" HIGH, 2X4 STUDS @ 16" OC, BATT INSUL., 5/8" FIRE CODE GYP. BD., 1 COAT PRIMER	41.33	LF	10.03	414.63	6.93	286.42	701.05
CAULK INTERIOR SIDE EDGES WINDOW FRAMES	510	LF	0.72	369.65	0.19	96.90	466.55
PAINT WINDOW FRAMES, INTERIOR, 1 COAT DEVOE	510	LF	0.56	287.03	0.04	20.40	307.43
MOD P00002 MOVE PIPING, HEATER, CONDUIT, LIGHT FIXTURES, ETC.	1	LS	0.00	0.00	0.00	0.00	0.00

CONSTRUCTION COST ESTIMATE

RETROFIT MOTOR VEHICLE REPAIR SHOP (BLDG. 633)
FORT CARSON, COLORADO

FEBRUARY 14, 1989

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
SUBTOTAL				6,961.97		15,177.48	22,139.45
PRIME OVERHEAD @ 10%							2,213.95
PRIME PROFIT @ 5%							1,217.67
PRIME BOND @ 1.2%							306.85
CONTINGENCY @ 20%							5,175.58
SUBTOTAL 1984 COST							31,053.50
ESCALATION TO 1989 COST @ -4.6%							(1,428.46)
TOTAL 1989 PROJECT COST							29,625.04

CONSTRUCTION COST ESTIMATE - BASED ON 1984 UNIT PRICES (CORPS OF ENGINEERS)

RETROFIT L-SHAPED BARRACKS (BLDG. 811) FEBRUARY 14, 1989
FORT CARSON, COLORADO

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
WINDOWS: 2'-6"X5'5", DOUBLE-GLAZED, DOUBLE HUNG, THERMAL	127	EA	53.34	6,774.00	175.00	22,225.00	28,999.00
WINDOWS: 5'-0"X5'5", DOUBLE-GLAZED, DOUBLE HUNG, THERMAL	56	EA	102.87	5,760.57	337.50	18,900.00	24,660.57
WINDOWS: 10'-0"X6'9", DOUBLE-GLAZED, DOUBLE HUNG, THERMAL	2	EA	257.23	514.46	843.75	1,687.50	2,201.96
WINDOWS: 3'-0"X8'-1", DOUBLE-GLAZED, DOUBLE HUNG, THERMAL	10	EA	92.42	924.21	303.13	3,031.30	3,955.51
WINDOWS: 3'-6"X5'5", DOUBLE-GLAZED, DOUBLE HUNG, THERMAL	1	EA	68.58	68.58	225.00	225.00	293.58
REMOVE EXISTING WINDOWS 21'-5"X 5'-5" & PATCH	56	EA	49.83	2,790.68	93.94	5,260.64	8,051.32
REMOVE EXISTING WINDOWS 11'X 5'-5" & PATCH	6	EA	25.56	153.37	57.47	344.82	498.19
REMOVE EXISTING WINDOWS 18'-0"X 5'-5" & PATCH	2	EA	41.89	83.77	81.97	163.94	247.71
REMOVE EXISTING WINDOWS 3'-0"X 5'-5" & PATCH	1	EA	6.98	6.98	29.47	29.47	36.45
REMOVE EXISTING WINDOWS 14'-3"X 8'-0" & PATCH	3	EA	48.97	146.92	77.88	233.64	380.56
REMOVE EXISTING WINDOWS 10'-10"X 7'-0" & PATCH	2	EA	32.54	65.08	62.42	124.84	189.92
4" WYTHES CONCRETE MASONRY UNITS	281	SF	2.70	759.77	1.22	342.82	1,102.59
6" CMU 6'-0"X5'-5"	112	EA	47.93	5,368.27	23.74	2,658.88	8,027.15
6" CMU 3'-9"X5'-5"	2	EA	29.99	59.98	14.84	29.68	89.66
6" CMU 5'-2"X5'-5"	6	EA	41.29	247.77	20.44	122.64	370.41
6" CMU 8'-0"X8'-2"	3	EA	96.35	289.06	47.69	143.07	432.13
6" CMU 8'-9"X8'-2"	2	EA	105.45	210.90	52.17	104.34	315.24

CONSTRUCTION COST ESTIMATE - BASED ON 1984 UNIT PRICES (CORPS OF ENGINEERS)

RETROFIT L-SHAPED BARRACKS (BLDG. 811)
FORT CARSON, COLORADO

FEBRUARY 14, 1989

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
1/4" CONC. COATING PLUS STUCCO FINISH COAT APPLIED TO PAINTED CONCRETE	2558	SF	1.82	4,655.56	2.16	5,525.28	10,180.84
1/4" CONC. COATING PLUS STUCCO FINISH COAT APPLIED TO PAINTED CONCRETE (FLUE)	363	SF	1.65	597.64	1.80	653.40	1,251.04
2" RIGID STYROFOAM, 3/8" NYLON MESH, 1/4" INSUL/CRETE, 1/8" STUCCO FINISH COAT	16400	SF	1.82	29,829.63	2.16	35,424.00	65,253.63
1 COAT OF PRIMER & 2 COATS OF #1XX TO GUTTERS 34' ABOVE GRADE	530	LF	1.27	671.14	0.11	58.30	729.44
1 COAT OF PRIMER & 2 COATS OF #1XX TO GUTTERS 17' ABOVE GRADE	254	LF	1.27	321.64	0.11	27.94	349.58
1 COAT OF PRIMER & 2 COATS OF #1XX TO IN PLACE LOUVERS	193	SF	1.41	271.55	0.11	21.23	292.78
1 COAT OF PRIMER & 2 COATS OF #1XX TO MTL DOUBLE MANDOORS	6	EA	35.18	211.05	4.65	27.90	238.95
1 COAT OF PRIMER & 2 COATS OF #1XX TO IN PLACE DOWNSPOUTS	341	LF	1.27	431.81	0.11	37.51	469.32
PAINT NEW INTERIOR CMU	4256	SF	0.42	1,796.46	0.06	255.36	2,051.82
MOD #P00004 COPPER COUNTERFLASHING AT 34' ABOVE GRADE	78	LF	1.46	113.95	1.01	78.78	192.73
COPPER COUNTERFLASHING AT 18' ABOVE GRADE	36	LF	1.46	52.59	1.01	36.36	88.95
MOD P00003 TRIM AT BOTTOM OF ALL NEW WIND. FRAMES TO HIDE EXIST. CONC. KEY	256	EA	0.00	0.00	0.00	0.00	3,970.00
MOD P00007 EXPANSION JOINT IN CMU'S	690	SF	0.70	486.04	3.90	2,691.00	3,177.04
MOD P00006 CURTAIN RODS, STL, TRAVERSE TYPE CENTER CLOSING FOR 2'6" WINDOWS	127	EA	5.14	653.20	12.65	1,606.55	2,259.75

