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ENERGY EFFICIENCY IN MILITARY FAMILY HOUSING: INSPECTION RESULTS

William P. Levins
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ENERGY DIVISION

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Existing Buildings Research Program
Energy Division

September 1994

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CONTENTS

LIST OF FIGURES v

LIST OF TABLES vii

ACRONYMS AND ABBREVIATIONS ix

ACKNOWLEDGMENTS xi

ABSTRACT xiii

EXECUTIVE SUMMARY xv

1. INTRODUCTION 1

2. PILOT AIR FORCE AND ARMY SITE SELECTIONS 3
   2.1 GEOGRAPHIC LOCATION 3
   2.2 CLIMATE 5
   2.3 ENERGY CONSUMPTION 7
   2.4 SITE SELECTION SUMMARY 10

3. DEIS DATA ANALYSIS 13
   3.1 MALMSTROM AFB 15
   3.2 ALTUS AFB 16
   3.3 FORT MONMOUTH 16
   3.4 DEIS ANALYSIS SUMMARY 17

4. ON-SITE INSPECTIONS OF MILITARY FAMILY HOUSING 19
   4.1 INSPECTION OVERVIEW 19
      4.1.1 House Survey 19
      4.1.2 Air-Leakage Measurements 19
      4.1.3 House Heating and Cooling Systems 19
      4.1.4 Distribution Systems 20
      4.1.5 Infrared Scans 20
      4.1.6 Safety Inspections 20
      4.1.7 Photographs 21
   4.2 MALMSTROM AFB 21
   4.3 ALTUS AFB 23
   4.4 FORT MONMOUTH 35
   4.5 SITE INSPECTION SUMMARY 38

5. RESULTS OF ENERGY MODELING 43
   5.1 COMPARISON OF NEAT ESTIMATES AND DEIS DATA 43
   5.2 MEASURES SUGGESTED BY NEAT 49
   5.3 NEAT MODELING SUMMARY 49

6. FAMILY HOUSING COMMUNITY PLAN REVIEW 51
6.1 MALMSTROM AFB 51
6.2 ALTUS AFB 52
6.3 SUMMARY OF FAMILY HOUSING PLANS 53

7. CONCLUSIONS AND RECOMMENDATIONS 55

8. REFERENCES 57

APPENDIX A. U.S. AIR FORCE AND U.S. ARMY FAMILY HOUSING DEIS DATA AND NEAT ENERGY ANALYSIS SUMMARY REPORTS A-1

APPENDIX B. FORMS USED DURING INSPECTIONS B-1

FIGURES

2.1. Potential sites to inspect 4
2.2. Sites selected for inspections 5
2.3. Heating vs cooling degree days for major Air Force bases 6
2.4. Heating vs cooling degree days for major Army installations 6
2.5. Heating degree days in FY92 vs heating energy used for major Air Force bases 8
2.6. Annual degree days vs heating energy used in FY92 for major Army installations 8
2.7. Cooling degree days vs electric energy used in FY92 for major Air Force bases 9
2.8. Cooling degree days vs electric energy used in FY92 for major Army installations 9
2.9. U.S. Air Force family housing consumptions of potential bases to inspect 11
2.10. U.S. Army family housing energy consumptions of potential installations to inspect 11
4.1. Return air supply under closet 24
4.2. Attic bypass above closet shown in Fig. 4.1 25
4.3. Supply air to and exhaust air from condensing furnace 26
4.4. Attic insulation not replaced after repair work on water pipes 27
4.5. Sealed off gable vent 27
4.6. Insulation covering soffit vents in attic 28
4.7. Access to outside air from refrigerant line entry 28
4.8. Access to attic air from flue pipe chaseway 29
4.9. Duct separation from trunk 30
4.10. Separated duct in attic 30
4.11. Damaged duct branch in attic 31
4.12. Poorly sealed supply duct to register termination in attic 32
4.13. Another poorly sealed supply duct to register termination in attic 32
4.14. Poorly fitting air-conditioner A-coil on gas furnace 33
4.15. Air-conditioner condensing unit covered by tree and pollen 34
4.16. Water-heater flue misaligned 34
4.17. Duct cut off too short at register, terminating inside interior wall 37
4.18. Another duct cut off too short at register, terminating inside interior wall 38
4.19. Damaged fins on air-conditioner condensing unit 39
4.20. Uninsulated 150-gal hot water storage tank 40

TABLES

3.1. Proposed military family housing total energy use budget for new construction 14
3.2. DEIS energy use data for potential Air Force base inspection sites 14
3.3. DEIS energy use data for potential Army installation inspection sites 14
4.1. Characteristics of housing at Malmstrom AFB 21
4.2. Characteristics of housing at Altus AFB 24
4.3. Family housing at Fort Monmouth 35
5.1. Summary data from Air Force family housing inspections 44
5.2. Summary of NEAT energy analysis for Air Force housing inspections 45
5.3. Summary data from Army family housing inspections 46
5.4. Summary of NEAT energy analysis for Army housing inspections 47
5.5. Summary of NEAT heating and cooling estimates and comparison with adjusted DEIS data 47
5.6. Summary of cost-effective measures recommended by National Energy Audit (NEAT) audit program 48

ACRONYMS AND ABBREVIATIONS

A&E	architectural and engineering (firms)
AFB	Air Force Base
AFUE	annual fuel utilization efficiency
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CDD	cooling degree day
CFC	chlorofluorocarbon
DEIS	Defense Energy Information System
DOE	U.S. Department of Energy
EEDO	Energy Economics of Design Options (computer program)
EUB	Energy Use Budget
gpm	gallons per minute
HDD	heating degree day
HVAC	heating, ventilating, and air conditioning
kSF	thousands of square feet
MFH	military family housing
NAHB	National Association of Home Builders
NEAT	National Energy Audit (DOE computer program)
ORNL	Oak Ridge National Laboratory
ppm	parts per million
RECS	Residential Energy Consumption Survey
USAF	U.S. Air Force

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We were also helped greatly by the personnel at Tyndall Air Force Base and Fort Belvoir who supplied us with DEIS data.

ABSTRACT

The U.S. military is currently upgrading its existing family housing through a revitalization process to meet its future needs. Each service must also reduce its total energy consumption intensity 25% by the year 2000 compared to the reference year 1985.

Oak Ridge National Laboratory is working with the U.S. Army and the U.S. Air Force to help meet these goals. Our overall goal is to develop a revitalization guidebook to aid architectural and engineering firms during the design phase of a project, to obtain effective energy efficiency in a cost-effective manner.

We conducted detailed instrumented inspections on a total of 25 houses from Altus Air Force Base (AFB), Oklahoma; Malmstrom AFB, Montana; and Fort Monmouth, New Jersey, in order to document the condition of existing housing from an energy viewpoint. We also reviewed their community housing plans.

Our inspections revealed that many energy-efficient measures had been taken during revitalization and other miscellaneous energy-related projects, but we also found much remaining to be done. Most (but not all) heating and cooling systems were in good shape. The problems we found are identical to those existing in private sector housing: leaky and damaged ducts and registers; missing insulation in attics, walls, and heated basements; and air leakage paths to attics and to outdoor air caused by shoddy or incomplete workmanship.

We analyzed the Defense Energy Information System (DEIS) family housing data from each location, reviewed it with the respective energy coordinators, and concluded that it may not be sufficiently accurate to make correct decisions regarding the implementation of projects designed to conserve energy in the family housing sector.

We modeled each house with the U.S. Department of Energy National Energy Audit (NEAT) computer program, which suggested that substantial cost-effective savings are available during the revitalization process.

We are using these sources of information as a basis for our guidebook.

EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

The U.S. military is currently upgrading its existing family housing through a revitalization process to meet its future needs. Each service must also reduce its total energy consumption intensity 25% by the year 2000, compared to the reference year 1985, and 30% by the year 2005.

Oak Ridge National Laboratory is working with the U.S. Army and the U.S. Air Force to help meet these goals. Our overall goal is to develop a revitalization guidebook to aid architectural and engineering (A&E) firms during the design phase of a project, to obtain effective energy efficiency in a cost-effective manner.

The purpose of the work described herein was to inspect military family housing (MFH) at several installations to determine its energy-efficiency strengths and weaknesses in support of our guidebook development.

METHODOLOGY

We reviewed climate and energy consumption data of five Air Force bases (AFBs) and six Army installations that were planning near-term MFH revitalization work and selected Altus AFB, Oklahoma; Malmstrom AFB, Montana; and Fort Monmouth, New Jersey, as sites to conduct family housing inspections. All three sites have reported high heating energy consumptions for their climates and comprise a well-distributed sample that is representative of the military. In addition to conducting energy audits of a sample of housing units from each selected installation, we also

- analyzed the Defense Energy Information System (DEIS) family housing data from each location and reviewed it with the respective energy coordinators;
- reviewed the Family Housing Community Plan for Malmstrom AFB and Altus AFB to determine how energy efficiency was integrated into each (Fort Monmouth did not have an equivalent book); and
- modeled each house that we inspected with the U.S. Department of Energy National Energy Audit (NEAT) computer program in order to estimate building loads and determine recommended energy-efficiency measures.

DEIS DATA

We estimated that MFH consumes about 5% to possibly 10% more energy on a square foot basis than the private sector when reported DEIS data are compared to 1987 Residential Energy Consumption Survey data. We feel that the overall DEIS data for energy use at each installation are accurate, but reported portions for family housing may not be sufficiently accurate to provide useful information about the present energy efficiency of housing units.

A database containing accurate energy usage for the MFH sector at each military installation is necessary in order to make correct decisions regarding the implementation of projects designed to conserve energy in that sector. The accuracy of reported MFH consumption data can be evaluated through a thorough review process at each installation.

RESULTS OF INSPECTIONS

Our inspections of Malmstrom AFB, Altus AFB, and Fort Monmouth showed many of the same deficiencies; they were also consistent with those found at Shaw AFB, which we had inspected for another study. Our experience in the private sector is no different from the military, with the same deficiencies showing up time and time again.

Problems related to forced-air distribution systems are widespread. Duct leakage is a very common and serious part of this. Duct joints fail because of faulty or poorly designed duct supports and/or as a result of human encounters with ducts. Ducts in attics can undergo extreme abuse and even separate when people enter attics to perform tasks such as furnace tune-ups and installing additional attic insulation. We found much of this type of damage at Altus AFB. Not locating HVAC equipment in attics will minimize the necessity of service people entering attics and reduce the human contribution to duct damage. When it is necessary to locate ducts in the attic space, duct layouts should be designed with service access in mind, and installed carefully, with the ducts well insulated.

We found many separated ducts. Duct joints should be sealed with a mechanical fastener (e.g., sheet metal screws), covered with a fiberglass drywall-seam type of tape, and coated with a mastic compound made for that purpose. Cloth duct tape should be avoided, as it only forms a temporary seal at best.

Inadequate duct supports were found at all three sites. Supports should be more substantial than a piece of wire, and they should be securely fastened to a suitable surface.

Return-air systems, particularly plenums, are vulnerable to design and construction flaws that result in energy-efficient mechanical equipment being supplied with heating and cooling loads much higher than they should be. The source of the increased loads is a quantity of return air originating from places other than the house living area—the attic and the outside. Air from these sources requires much more energy to condition than that from the living area.

The house structure was often used as part of the duct system, and many areas not permanently sealed from interior walls were prime sources of attic and outside return air. Dirty air filters at the entrance to return-air registers aggravate this situation as the increased pressure drop across the dirty filter reduces the airflow through the filter and increases the amount of attic or outside air in the return air to the furnace/air conditioner.

Those locations where ducts connect with air supply and return registers were often sources of leakage because of the use of improper materials or poor installation. Such connections should be secure and decoupled from the interior wall or attic spaces, with no air gaps remaining. Better designed transition pieces or supply registers would help alleviate this common problem.

Bypasses are minimal resistance air-infiltration leakage paths to attics or the outside that allow relatively large quantities of conditioned air to easily exit a house by way of interior or exterior walls. Usual infiltration paths such as small cracks admit only small quantities of air, but a single bypass can avoid the higher resistance paths and increase air infiltration significantly, often by 20 to 40% or more. We found such bypasses existed in unsealed areas where ducts went through walls and where the house structure was used as part of the duct system. Cutouts in walls (including electrical outlets) should be properly sealed so the wall interior is decoupled from the room space.

Uninsulated overhang areas under a second or third story of a house or under bay windows are also sources of bypasses. We found several instances of uninsulated and partially insulated overhangs at Altus AFB and Fort Monmouth.

Many houses at Malmstrom AFB and at Fort Monmouth have improperly defined thermal boundaries. These houses have uninsulated basements that are essentially heated, and the basement area should be treated as conditioned areas and insulated appropriately. Many houses at Fort Monmouth had uninsulated attics even after they were revitalized. We also found several floors over crawl spaces and ducts in crawl spaces that were not insulated. All floors over crawl spaces and ducts should be insulated.

Most original heating, ventilating, and air-conditioning (HVAC) systems are probably oversized after any house shell, air infiltration, and duct improvements have been performed, and they were most likely initially oversized anyway. We found a newly revitalized house at Altus AFB with a new, oversized furnace. Replacement systems should be properly sized. A slightly undersized air-conditioning system is often more comfortable to occupants than an oversized system because it controls temperature and humidity more effectively due to longer run times. An oversized system costs more to buy, has a higher energy input demand, and costs more to operate because of increased losses associated with more system on-off cycling.

Efficient HVAC systems, especially air conditioners, should be installed at Altus AFB during revitalization. When existing furnaces are replaced at Altus, we do not necessarily recommend state-of-the-art condensing furnaces as replacements. Medium-efficiency (80% AFUE) furnaces may be more cost-effective replacements in the Altus climate, which has moderate winters. However, we believe that high-efficiency air conditioners are cost effective

at Altus because of the long and hot summers. A recently revitalized Altus house had such an HVAC combination, which we think is a good choice, but the furnace was oversized for the house. These recommendations should be checked out more closely because discounts from quantity purchases, any available utility incentives, and the savings from using plastic pipe for venting exhausts of condensing furnaces instead of building a conventional flue through the roof, may change the situation.

Malmstrom AFB currently has no central air conditioning, but it is being considered during revitalization. This should be considered very carefully because air conditioning is expensive to install and will only be used a few times during the summer. Whole-house fans may be a suitable and effective substitute for the Malmstrom climate. The potential safety hazards caused by the exit points of condensing furnace flues and supply pipes at Malmstrom should be looked into to see if a suitable and effective solution can be found. Perhaps a small wire fence around the area would suffice.

The boarded-up gable vents and covered soffit vents at Altus (to prevent water pipes from freezing in winter) do not provide enough venting to the attics for dissipation of moisture migrating there from the living area. The living area should be sealed from the attic to reduce moisture flow to the attic. Adding ridge vents and removing the sliding covers on soffit vents should be considered for all houses at Altus. The problem of freezing water pipes in winter should be readdressed. If windows are to be replaced, consideration should be given to installing energy-efficient double-pane windows with low-E glass and argon filling. However, single-pane windows with storm windows will suffice, and replacements cannot be justified on a cost-effectiveness basis.

Many cases of hot water delivery temperatures in excess of 145°F were found at all installations, as were shower flow rates of 5 to 6 gallons per minute (gpm). All hot water temperatures should be set to a maximum of 130°F, and inlet and exit water piping should be insulated to a distance of about 12–24 in. back from the water heater tank. Low-flow showerheads (2.25 gpm) should be installed in all houses. Low-flush toilets (1.7 gal per flush) should also be considered.