CONSTRUCTION COST ESTIMATE - BASED ON 1984 UNIT PRICES (CORPS OF ENGINEERS)
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RETROFIT L-SHAPED BARRACKS (BLDG. 811) FEBRUARY 14, 1989
FORT CARSON, COLORADO

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
CURTAIN RODS, STL, TRAVERSE TYPE CENTER CLOSING FOR 5'0" WINDOWS	56	EA	5.65	316.51	19.60	1,097.60	1,414.11
SUBTOTAL				64,633.14		103,168 [illegible]	171,771.93
PRIME OVERHEAD @ 10%							17,040.70
PRIME PROFIT @ 5%							9,372.38
PRIME BOND @ 1.2%							2,361.84
CONTINGENCY @ 20%							39,836.38
SUBTOTAL 1984 COST							239,018.28
ESCALATION TO 1989 COST @ -4.6%							(10,994.84)
TOTAL 1989 PROJECT COST							228,023.44

CONSTRUCTION COST ESTIMATE - BASED ON 1984 UNIT PRICES (CORPS OF ENGINEERS)

RETROFIT DINING HALL (BLDG. 1361)
FORT CARSON, COLORADO

FEBRUARY 14, 1989

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
PAINT NEW METAL TRIM SURROUNDING NEW METAL PANELS	453	LF	0.42	190.26	0.05	22.65	212.91
PAINT EXISTING METAL TRIM AROUND EXISTING METAL PANELS	530	LF	0.42	222.60	0.05	26.50	249.10
PAINT EXISTING H.M. DOORS & FRAMES	5	EA	35.18	175.90	4.65	23.25	199.15
PAINT GUTTERS & DOWNSPOUTS	626	LF	0.42	262.92	0.05	31.30	294.22
PAINT EXISTING LOUVERS	324	SF	1.41	456.84	0.11	35.64	492.48
INSTALL/PAINT 5/8" GYP. BRD.	192	SF	0.51	97.92	0.30	57.60	155.52
INSTALL 1 1/2" THK RIGID INSULATION	192	SF	0.09	17.28	0.78	149.76	167.04
1 1/2" MTL Z-FURRING CHANNELS	104	LF	0.18	18.72	0.34	35.36	54.08
J-METAL/SEALANT	64	LF	0.54	34.56	0.43	27.52	62.08
REPLACE EXISTING INCANDESCENT LIGHTS W/FLUOR. FIXTURES	5	EA	27.65	138.23	64.88	324.40	462.63
DOORS 3'-0"X6'-8", STLCRAFT #L18	8	EA	70.65	565.20	161.00	1,288.00	1,853.20
BUTTS	24	EA	7.07	169.56	18.50	444.00	613.56
MORT EXIT DEVICE	2	EA	44.23	88.45	300.00	600.00	688.45
U.R. EXIT DEVICE	2	EA	44.23	88.45	300.00	600.00	688.45
CLOSERS, RUSSWIN #P2810BH-4	8	EA	21.76	174.08	60.00	480.00	654.08
THRESHOLD, MASTER #41A, 72"	2	EA	28.26	56.52	60.00	120.00	176.52
ASTRIGAL SEAL, 80"	4	EA	9.89	39.56	42.00	168.00	207.56
WEATHERSTRIP	2	SETS	50.44	100.89	30.00	60.00	160.89
PUSH, MASTER #604EX	4	EA	4.24	16.96	10.00	40.00	56.96

CONSTRUCTION COST ESTIMATE - BASED ON 1984 UNIT PRICES (CORPS OF ENGINEERS)

RETROFIT DINING HALL (BLDG. 1361)
FORT CARSON, COLORADO

FEBRUARY 14, 1989

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
PULL, MASTER #604EX	4	EA	4.24	16.96	10.00	40.00	56.96
MOD P00007 INSULATE DOOR FRAMES	40	LF	0.99	39.56	0.25	10.00	49.56
PATCH & PAINT DOORS AT CEILING	30	SF	1.23	36.86	0.20	6.00	42.86
MOD P00004 INSTALL REFL. FILM ON OUTSIDE OF WINDOWS TO BE PANELED OVER	522	SF	2.28	1,190.16	14.75	7,699.50	8,889.66
PORCELAIN METAL WALL PANELS OVER EXISTING WINDOWS 2" THK	522	SF	2.26	1,179.98	30.00	15,660.00	16,839.98
MOD P00004 MODIFY EXISTING SCREENS TO FIT OVER EXISTING WINDOWS	41	EA	10.74	440.34		0.00	440.34
MOD P00007 INSULATE STRIP & CAULK BETWEEN NEW METAL PANELS	75	LF	0.27	20.25	3.61	270.75	291.00
SUBTOTAL				5,839.01		28,220.23	34,059.24
PRIME OVERHEAD @ 10%							3,405.92
PRIME PROFIT @ 5%							1,873.26
PRIME BOND @ 1.2%							472.06
CONTINGENCY @ 20%							7,962.10
SUBTOTAL 1984 COST							47,772.58
ESCALATION TO 1989 COST @ -4.6%							(2,197.54)
TOTAL 1989 PROJECT COST							45,575.04