We found a potential safety problem at Altus AFB where gas-fired water heaters were located in garages inside sheet metal housings with poor-fitting sheet metal. Gas-fired water heaters in garages should be located 24 in. off the floor (or follow local building code guidelines) and away from flammable substances such as gasoline vapors.

We found no energy-efficient lighting at any installations. Energy-efficient lighting should be considered for all permanent wall and ceiling lighting fixtures. When the existing refrigerators are replaced, high-efficiency non-CFC (R134a refrigerant) replacements should be purchased. Replacement dishwashers should use low amounts of hot water in their cycles. Occupants should be made aware that efficient washing machines and dryers are available in the marketplace and urged to consider them when they purchase one.

NEAT RESULTS

Comparisons of NEAT pre-retrofit heating and cooling estimates with DEIS data (after adjusting the data with estimates for thermal and electric base load consumptions) suggest the following:

- Altus AFB heating and cooling DEIS data are high. Duct leakage could be a major cause of this.
- Malmstrom AFB heating DEIS data could be correct, but DEIS electric data may be slightly high.
- Fort Monmouth DEIS heating data are high, but electric consumption is correct.

NEAT suggested that there is still a great deal of energy (upwards of 20%) to be saved in the houses we inspected. These savings can probably be attained throughout the entire MFH spectrum, since many common problem areas exist. Smart thermostats for heating and additional insulation in attics, sill boxes, and basements are the most common cost-effective measures recommended by NEAT to save energy. Because NEAT does not currently address duct leakage, we expect that much more energy can be saved (up to 35%) by repairing duct leaks and by properly installing and sealing ducts to avoid leakage paths to attics and to the outside.

FAMILY HOUSING PLANS

The Family Housing Plans for Malmstrom and Altus (Fort Monmouth did not have one) were all-encompassing but tended to emphasize matching military square footage requirements with rank and family size, aesthetics, outside facilities, and landscaping. Energy efficiency is not ignored in the plans, but it is not stressed nearly as much as it should be.

The shortcomings of the Family Housing Plans in the energy-efficiency area and the findings from our inspections accentuate the need for a guidebook to promote energy efficiency. The guidebook will alert A&E firms to specify sources and installation methods of cost-effective measures that promote savings. It will show that not all energy-efficient measures are cost-effective for all situations.

1. INTRODUCTION

The military branches of the United States are in the process of upgrading their existing family housing through a revitalization process aimed at meeting the future needs of each respective service. They must also meet the goals of the National Energy Policy Act, including compliance with Executive Order 12579, requiring them to meet an initial reduction in total energy consumption intensity of 25% by the year 2000 compared to the reference year 1985.

Oak Ridge National Laboratory (ORNL) has demonstrated a high level of expertise in the field of energy efficiency in existing buildings and therefore is working with the U.S. Army and the U.S. Air Force to help them meet these goals in a cost-effective manner. We will develop guides for revitalization work and also for retrofit work that stress energy efficiency. Revitalization takes place when a housing unit is completely done over. Often the interior walls are removed and the floor plan is changed to add or delete bedrooms, enlarge or relocate kitchens, etc. Retrofit work does not involve major changes in floor plans but rather concentrates on adding insulation, upgrading furnaces and air-conditioners, replacing windows, and so on. Because the study is of significant national importance and provides an excellent opportunity to develop and field validate procedures that can be transferred to the private sector, the U.S. Department of Energy (DOE) is also a sponsor of the project. ORNL has enlisted the National Association of Home Builders (NAHB) Research Center to assist us in the project.

Most military installations have initiated various projects over the past 5 to 10 years that deal with energy efficiency and conservation. The projects vary from installing insulation and high-efficiency heating, ventilating, and air-conditioning (HVAC) equipment to remote microwave demand-reduction controllers for air-conditioners. Most of these projects are carried out when budget money is available, and as such, they are treated as separate entities without using a systematic approach. Including energy efficiency in the revitalization process allows the house to be looked at as a system, and a maximum impact of installed energy efficiency measures may be obtained.

Prior to this present project, ORNL and NAHB Research Center had visited Shaw Air Force Base (AFB) in Sumter, South Carolina, to determine if energy efficiency was adequately addressed in their Family Housing Community Plan developed by an architectural and engineering (A&E) firm for the Air Force.[1] The inspections done at Shaw on representative housing types showed that although some energy-efficiency was addressed, the measures were implemented in a manner that would obtain desired achievable savings. Design and construction flaws existed in the housing that reduced expected savings. It was recommended that a universal guidebook be written based on inspections of military housing, that addressed energy-efficiency implementation in revitalization and retrofit projects. The guidebook would be used by A&E firms during the design phase of a revitalization project.

The design guide would aid and advise the A&Es to select and specify measures in sufficient detail to obtain effective energy efficiency in a cost-effective manner.

The purpose of this report is to document the specific findings of family housing inspections made at three military bases, to identify common deficiencies in the various housing communities, and to provide substance for the writing of the design guide. A review of the Family Housing Community Plans of the locations we visited was done to determine those areas where energy efficiency is addressed, those where it is not, and any problems created by designs recommended in the plans.

2. PILOT AIR FORCE AND ARMY SITE SELECTIONS

The Air Force Housing Technical Branch identified for us five AFBs that were scheduled to perform family housing renovation in a time frame that would allow the 30% level of design to be achieved between September and December of 1993. This time frame was desirable so that we could inspect the housing on the bases, determine what deficiencies were present, and relate our recommendations to overcome the deficiencies to the A&E firm doing the design work. We would then be able to assess the impact of our input by a suitable monitoring program. The five bases were the U.S. Air Force (USAF) Academy, Colorado; Mountain Home, Idaho; Malmstrom, Montana; Altus, Oklahoma; and McChord, Washington.

Six Army installations were also identified by the Army Housing Facilities Division that were scheduled to perform family housing renovation in the same time frame (30% level of design achieved between September and December, 1993). These installations were Aberdeen Proving Ground, Maryland; Fort Campbell, Kentucky; Fort Lee, Virginia; Fort Monmouth, New Jersey; West Point Military Academy, New York; and White Sands Missile Range, New Mexico.

We examined the above sites with respect to geographic location, climate, HVAC system fuel and type, housing stock, and energy consumption. We had concerns as to whether or not the USAF Academy and the U.S. Military Academy have family housing that is representative of the other military sites, and finally decided not to consider the academies for inspection sites. We finally selected two AFBs—Malmstrom AFB in Great Falls, Montana, and Altus AFB in Altus, Oklahoma—and one Army installation, Fort Monmouth in Fort Monmouth, New Jersey, as pilot inspection sites for our study. Because we had conducted a family housing inspection at Shaw AFB in Sumter, South Carolina, we used it as a guideline reference for our selections. The 12 sites are plotted on a map of the United States in Fig. 2.1.

2.1 GEOGRAPHIC LOCATION

One factor that was important to us in selecting sites was geographic location because we wanted a well-rounded group that was representative of the United States. Our initial goal was to select a site from each region for inspection, provided significant differences existed between the regions. We therefore divided the continental United States into five regions (see Fig. 2.2): northeast, southeast, southwest, northwest, and the Pacific coast. The exact boundaries of these regions are somewhat arbitrary, but they were created after considering the following criteria and how they might differ among regions: housing type (slab, crawl space, and basement); fuel types; equipment (space-heating systems, distribution systems, water heating systems, etc.); and climate (heating and cooling loads).

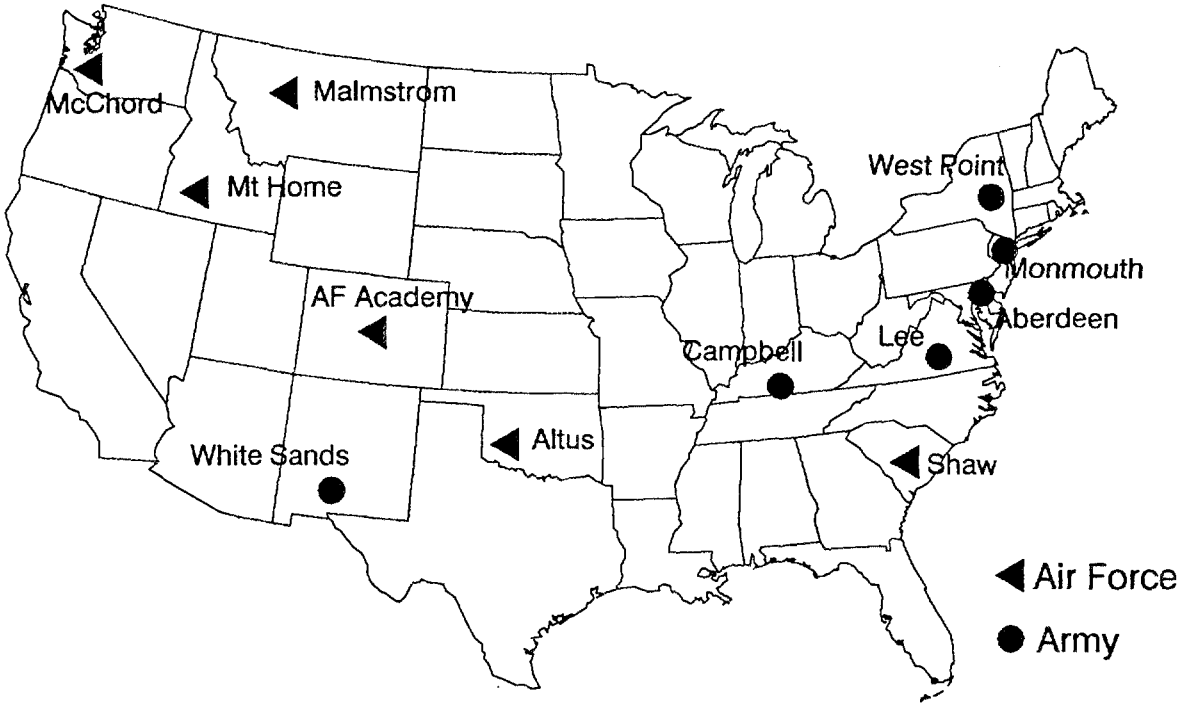

Fig. 2.1. Potential sites to inspect.

We decided that sites in the Pacific coast region would not be good choices for a pilot project involving energy savings because it generally has a temperate climate that leads to relatively low energy usage. McChord AFB is located in the Pacific region and was therefore dropped from consideration. We also realized that most AFBs are located in the northeast, southeast, and southwest regions, with few bases located in the northwest, and that most Army installations are located in the northeast, with relatively few located in the northwest or southwest.

As mentioned earlier, Shaw AFB had been inspected under a previous project. The results at Shaw could therefore be used to represent the southeast region, and no other sites from the southeast need be selected for housing inspections.

Altus AFB is located in the southwest, Malmstrom AFB is located in the northwest, and Fort Monmouth is located in the northeast. Therefore, our selections satisfied our geographic requirements.

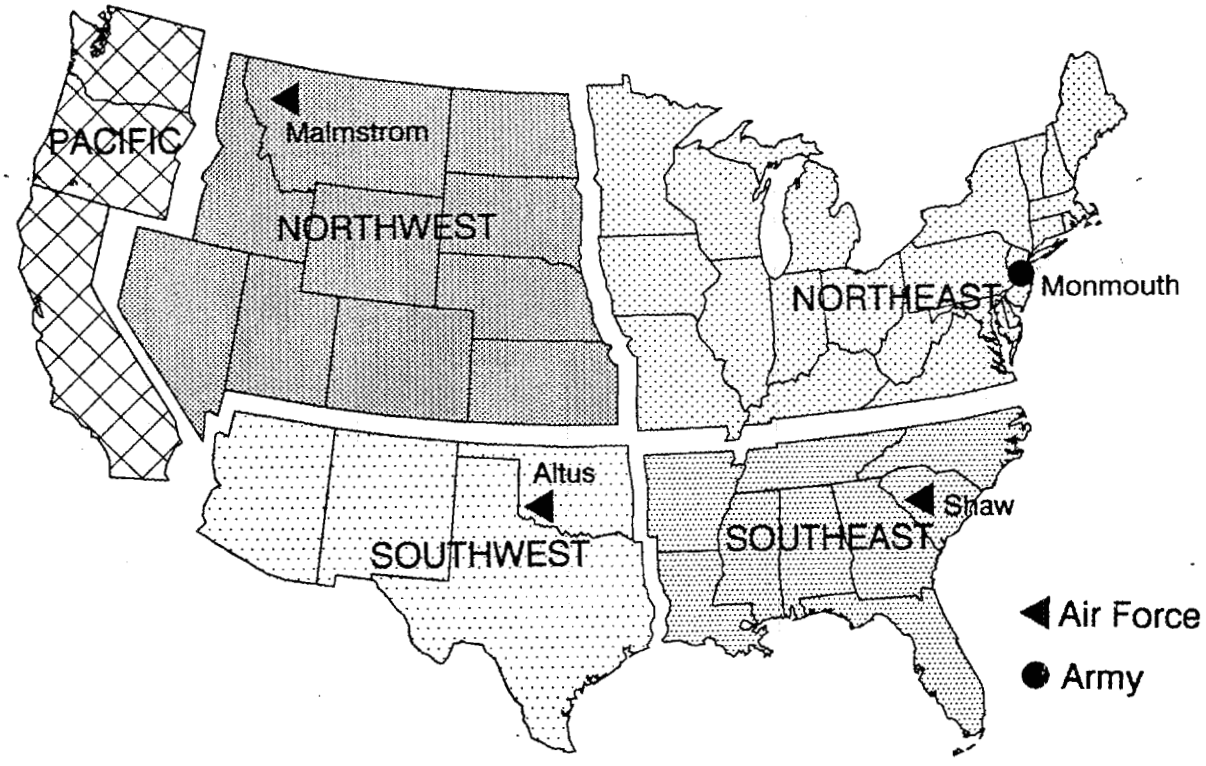

Fig. 2.2. Sites selected for inspections.

2.2 CLIMATE

The major Air Force and Army Sites [those identified on maps sent to us that also had consumption records in the Defense Energy Information System (DEIS) database] are plotted in Figs. 2.3 and 2.4, respectively, by their heating and cooling degree days. The candidate sites are individually identified in these figures. We wanted to obtain a good spread of weather conditions for the sites we selected, which means that one site should preferably have a relatively high cooling load, one or two sites should have both heating and cooling loads, and one site should have a high heating load.

Shaw AFB with 2500 heating degree days (HDDs) and 2000 cooling degree days (CDDs) is representative of the former. Altus AFB has a relatively high, but not extreme, number of cooling degree days (2347 CCDs), coupled with a moderate number of heating degree days (3346 HDDs). Malmstrom AFB has an extreme number of heating degree days (7671 HDDs) with very few cooling degree days. These bases satisfied our climate requirements in two desired categories.