CONSTRUCTION COST ESTIMATE - BASED ON 1984 UNIT PRICES (CORPS OF ENGINEERS)

RETROFIT ROLLING PIN BARRACKS (BLDG. 1363)
FORT CARSON, COLORADO

FEBRUARY 13, 1989

Description	# of Units	Unit Measure	$/Unit Labor	Subtotal Labor	$/Unit Mat'l	Subtotal Mat'l	Total Cost
REMOVE EXIST. WINDOWS & REPLACE W/ALENCO MODEL 2000 W/SEALANT 2'-8"X4'-8"	2	EA	40.53	81.05	75.25	150.50	231.55
REMOVE EXIST. WINDOWS & REPLACE W/ALENCO MODEL 2000 W/SEALANT 7'-8"X4'-8"	14	EA	94.47	1,322.54	440.00	6,160.00	7,482.54
REMOVE EXIST. WINDOWS & REPLACE W/ALENCO MODEL 2000 W/SEALANT 11'-8"X4'-8"	24	EA	132.85	3,188.49	680.00	16,320.00	19,508.49
REMOVE EXIST. WINDOWS & REPLACE W/ALENCO MODEL 2000 W/SEALANT 15'-8"X4'-8"	46	EA	171.24	7,877.04	880.00	40,480.00	48,357.04
PATCH ANY DAMAGE TO WINDOWS DUE TO REMOVAL	10400	LF	0.54	5,584.80	0.13	1,352.00	6,936.80
PREFINISHED WOOD 4'-8" BLOCKS	28	EA	1.27	35.61	1.54	43.12	78.73
PREFINISHED METAL TRIM 4'-8"	56	EA	18.79	1,052.40	16.00	896.00	1,948.40
PAINT ENTIRE WALL ADJACENT TO WINDOW OPENINGS	6927	SF	0.20	1,418.65	0.07	484.89	1,9[illegible]3.54
SUBTOTAL				20,560.58		65,866.31	86,447.09
PRIME OVERHEAD @ 10%							5,463.41
PRIME PROFIT @ 5%							3,004.87
PRIME BOND @ 1.2%							757.23
CONTINGENCY @ 20%							12,771.92
SUBTOTAL 1984 COST							76,631.50
ESCALATION TO 1989 COST @ -4.6%							(3,525.05)
TOTAL 1989 PROJECT COST							73,106.45

MECHANICAL SYSTEM ESTIMATE
BUILDING 633 PROJECT YEAR

	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
T-STATS, PROGMBLE	3	EA		40.33	0.93		56	1.17	309.0807
RELAYS W/SOCKETS SPST	1	EA		69.14	0.93		31	1.17	100.5702
RELAYS W/SOCKET SPDT	2	EA		69.14	0.93		33	1.17	205.8204
NEMA ENCL 6X6X4	3	EA		30.25	0.93		53.73	1.17	272.9898
COND 1/2"C(3#12)	150	LF			1		3.97	1.05	625.275
JCTN BOXES 4X4	7	EA		24.2	0.93		3.66	1.17	187.5174
COND 1/2"C(2#12)	40	LF			1		3.73	1.05	156.66
COND 3/4"C(5#12)	30	LF			1		5.01	1.05	157.815
JCA19 BOILER T CNTRLR	1	EA		197.72	0.93		500	1	683.8796
COND 1/2:C(3#12)	30	LF			1		3.97	1.05	125.055
REM EXIST COND	220	LF			1		1.56	1.05	360.36
MANUAL MTR STARTRS	3	EA		238.97	0.93		118.62	1.17	1083.082
									4268.105

MECHANICAL SYSTEM ESTIMATE
BUILDING 811 PROJECT YEAR

	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
MINIMIZE OA AIR									
CUT 70X14 IN HOLE	1	EA	4	48.18	0.93				179.2296
DISC. DAMP. MTR ACU2	1	EA	3	49.43	0.93				137.9097
LOCK DAMPER	1	EA	2	49.43	0.93		10	1	101.9398
REMOVE CONDUCTORS	1	EA	2	30.25	0.93				56.265
DISC DAMP MTR ACU1	1	EA	3	49.43	0.93				137.9097
LOCK DAMPER	1	EA	2	49.43	0.93		10	1	101.9398
REM FLEX CONNCTR	1	EA	2	49.43	0.93				91.9398
FILL OA HSNG INSUL	1	EA	6	48.18	0.93				268.8444
INSUL BOARD	100	SF			1		1.28	1.05	134.4
20 GA GALV SHT	100	SF			1		1.2	1.05	126
SEALANT	40	LF			1		0.78	1.05	32.76
NEW HW CONTROLS									
REM EXIST OA CNTRLR	2	EA	4	49.43	0.93				367.7592
REM EXIST HW CNTRLR	2	EA	4	49.43	0.93				367.7592
REPAIR HW SYST	1	EA	24	49.43	0.93		1000	1	2103.277
NEW OA RESET CNTRLR	2	EA	10	49.43	0.93		1040	1	2999.398
NEW HW RESET CNTRLR	2	EA	10	49.43	0.93		1040	1	2999.398
8 INCH DA ACTUATOR	2	EA	3	49.43	0.93		162.85	1	601.5194
1/4 COPPER TUBING	100	LF			1		4.88	1.05	512.4
									11320.64