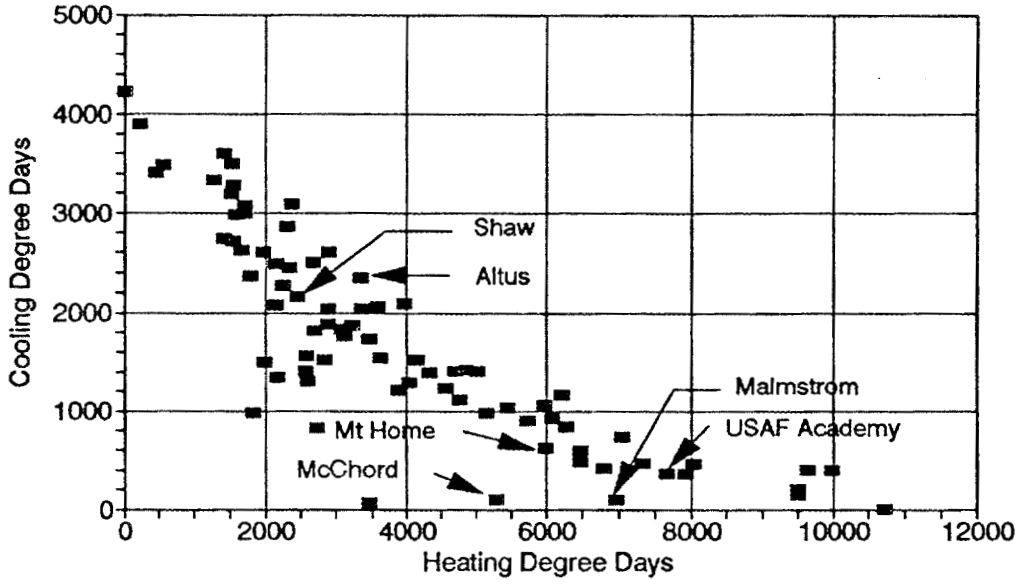

Fig. 2.3. Heating vs cooling degree days for major Air Force bases.

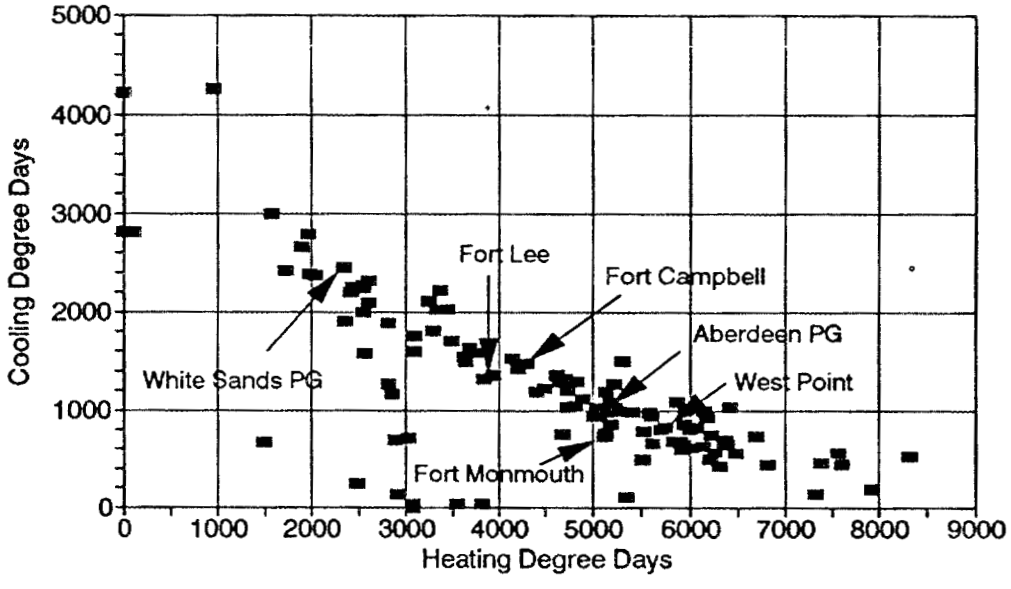

Fig. 2.4. Heating vs cooling degree days for major Army installations.

About 70% of the Army installations have 3000–7000 HDDs, while about 60% have 500–2000 CDDs. Fort Monmouth, with 5128 HDDs and 770 CDDs, is a good choice because it is representative of an average of Army installation, especially one located in the Northeast.

Of the other candidate locations, Mountain Home AFB, like Malmstrom AFB, is representative of the sites in the northwest region, Aberdeen Proving Ground is located about 100 miles southwest of Fort Monmouth and approximates its climate, and Fort Campbell and Fort Lee are close to the lower edge of the northeast region boundary and somewhat approximate Shaw AFB in climate.

2.3 ENERGY CONSUMPTION

The major AFBs and Army installations are plotted in Figs. 2.5 and 2.6 by heating degree days and their respective space-heating energy consumption intensity. All 12 candidate sites are individually identified in each figure. These data come from databases maintained by the Air Force at Tyndall AFB in Florida and by the Army at Fort Belvoir in Virginia and are known as Defense Energy Information System data.

Three general categories of energy consumption are provided in the DEIS data for family housing: total consumption, electricity consumption, and other fuel types energy consumption. In general, the sum of the electricity consumption and the consumptions for the other fuel types equals the total consumption for each site. We assumed for our work that the sum of the consumptions of the other fuel types (or, equivalently, total consumption minus electricity consumption) represents primarily space-heating energy consumption, with a certain amount of baseload consumption included for hot water, cooking, and the like. Similarly, we assumed that the electricity consumption represents air-conditioning consumption, with a significant amount of baseload included for hot water, cooking, and lighting.

This "space-heating" consumption, divided by the total floor area for the site family housing, is plotted in Figs. 2.5 and 2.6 as a function of heating degree days for the Air Force and Army installations, respectively. The average space-heating energy consumption intensity of private-sector housing is also plotted in Figs. 2.5 and 2.6 as a function of heating degree days by the solid line.[2] Sites that fall above this line have greater space-heating energy consumption intensities for family housing than private-sector housing. Thus, these sites are probably good candidates for energy improvements. Note that the solid line represents all private-sector housing, which includes both energy-efficient and inefficient houses. In general, the heating energy consumption intensity of Military Family Housing (MFH) appears to be about 5–10% higher on average than the private sector. This conclusion was reached after comparing a regression line for MFH (which has a poor R^2) to the private-sector line. Figures 2.7 and 2.8 contain plots of electrical energy consumption intensity vs cooling degree days for

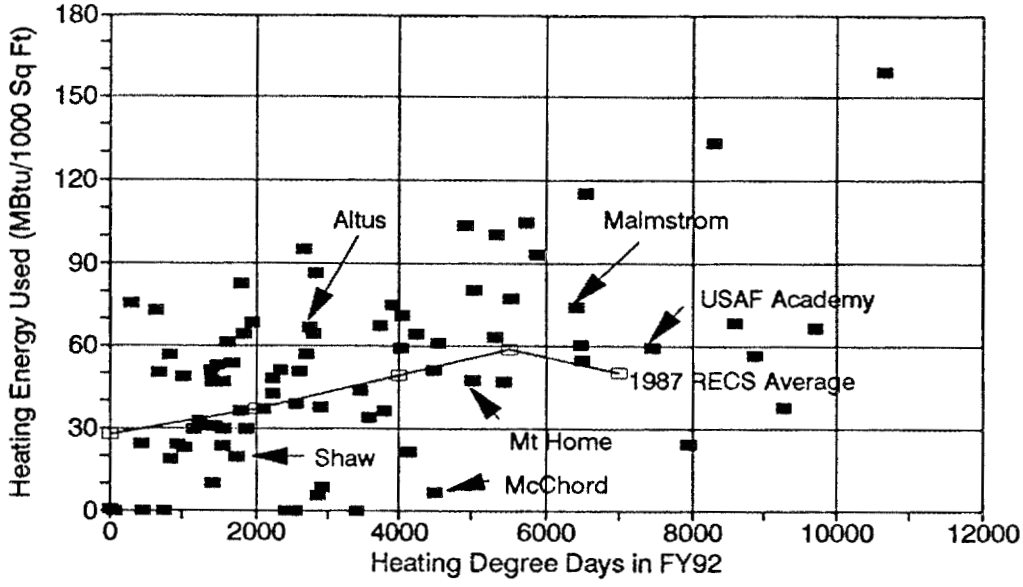

Fig. 2.5. Heating degree days in FY92 vs heating energy used for major Air Force bases.

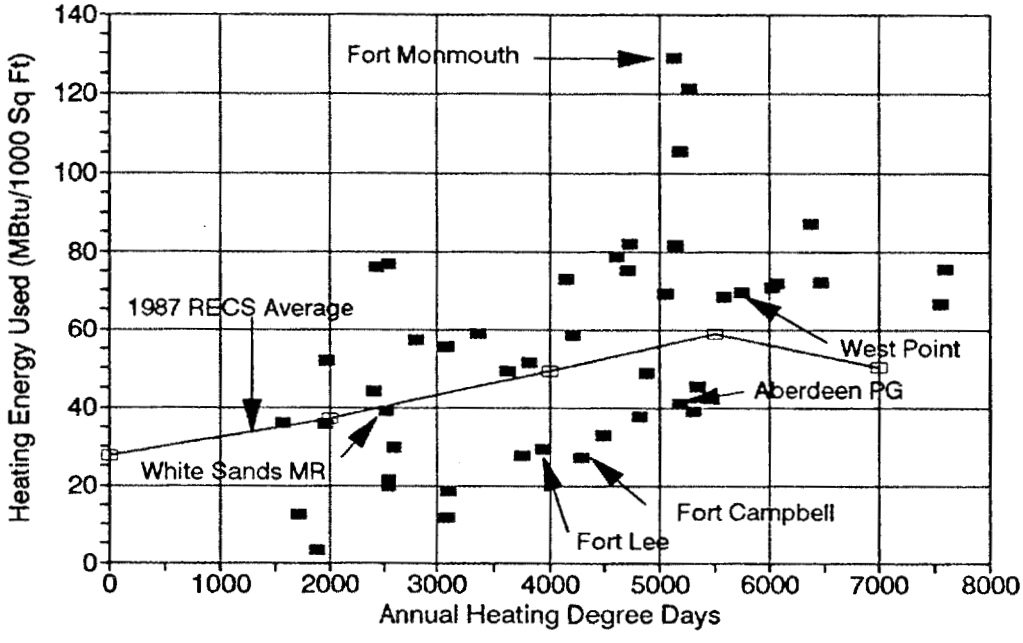

Fig. 2.6. Annual degree days vs heating energy used in FY92 for major Army installations.

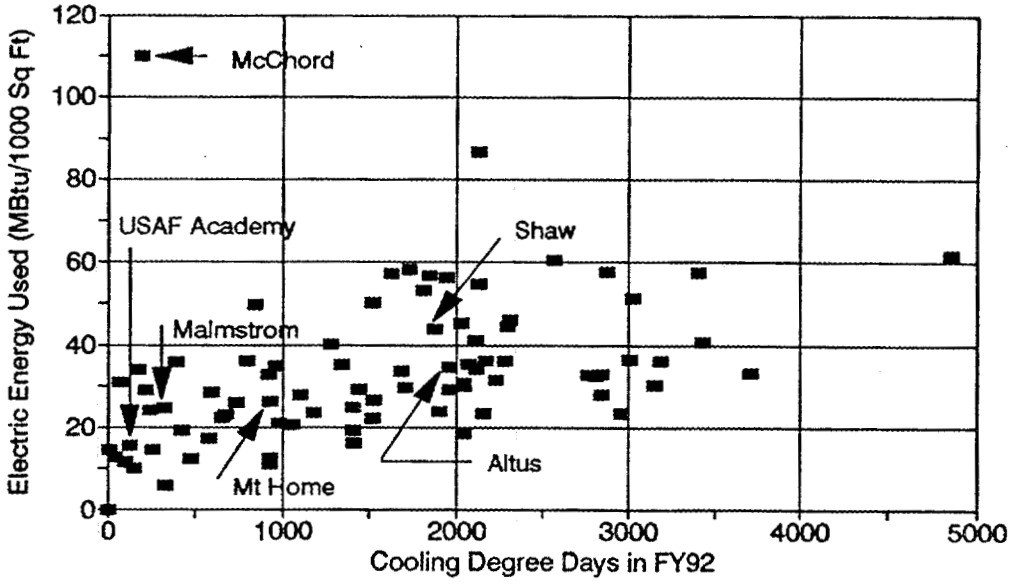

Fig. 2.7. Cooling degree days vs electric energy used in FY92 for major Air Force bases.

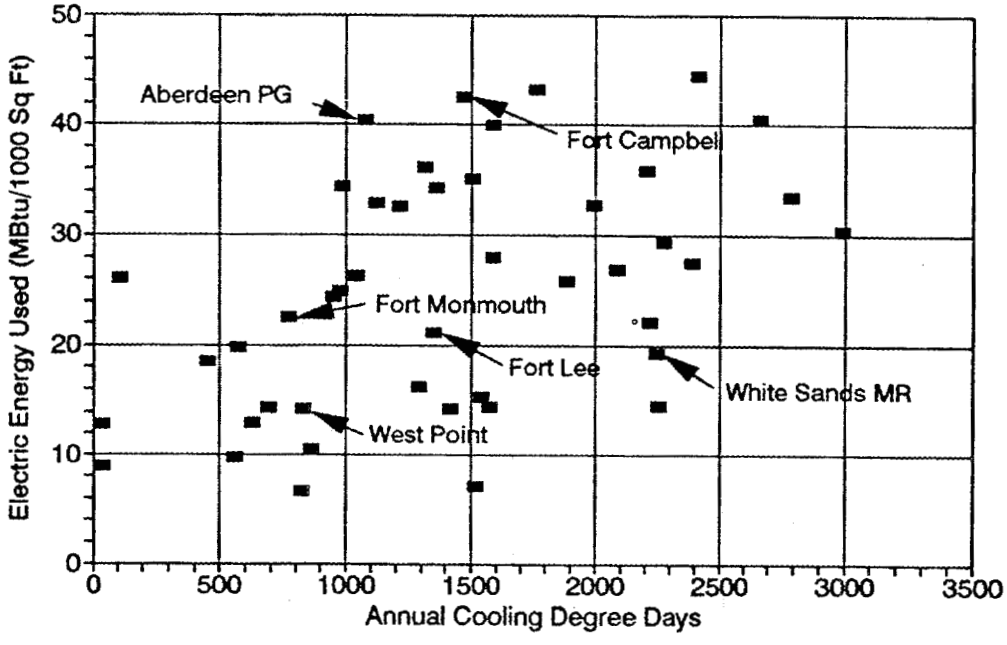

Fig. 2.8. Cooling degree days vs electric energy used in FY92 for major Army installations.

the Air Force and Army sites, respectively. Figures 2.9 and 2.10 show total energy consumption intensities (in 1985 and in 1992) for the five AFBs (and Shaw AFB also) and six Army installations considered as candidate locations for this study, respectively.

We must stress that our "definitions" of space-heating and air-conditioning consumptions are only approximate and are not applicable to some bases. McChord AFB, for example, uses electricity for heating, which makes it appear to be an outlier on Figs. 2.5 and 2.7. Sites falling on either of the axis on these figures or deviating significantly from the other sites may consume energy in forms that do not conform with our definitions.

Sites in the upper right quadrant of the main group in Figs. 2.5–2.8 are good candidates for this study because they have more extreme climates (higher heating or cooling degree days) and have higher energy consumption intensities than other sites including the private sector. Malmstrom AFB satisfies this requirement in Fig. 2.5, and Fort Monmouth satisfies it in Fig. 2.6. Fort Monmouth was the obvious choice for the northeast sector based on its climate and extremely high reported energy consumption intensity.

Altus AFB is the only base of the five Air Force candidates that is close to the upper right quadrant of Fig. 2.7, bases with high cooling degree days and high electricity consumptions. Altus AFB was not an ideal selection on this basis, though, because many AFBs have hotter summers (more cooling degree days), and its electric consumption intensity is just average for bases experiencing about 2000 CDD.