MECHANICAL SYSTEM ESTIMATE
BUILDING 1361 PROJECT YEAR

	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
T-STATS/HW CNTRLR									
REM EXIST OA CONTRLR	1	EA	4	48.43	0.93			1.17	180.1596
REM EXIST T-STATS	3	EA	1	49.43	0.93			1.17	137.9097
REM EXIST HW CONTRLR	1	EA	4	49.43	0.93			1.17	183.8796
REPAIR HW SYST.	1	EA	24	49.43	0.93		1000	1	2103.277
NEW T-STATS	3	EA	1	40.33	0.93		56	1.17	309.0807
NEW OA RESET CNTRLR	1	EA	8	49.43	0.93		1040	1	1407.759
NEW HW RESET CNTRLR	1	EA	8	49.43	0.93		1040	1	1407.759
ELEC-PNEU RELAY	1	EA	2	49.43	0.93		200	1	291.9398
TIME CLOCK 7-DAY	1	EA	1	39.32	0.93		75.98	1.17	125.4642
RELAYS SPDT	3	EA	1	69.14	0.93		33	1.17	308.7306
CNTRL CABNT 9X6X4	1	EA	1	30.25	0.93		78.85	1.17	120.387
1/2 C(2#12)	60	LF			1		3.73	1.05	234.99
1/2 C(4#12)	50	LF			1		4.21	1.05	221.025
1/4 COPPER TUBE	260	LF			1		4.88	1.05	1332.24
KTCHN HOOD VENT UNIT									
REM EXIST 24X24 DUCT	1	EA	6	48.18	0.93			1.17	268.8444
CAP DUCT	1	EA	2	48.18	0.93			1.17	89.6148
CAP 16 GA 2(29X24)	9.67	SF			1		0.84	1.05	8.52894
REM EXIST 36X36 DUCT	1	EA	4	48.18	0.93			1.17	179.2296
REM EXHAUST FAN	1	EA	4	48.18	0.93			1.17	179.2296
REM EXIST 9X15 HOOD	1	EA	6	48.18	0.93			1.17	268.8444
REM WIRING AND COND	1	EA	2	49.43	0.93			1.17	91.9398
NEW MAKEUP FURNACE	1	EA	12	127.26	0.93	235	11000	1	12655.22
NEW SS 9X15 HOOD	1	EA	12	101.76	0.93		10000	1	11135.64
WITH FIRE CONTROL									
GAS REGULATOR W/FITTIN	1	EA	3	49.26	0.93		350	1	487.4354
ROOF FAN W/CURB+DMPER	1	EA	8	49.43	0.93		2296	1	2663.759
3/4 C(5#12)	20	LF			1		5.01	1.05	105.21
1/2 C(2#12)	70	LF			1		3.73	1.17	305.487
3/4 C(3#10)	85	LF			1		4.87	1.17	484.3215
30 AMP DISC SW+FUSES	1	EA	1	84.7	0.93		91.46	1.17	185.7792
MISC MOUNTING HDWR									
16 GA GALV ST 4X4	16	SF			1		0.97	1.05	16.296
ROOF FLASHING	10	SF			1		3.18	1.05	33.39
26 GA GALV 4X4 ST	16	SF			1		0.72	1.05	12.096
20 GA SS. 4(1X9)	36	SF			1		5.06	1.05	191.268
4-1/2 TIE RODS	16	LF			1		0.92	1.05	15.456
									37742.19

MECHANICAL SYSTEM ESTIMATE
BUILDING 1363 PROJECT YEAR

	NO.	UNITS	LABOR HRS	RATE	REGION ADJUST	EQUIP PRICE	MATLS PRICE	REGION ADJUST	TOTAL
HEATING SYST CONTRLR									
REM EXIST OA CNTRLR	1	EA	4	49.43	0.93			1	183.8796
REM EXIST HW CTRLR	1	EA	4	49.43	0.93			1	183.8796
REM EXIST 3X9 DMPERS	2	EA	8	48.18	0.93			1	716.9184
INSPECT REP AHU1 AHU2	1	EA	24	49.43	0.93		1000	1	2103.277
INSPECT REP HW SYST	1	EA	24	49.43	0.93		1000	1	2103.277
NEW OA CNTRLR	1	EA	10	49.43	0.93		1040	1	1499.699
NEW HW RESET CNTRLR	1	EA	10	49.43	0.93		1040	1	1499.699
1/4 COPPER TUBE	100	LF			1		4.88	1.05	512.4
NEW OA DAMPERS	2	EA	8	48.18	0.93		450	1	1616.918
									10419.94

APPENDIX M:

LCCID PRINTOUTS

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            LIFE CYCLE COST ANALYSIS SUMMARY             STUDY: B633A
        ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)     LCCID  1.028
INSTALLATION & LOCATION: FT. CARSON                    REGION NO.  8
PROJECT NO. & TITLE: 1   BUILDING 633 ACTUAL
FISCAL YEAR 1984    DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE:  03-30-89  ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1.  INVESTMENT
    A. CONSTRUCTION COST                                       $     91310.
    B. SIOH                                                    $      5022.
    C. DESIGN COST                                             $      5479.
    D. ENERGY CREDIT CALC (1A+1B+1C)X.9                        $     91630.
    E. SALVAGE VALUE COST                                      $         0.
    F. TOTAL INVESTMENT (1D-1E)                                $     91630.

2.  ENERGY SAVINGS (+) / COST (-)
    ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

                  UNIT COST   SAVINGS      ANNUAL $      DISCOUNT    DISCOUNTED
    FUEL          $/MBTU(1)   MBTU/YR(2)   SAVINGS(3)    FACTOR(4)   SAVINGS(5)

    A.  ELECT     $    .00         0.      $        0.       11.44           0.
    B.  DIST      $    .00         0.      $        0.       16.79           0.
    C.  RESID     $    .00         0.      $        0.       17.92           0.
    D.  NAT G     $  4.03        744.      $     2997.       17.90       53643.
    E.  COAL      $    .00         0.      $        0.       13.24           0.