2.4 SITE SELECTION SUMMARY

After reviewing the climates and energy consumption intensities of five AFBs and six Army installations that were planning military family housing revitalization work within the framework of our study, we concluded that Altus AFB, Oklahoma; Malmstrom AFB, Montana; and Fort Monmouth, New Jersey, were our best choices for inspection sites. Altus and Malmstrom AFBs have high reported heating energy consumption intensities for their climates. Fort Monmouth has an extremely high reported energy usage intensity and complements (geographically) the two AFBs, Altus and Malmstrom (see Fig. 2.2).

We did not consider the USAF Academy or the West Point Military Academy for inspection sites because we thought that their family housing was not representative of the other military installations. We decided not to inspect McChord AFB because it is located in the temperate Pacific coast region. Forts Lee and Campbell were not chosen because their climates were similar to Shaw AFB. Aberdeen Proving Ground was not selected because of its proximity to Fort Monmouth, a very high energy user. Mountain Home AFB and White Sands Proving Grounds were not chosen because of their closeness to Malmstrom AFB and Altus AFB, respectively.

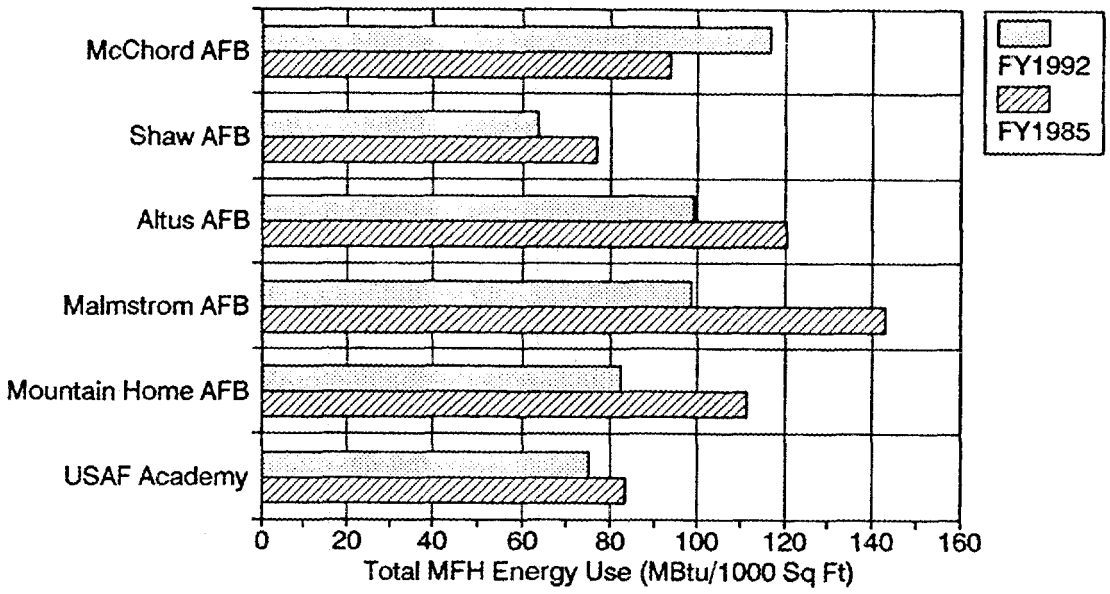

Fig. 2.9. U.S. Air Force family housing consumptions of potential bases to inspect.

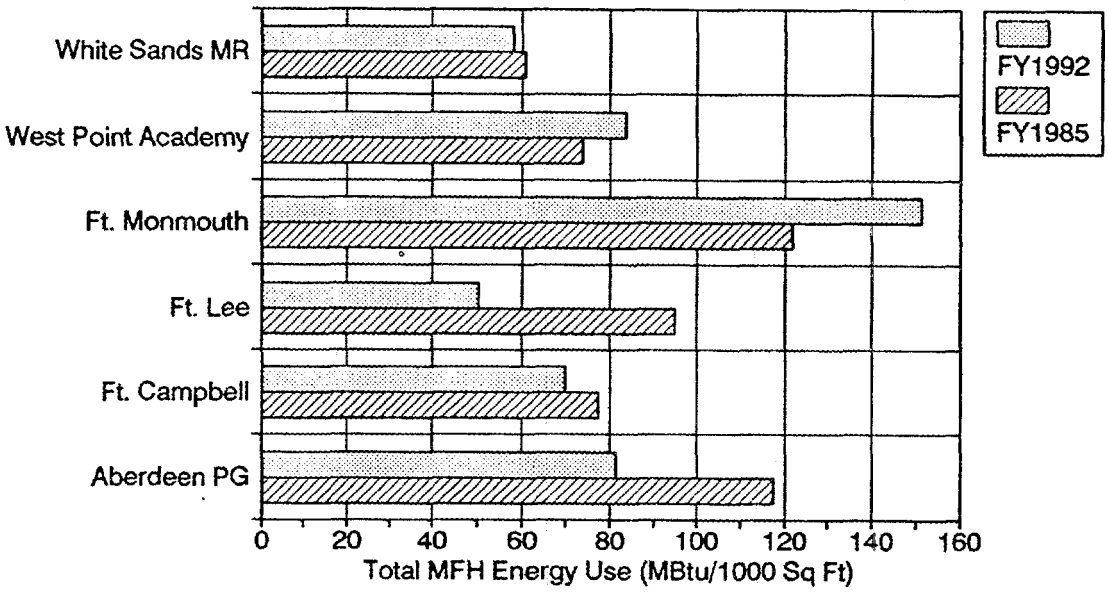

Fig. 2.10. U.S. Army family housing energy consumptions of potential installations to inspect.

3. DEIS DATA ANALYSIS

The Defense Energy Information System is an annual (fiscal year basis) database maintained by each branch of the military that describes the physical parameters of each installation (e.g., number and floor area of the buildings) and its energy consumption by end use (industrial or family housing) and type of energy (electrical or thermal). The energy coordinators for each installation typically send a monthly summary of the energy usage from their installations to the proper headquarters location (either Tyndall AFB, Florida, or Fort Belvoir, Virginia). Annual heating and cooling degree day data for each installation are available for the Air Force. The Army did not have heating and cooling degree day data for most of its locations but is in the process of retroactively obtaining these data.

DEIS data are important because they are the prime reference for the energy used by each service installation. Each service has been mandated by Congress in the Energy Policy Act to reduce its total building energy consumption (on a square-foot basis) relative to the year 1985; 20% by 1995, 25% by 2000, and 30% by 2005. DEIS data are a primary source for the consumption estimates of each site and will also be used in the guidebook being developed to determine the relative need for efficiency improvements and to compare to a target consumption value. There is a definite need to know just how good DEIS data are.

A potential shortcoming of comparing DEIS data between different years is that the DEIS data are not normalized for weather differences (such as heating and cooling degree days) for given years. Warm winters and cool summers can reduce energy consumptions significantly, so that whether a given year was warm or cold compared to the 1985 reference year could either mask or amplify any energy savings associated with energy-efficiency measures undertaken (or not undertaken) at an installation.

Also, electricity is measured as consumed on site and does not include a power plant generation factor (usually about 30% of the energy input to an electric generating plant arrives at a home as electricity). A site could switch from gas to electric resistance heat and reduce its heating energy consumption by a factor of 3, although its heating costs would most likely increase significantly.

Tables A.1 and A.2 in Appendix A contain a summary of Air Force DEIS data for most major bases for 1985 and 1992, while Tables A.3, A.4, and A.5 contain essentially the same data for most major Army installations. We stated earlier that MFH heating energy consumption intensity (based on DEIS data) appears to be about 5–10% higher than that of the private sector [based on 1987 Residential Energy Consumption Survey (RECS) data].