    F.  TOTAL                    744.      $     2997.                $  53643.

3.  NON ENERGY SAVINGS(+) / COST(-)

    A.  ANNUAL RECURRING (+/-)                                 $         0.
        (1) DISCOUNT FACTOR (TABLE A)                  11.65
        (2) DISCOUNTED SAVING/COST (3A X 3A1)                  $         0.

    C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $      0.

    D.  PROJECT NON ENERGY QUALIFICATION TEST
        (1) 25% MAX NON ENERGY CALC (2F5 X .33)        $    17702.
             A IF 3D1 IS = OR > 3C   GO TO ITEM 4
             B IF 3D1 IS < 3C   CALC    SIR = (2F5+3D1)/1F)= ______
             C IF 3D1B IS = > 1   GO TO ITEM 4
             D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4.  FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $  2997.

5.  TOTAL NET DISCOUNTED SAVINGS (2F5+3C)                      $     53643.

6.  DISCOUNTED SAVINGS RATIO              (SIR)=(5 / 1F)=      .59
    (IF < 1 PROJECT DOES NOT QUALIFY)

7.  SIMPLE PAYBACK PERIOD (ESTIMATED)    SPB=1F/4            30.58
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LIFE CYCLE COST ANALYSIS SUMMARY STUDY: 8011A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 2 BUILDING 811 ACTUAL
FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03 10-89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	356019.
B. SIOH	$	19583.
C. DESIGN COST	$	21063.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	357296.
E. SALVAGE VALUE COST	$	0.
F. TOTAL INVESTMENT (1D 1E)	$	357296.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0.	17.92	0.
D. NAT G	$ 4.03	1973.	$ 7947.	17.90	142256.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		1973.	$ 7947.		$ 142256.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 46944.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7947.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 142256.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .40
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 44.96

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: 1361A25
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1 1361 ACTUAL
FISCAL YEAR 1984 DISCRETE PORTION NAME: RETRO
ANALYSIS DATE: 05-10-89 ECONOMIC LIFE 25 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	113207.
B. SIOH	$	6227.
C. DESIGN COST	$	6793.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	113604.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	113604.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0	17.92	0.
D. NAT G	$ 4.03	64.	$ 258.	17.90	4617.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		64.	$ 258.		$ 4617.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 1524.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 258.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 4617.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .04
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 440.46

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              LIFE CYCLE COST ANALYSIS SUMMARY              STUDY: B1363A
          ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)      LCCID  1.028
INSTALLATION & LOCATION: FT. CARSON                     REGION NO.  8
PROJECT NO. & TITLE: 4   BUILDING 1363 ACTUAL
FISCAL YEAR 1984    DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE:  03 30 33  ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1.  INVESTMENT
    A. CONSTRUCTION COST                                        $   113903.
    B. SIOH                                                     $     6265.
    C. DESIGN COST                                              $     6835.
    D. ENERGY CREDIT CALC (1A+1B+1C)X.9                         $   114303.
    E. SALVAGE VALUE COST                                       $       0.
    F. TOTAL INVESTMENT (1D-1E)                                 $   114303.

2.  ENERGY SAVINGS (+) / COST (-)
    ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

                 UNIT COST   SAVINGS      ANNUAL $      DISCOUNT    DISCOUNTED
    FUEL         $/MBTU(1)   MBTU/YR(2)   SAVINGS(3)    FACTOR(4)   SAVINGS(5)

    A.  ELECT    $    .00        0.       $        0.      11.44            0.
    B.  DIST     $    .00        0.       $        0.      16.79            0.
    C.  RESID    $    .00        0.       $        0.      17.92            0.
    D.  NAT G    $  4.03      1777.       $     7158.      17.90       128124.
    E.  COAL     $    .00        0.       $        0.      13.24            0.

    F.  TOTAL                 1777.       $     7158.               $  128124.

3.  NON ENERGY SAVINGS(+) / COST(-)

    A.  ANNUAL RECURRING (+/-)                                  $        0.
        (1) DISCOUNT FACTOR (TABLE A)                 11.65
        (2) DISCOUNTED SAVING/COST (3A X 3A1)                   $        0.

    C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $       0.

    D.  PROJECT NON ENERGY QUALIFICATION TEST
        (1) 25% MAX NON ENERGY CALC (2F5 X .33)        $     42281.
             A IF 3D1 IS = OR > 3C  GO TO ITEM 4
             B IF 3D1 IS < 3C  CALC    SIR = (2F5+3D1)/1F)= ______
             C IF 3D1B IS = > 1   GO TO ITEM 4
             D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4.  FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $     7158.

5.  TOTAL NET DISCOUNTED SAVINGS (2F5+3C)                       $   128124.

6.  DISCOUNTED SAVINGS RATIO              (SIR)=(5 / 1F)=     1.12
    (IF < 1 PROJECT DOES NOT QUALIFY)

7.  SIMPLE PAYBACK PERIOD (ESTIMATED)    SPB=1F/4             15.97
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LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B633A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 1 BUILDING 633 ACTUAL
FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	91310.
B. SIOH	$	5022.
C. DESIGN COST	$	5479.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	91630.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	91630.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	8.83	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	744.	$ 2997.	11.87	35572.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		744.	$ 2997.		$ 35572.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 11739.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 2997.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 35572.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .39
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 30.58

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: [illegible]
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) [illegible]
INSTALLATION & LOCATION: FT. CARSON REGION NO. 3
PROJECT NO. & TITLE: [illegible] BUILDING 811 ACTUAL
FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: [illegible] ECONOMIC LIFE 15 YEARS PREPARED BY: [illegible]

1. INVESTMENT

A. CONSTRUCTION COST	$	[illegible]049.
B. SIOH	$	13530.
C. DESIGN COST	$	[illegible]
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	[illegible]296.
E. SALVAGE VALUE COST	$	0.
F. TOTAL INVESTMENT (1D 1E)	$	[illegible]

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	[illegible]	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	1973.	$ 7947.	11.87	94334.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		1973.	$ 7947.		$ 94334.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 31130.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)=
C IF 3D1B IS > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7947.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 94334.

6. DISCOUNTED SAVINGS RATIO (SIR) (5 / 1F)= [illegible]
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB 1F/4 [illegible]

LIFE CYCLE COST ANALYSIS SUMMARY   STUDY: 1361A15
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)   LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON   REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1   1361 ACTUAL
FISCAL YEAR 1984   DISCRETE PORTION NAME: RETRO
ANALYSIS DATE: 05-10-89 ECONOMIC LIFE 15 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	113207.
B. SIOH	$	6227.
C. DESIGN COST	$	6793.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	113604.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	113604.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	8.83	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	64.	$ 258.	11.87	3062.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		64.	$ 258.		$ 3062.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A)   9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 1010.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 258.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 3062.

6. DISCOUNTED SAVINGS RATIO   (SIR)=(5 / 1F)=   .03
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4   440.46

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B13C3A

ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028

INSTALLATION & LOCATION: FT. CARSON REGION NO. 8

PROJECT NO. & TITLE: 4 BUILDING 1363 ACTUAL

FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT

ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	113903.
B. SIOH	$	6265.
C. DESIGN COST	$	6835.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	114303.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	114303.

2. ENERGY SAVINGS (+) COST ( )

ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	8.83	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	1777.	$ 7158.	11.87	84963.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		1777.	$ 7158.		$ 84963.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.

(1) DISCOUNT FACTOR (TABLE A) 9.11

(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST

(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 28038.

A IF 3D1 IS = OR > 3C GO TO ITEM 4

B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______

C IF 3D1B IS = > 1 GO TO ITEM 4

D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7158.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 84963.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .74

(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 15.97

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B633A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 1 BUILDING 633 PROJ. YEAR ESTIMATE
FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	38079.
B. SIOH	$	2095.
C. DESIGN COST	$	2285.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	38213.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	38213.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0.	17.92	0.
D. NAT G	$ 4.03	744.	$ 2997.	17.90	53643.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		744.	$ 2997.		$ 53643.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 17702.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 2997.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 53643.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= 1.40
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 12.75

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B811A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 2 BUILDING 811 PROJ. YEAR ESTIMATE
FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03 30-89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	257600.
B. SIOH	$	14173.
C. DESIGN COST	$	15462.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	258533.
E. SALVAGE VALUE COST	$	0.
F. TOTAL INVESTMENT (1D-1E)	$	258533.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0.	17.92	0.
D. NAT G	$ 4.03	1973.	$ 7947.	17.90	142256.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		1973.	$ 7947.		$ 142256.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 46944.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7947.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 142256.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .55
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 32.54

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: 1361P15
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1 1361 PROJ. YR. EST.
FISCAL YEAR 1984 DISCRETE PORTION NAME: RETRO
ANALYSIS DATE: 05-10-89 ECONOMIC LIFE 15 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	112594.
B. SIOH	$	6193.
C. DESIGN COST	$	6756.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	112989.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	112989.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	8.83	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	64.	$ 258.	11.87	3062.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		64.	$ 258.		$ 3062.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 1010.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 258.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 3062.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .03
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 438.08

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B1363A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 4 BUILDING 1363 PROJ. YEAR ESTIMATE
FISCAL YEAR 19[illegible]4 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	137867.
B. SIOH	$	7583.
C. DESIGN COST	$	8272.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	138350.
E. SALVAGE VALUE COST	$	.
F. TOTAL INVESTMENT (1D-1E)	$	138350.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.[illegible]	0.
C. RESID	$ .00	0.	$ 0.	17.02	0.
D. NAT G	$ 4.03	1777.	$ 7158.	17.90	128124.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		1777.	$ 7158.		$ 128124.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 42281.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7158.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 128124.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .93
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 19.33

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B633A

ENERGY CONSERVATION INVESTMENT PROGRAM (E[illegible]) [illegible]

INSTALLATION & LOCATION: FT. CARSON REGION NO. [illegible]

PROJECT NO. & TITLE: 1 BUILDING 633 PROJ. YEAR ESTIMATE

FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT

ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	33079.
B. SIOH	$	2095.
C. DESIGN COST	$	[illegible]85.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	38213.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	38213.

2. ENERGY SAVINGS (+) / COST (-)

ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	8.83	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	744.	$ 2997.	11.87	35572.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		744.	$ 2997.		$ 35572.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.

(1) DISCOUNT FACTOR (TABLE A) 9.11

(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST

(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 11739.

A IF 3D1 IS = OR > 3C GO TO ITEM 4

B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______

C IF 3D1B IS = > 1 GO TO ITEM 4

D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 2997.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 35572.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .93

(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 12.75

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: B811A

ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.028

INSTALLATION & LOCATION: FT. CARSON — REGION NO. [illegible]

PROJECT NO. & TITLE: 2 BUILDING 811 PROJ. YEAR ESTIMATE

FISCAL YEAR 1984 DISCRETE PORTION NAME: BUILDING RETROFIT

ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	257690.
B. SIOH	$	14173.
C. DESIGN COST	$	15462.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	258593.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	258593.

2. ENERGY SAVINGS (+) / COST (-)

ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	8.83	0.
B. DIST	$ .00	0.	$ 0.	11.31	0.
C. RESID	$ .00	0.	$ 0.	12.15	0.
D. NAT G	$ 4.03	1973.	$ 7947.	11.87	94334.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		1973.	$ 7947.		$ 94334.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.

(1) DISCOUNT FACTOR (TABLE A) 9.11

(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST

(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 31130.

A IF 3D1 IS = OR > 3C GO TO ITEM 4

B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______

C IF 3D1B IS = [illegible] 1 GO TO ITEM 4

D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7947.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 94334.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .36

(IF [illegible] 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 32.54

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: 1361P25
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1 1361 PROJ. YR. EST.
FISCAL YEAR 1984 DISCRETE PORTION NAME: RETRO
ANALYSIS DATE: 05-10-89 ECONOMIC LIFE 25 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	112594.
B. SIOH	$	6193.
C. DESIGN COST	$	6756.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	112989.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	112989.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0.	17.92	0.
D. NAT G	$ 4.03	64.	$ 258.	17.90	4617.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		64.	$ 258.		$ 4617.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 1524.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 258.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 4617.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .04
(IF < 1 PROJECT DOES NCT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 438.08

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             LIFE CYCLE COST ANALYSIS SUMMARY               STUDY: B1363A
        ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)         LCCID [illegible]
INSTALLATION & LOCATION: FT. CARSON                        REGION NO. [illegible]
PROJECT NO. & TITLE: 4   BUILDING 1363 PROJ. YEAR ESTIMATE
FISCAL YEAR 19[illegible]    DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: [illegible]  ECONOMIC LIFE 15 YEARS PREPARED BY: [illegible]

1.  INVESTMENT
    A. CONSTRUCTION COST                                        $   1[illegible]367[illegible].
    B. SIOH                                                     $     758[illegible].
    C. DESIGN COST                                              $     [illegible] .
    D. ENERGY CREDIT CALC (1A+1B+1C)X.9                         $   [illegible]335 .
    E. SALVAGE VALUE COST                                       $         .
    F. TOTAL INVESTMENT (1D-1E)                                 $   13835[illegible].

2.  ENERGY SAVINGS (+) / COST (-)
    ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS
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FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	[illegible].33	0.
B. DIST	$ .00	0.	$ 0.	11.[illegible]1	0.
C. RESID	$ .00	0.	$ 0	1[illegible].15	0.
D. NAT G	$ 4.03	1777.	$ 7158.	11.87	84[illegible]63.
E. COAL	$ .00	0.	$ 0.	10.02	0.
F. TOTAL		1777.	$ 7158.		$ 84[illegible].

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3.  NON ENERGY SAVINGS(+) / COST(-)

    A. ANNUAL RECURRING (+/-)                                   $         .
       (1) DISCOUNT FACTOR (TABLE A)                   9.11
       (2) DISCOUNTED SAVING/COST (3A X 3A1)                    $         .

    C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $       .

    D. PROJECT NON ENERGY QUALIFICATION TEST
       (1) 25% MAX NON ENERGY CALC (2F5 X .33)         $    28038.
           A IF 3D1 IS = OR > 3C  GO TO ITEM 4
           B IF 3D1 IS < 3C  CALC   SIR = (2F5+3D1)/1F)= ______
           C IF 3D1B IS = > 1  GO TO ITEM 4
           D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4.  FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $    715 .

5.  TOTAL NET DISCOUNTED SAVINGS (2F5+3C)                       $   8496[illegible].

6.  DISCOUNTED SAVINGS RATIO              (SIR)=(5 / 1F)=     .61
    (IF < 1 PROJECT DOES NOT QUALIFY)

7.  SIMPLE PAYBACK PERIOD (ESTIMATED)   SPB=1F/4            19.33
```

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B633A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.[illegible]
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 1 BUILDING 633 CURRENT YEAR ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	52722.
B. SIOH	$	2900.
C. DESIGN COST	$	3164.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	52907.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	52907.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.34	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 3.11	744.	$ 2311.	22.69	52434.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		744.	$ 2311.		$ 52434.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 17303.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 2311.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 52434.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .99
(IF 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 22.90

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B811A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 2 BUILDING 811 CURRENT YEAR ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 04 13 89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$ 298588.
B. SIOH	$ 16423.
C. DESIGN COST	$ 17916.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$ 299634.
E. SALVAGE VALUE COST	$ 0.
F. TOTAL INVESTMENT (1D-1E)	$ 299634.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 3.11	1973.	$ 6128.	22.69	139047.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		1973.	$ 6128.		$ 139047.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 45886.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 6128.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 139047.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .46
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 48.89

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: 1361C15
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1 1361 CURR. YR. EST.
FISCAL YEAR 1989 DISCRETE PORTION NAME: RETRO
ANALYSIS DATE: 05-10-89 ECONOMIC LIFE 15 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	99526.
B. SIOH	$	5474.
C. DESIGN COST	$	5972.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	99875.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	99875.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	7.96	0.
B. DIST	$ .00	0.	$ 0.	13.77	0.
C. RESID	$ .00	0.	$ 0.	15.51	0.
D. NAT G	$ 3.11	64.	$ 199.	14.17	2820.
E. COAL	$ .00	0.	$ 0.	9.44	0.
F. TOTAL		64.	$ 199.		$ 2820.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 931.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 199.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 2820.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .03
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 501.78

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B1363A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO 8
PROJECT NO. & TITLE: 4 BUILDING 1363 CURRENT YEAR ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03 30 89 ECONOMIC LIFE 25 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	160673.
B. SIOH	$	8837.
C. DESIGN COST	$	9641.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	161236.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D 1E)	$	161236.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 3.11	1777.	$ 5519.	22.69	125234.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		1777.	$ 5519.		$ 125234.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 41327.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 5519.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 125234.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .78
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 29.21

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B633A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 1 BUILDING 633 CURRENT YEAR ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	52722.
B. SIOH	$	2900.
C. DESIGN COST	$	3164.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	52907.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	52907.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	7.96	0.
B. DIST	$ .00	0.	$ 0.	13.77	0.
C. RESID	$ .00	0.	$ 0.	15.51	0.
D. NAT G	$ 3.11	744.	$ 2311.	14.17	32745.
E. COAL	$ .00	0.	$ 0.	9.44	0.
F. TOTAL		744.	$ 2311.		$ 32745.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 10806.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 2311.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 32745.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .62
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 22.90

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B811A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 2 BUILDING 811 CURRENT YEAR ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: BUILDING RETROFIT
ANALYSIS DATE: 04-13-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	298588.
B. SIOH	$	16423.
C. DESIGN COST	$	17916.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	299634.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	299634.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	7.36	0.
B. DIST	$ .00	0.	$ 0.	13.77	0.
C. RESID	$ .00	0.	$ 0.	15.51	0.
D. NAT G	$ 3.11	1973.	$ 6128.	14.17	86836.
E. COAL	$ .00	0.	$ 0.	9.44	0.
F. TOTAL		1973.	$ 6128.		$ 86836.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 28656.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 6128.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 86836.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .29
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 48.89

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: 1361C25
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1 1361 CURR. YR. EST.
FISCAL YEAR 1989 DISCRETE PORTION NAME: RETRO
ANALYSIS DATE: 05-10-89 ECONOMIC LIFE 25 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	99526.
B. SIOH	$	5474.
C. DESIGN COST	$	5972.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	99875.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	99875.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 3.11	64.	$ 199.	22.69	4516.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		64.	$ 199.		$ 4516.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) *DISCOUNTED SAVING/COST* (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 1490.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 199.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 4516.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .05
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 501.78

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: B1363A

ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.028

INSTALLATION & LOCATION: FT. CARSON — REGION NO. 8

PROJECT NO. & TITLE: 4 BUILDING 1363 CURRENT YEAR ESTIMATE

FISCAL YEAR 1989 DISCRETE PORTION NAME: BUILDING RETROFIT

ANALYSIS DATE: 03-30-89 ECONOMIC LIFE 15 YEARS PREPARED BY: SLIWINSKI

1. INVESTMENT

A. CONSTRUCTION COST	$	160673.
B. SIOH	$	8837.
C. DESIGN COST	$	9641.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	161236.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	161236.

2. ENERGY SAVINGS (+) / COST ( )

ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	7.96	0.
B. DIST	$ .00	0.	$ 0.	13.77	0.
C. RESID	$ .00	0.	$ 0.	15.51	0.
D. NAT G	$ 3.11	1777.	$ 5519.	14.17	78209.
E. COAL	$ .00	0.	$ 0.	9.44	0.
F. TOTAL		1777.	$ 5519.		$ 78209.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.

(1) DISCOUNT FACTOR (TABLE A) 9.11

(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST

(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 25809.

A IF 3D1 IS = OR > 3C GO TO ITEM 4

B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______

C IF 3D1B IS = > 1 GO TO ITEM 4

D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 5519.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 78209.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .49

(IF 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 29.21

LIFE CYCLE COST ANALYSIS SUMMARY   STUDY: 8110A15X
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)   LCCID 1.035
INSTALLATION & LOCATION: FT.CARSON   REGION NOS. 8 CENSUS: 4
PROJECT NO. & TITLE: 1   8110 ACTUAL
FISCAL YEAR 88   DISCRETE PORTION NAME: OP
ANALYSIS DATE: 05-05-89 ECONOMIC LIFE 15 YEARS PREPARED BY: R.NORTHRUP

1. INVESTMENT

A. CONSTRUCTION COST	$	19150.
B. SIOH	$	1054.
C. DESIGN COST	$	1149.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	19218.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	19218.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	7.96	0.
B. DIST	$ .00	0.	$ 0.	13.77	0.
C. RESID	$ .00	0.	$ 0.	15.51	0.
D. NAT G	$ 4.08	1741.	$ 7103.	14.17	100653.
E. COAL	$ .00	0.	$ 0.	9.44	0.
F. TOTAL		1741.	$ 7103.		$ 100653.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ -200.
(1) DISCOUNT FACTOR (TABLE A)   9.11
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ -1822.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ -1822.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 33216.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= _____
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 6903.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 98831.

6. DISCOUNTED SAVINGS RATIO   (SIR)=(5 / 1F)= 5.14
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4   2.78

APPENDIX N:

MARKET SCENARIO PROGRAM

This program computes market scenarios (acceptable construction and fuel costs with various annual non-energy savings) which allow a retrofit to meet the ECIP criteria for a specified annual energy savings and retrofit life.

Out.dat is the output file
Esav is the annual energy savings of the retrofit (MBtu)
J is the cost of fuel ($/MBtu)
SN is annual non-energy savings of the retrofit ($1000)
SG is the annual gas energy cost savings ($)
CC is the cost of retrofit construction ($1000)

```
10 OPEN "O",#1,"OUT.DAT"  'OPEN OUTPUT FILE
20 INPUT "ENTER ACTUAL ENERGY SAVED"; ESAV
30 FOR J=1 TO 10 'LET FUEL COST VARY $1-$10/MBTU
40 SG=J*ESAV 'COMPUTE ANNUAL COST SAVINGS
50 K=0! 'INCREMENTOR FOR NON ENERGY SAVINGS
60 IF K>=1.1 GOTO 120 'COMPUTE 11 VALUES
70 SN=K*.649*SG 'EQN 11
80 CC=(22.69*SG+11.65*SN)/1.0035 ' EQN 12
81 PRINT K,J,SG,SN,CC ' PRINT TO SCREEN
90 PRINT#1, K;J;SG;SN;CC
100 K=K+.1
110 GOTO 60
120 NEXT J
130 END
```

NOTE: Constants in lines 70 and 80 assume a 25 yearlife, Region 8, and 1987 escalation factors. The derivation of equations 11 and 12 is in Chapter 3, **Economic Analysis**.

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