The Army is instituting an Energy Use Budget (EUB) to be used as the energy use standard for all new MFH construction. The EUB defines 11 weather regions using heating and cooling degree day boundaries and proposes an annual total energy intensity usage [in MBtu/(kSF · year)] for new MFH construction. Table 3.1 lists the proposed values for the EUB for each weather region and defines the regions. Tables 3.2 and 3.3 contain DEIS data and the proposed EUB for each of the five Air Force bases (and Shaw AFB) and six Army

Table 3.1. Proposed military family housing total energy use budget for new construction

Region	Cooling degree days	Heating degree days		Proposed usage[a] (MBtu/kSF/year)
		Minimum	Maximum	
1	---	15000	---	70
2	---	13000	15000	65
3	---	11000	13000	60
4	<2000	9000	11000	55
5	<2000	7000	9000	55
6	<2000	5500	7000	45
7	<2000	4000	5500	45
8	<2000	2000	4000	45
9	<2000	---	2000	40
10	>2000	---	2000	50
11	>2000	>2000	---	55

[a]Proposed by U.S. Department of Defense and revised in September 1992.

Table 3.2. DEIS energy use data for potential Air Force base inspection sites

Air Force Base	State	AFM 88-29 Data[a]		Number MFH[b] Bldgs.	Area (kSF)	DEIS Reported MFH Energy Usage (MBtu/kSF/year)						DOD New MFH Goal Total Use
		Heat DD	Cool DD			Total 85	Total 92	Heat 85	Heat 92	Elec 85	Elec 92	
USAF Academy	CO	6973	100	---	2345	83.53	74.94	70.15	59.38	13.37	15.55	45
Mountain Home	ID	5732	907	---	2187	111.36	82.29	79.39	47.31	31.97	34.97	45
Malmstrom	MT	7671	370	---	2115	143.19	98.46	120.46	73.88	22.72	24.58	55
Altus	OK	3346	2347	---	1110	120.45	98.98	77.76	64.28	42.69	34.69	55
Shaw	SC	2453	2160	---	2464	76.79	63.55	30.25	19.66	46.54	43.89	55
McChord	WA	5287	94	---	1212	93.81	116.64	23.64	6.54	70.17	110.09	45

[a]Degree day.
[b]Military family housing.

Table 3.3. DEIS energy use data for potential Army installation inspection sites

Army Base	State	AFM 88-29 Data[a]		Number MFH[b] Bldgs.	Area (kSF)	DEIS Reported MFH Energy Usage (MBtu/kSF/year)						DOD New MFH Goal Total Use
		Heat DD	Cool DD			Total 85	Total 92	Heat 85	Heat 92	Elec 85	Elec 92	
Aberdeen PG	MD	5184	1076	400	1876	117.51	81.27	96.36	40.88	21.16	40.39	45
Ft. Campbell	KY	4290	1472	1631	5991	77.26	69.71	30.66	27.19	46.60	42.51	45
Ft. Lee	VA	3939	1353	471	2120	94.81	50.39	57.34	29.33	37.47	21.06	45
Ft. Monmouth	NJ	5128	770	228	1646	121.85	151.50	98.65	128.96	23.20	22.54	45
West Point	NY	5753	830	632	3276	73.58	83.67	60.09	69.43	13.49	14.24	45
White Sands MR	NM	2526	2243	898	1252	61.02	58.27	42.87	39.04	18.16	19.23	55

[a]Degree day.
[b]Military family housing.

installations, respectively, considered for inspections for this work. None of the twelve bases meets the proposed EUB (which, as noted, is for new construction), but three (Shaw AFB, Fort Lee, and White Sands Missile Range) came quite close to the proposed values during FY 1992.*

One task carried out at each installation we inspected was to review the DEIS data with the energy coordinator of that location. The purpose of this was to determine if the DEIS data are sufficiently accurate to reflect the current energy consumption of the family housing. A summary of our findings follows.

3.1 MALMSTROM AFB

Malmstrom AFB is located in Great Falls, Montana, about 40 miles east of the Rocky Mountains. It averages 7671 HDDs and 370 CDDs.[3] This climate provides a high heating load for the housing at Malmstrom but relatively little cooling. DEIS data from Table 3.2 show Malmstrom reported 98 MBtu/kSF total energy usage for 1992 compared to 143 MBtu/kSF in 1985. This reduction of 31% implies that a great deal of energy-efficiency work must have gone on at Malmstrom. However, the EUB for Malmstrom is 55 MBtu/kSF, about half of the 1992 usage. We felt that the reported DEIS data for Malmstrom was too high after we had inspected several houses. The housing at Malmstrom seemed to be in too good of a shape from an energy viewpoint to explain such high values.

We uncovered two reasons for the high values at Malmstrom: the method used to estimate MFH usage and the inclusion of the base hospital consumption in the MFH data. Some apparently outdated assumptions were being used to estimate MFH natural gas use from a single meter that recorded the total base gas usage. Two additional gas meters that essentially measured MFH usage were found at the main gas entrance point to the base. Although both meters are read on a regular basis, the data were not being utilized to determine MFH usage. One of the meters appeared to be damaged because its reading did not change. When it was removed for repair and recalibration, a shutoff valve on one side of the meter was found to be closed. We expect that when these two newly calibrated meters are used for determining consumption, future MFH DEIS data from Malmstrom will show much lower MFH usage than has previously been reported. Current MFH data from Malmstrom also include the base hospital use and MFH usage from nearby small extension stations at Havre and Conrad. These data will soon be excluded from Malmstrom MFH data.

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*The proposed EUB values appear to be reasonable, at least for Region 8. A check of the total energy usage (electric and gas bills) for the author's 2400 ft^2 home that was built in 1978 and is located in Oak Ridge, Tennessee, showed that the house has averaged 43.6 MBtu/(kSF · year) over the years. This is just below the 45 MBtu/kSF EUB annual value for the region. No unusual attempts were made in this house to make it an energy miser, and two children grew up in it.

3.2 ALTUS AFB

Altus AFB is located in Altus, a small town in the southwest corner of Oklahoma. It averages 3346 HDDs and 2347 CDDs annually.[3] The climate at Altus provides a rather high cooling load but a moderate heating load. DEIS data from Table 3.2 show total energy consumptions of 120 MBtu/kSF for 1985 and 100 MBtu/kSF for 1992, for a reduction of 17%. These total energy MFH data seem too high when they are compared to the EUB for an Altus-type climate of 55 MBtu/kSF, which is about half that of the present consumption. A closer look at Table 3.2 shows that the energy used for heating appears high, while the electrical usage is more reasonable. Figure 2.5 shows Altus as having a high heating energy consumption relative to other AFBs, with about 3000 annual heating degree days. Figure 2.7 shows that the energy used for cooling is about average for Air Force bases with around 2000 annual CDDs.

An inspection of the meters used to monitor MFH gas and electric consumptions showed that the electric and gas meters appeared to be in the proper locations to read MFH consumptions. Also, the meters were on a calibration schedule and had been calibrated in June 1993. Therefore, we concluded that the DEIS data for the MFH sector at Altus were correct.

3.3 FORT MONMOUTH

Fort Monmouth is located near Eatontown, New Jersey, about 30 miles southeast of Newark and very close to the ocean. It averages 5128 HDDs and 770 CDDs annually.[3] Such a climate provides a moderate heating load and a mild cooling load for the housing. DEIS data in Table 3.3 show that the total energy consumption at Monmouth was 122 MBtu/kSF in 1985 and 151 MBtu/kSF in 1992, an increase of 24%. Not only are these data heading in the wrong direction, but they appear to be much too high, especially the heating part of the consumption. The EUB for Fort Monmouth is 45 MBtu/kSF, which is a third of present reported consumption. Fort Monmouth uses fuel oil for heating its on-post housing and natural gas for heating its off-post housing.

We were quite sure that something was wrong with the reported DEIS data at Fort Monmouth because it was so high. We discussed our concerns with the energy coordinator there. These discussions resulted in the discovery that fuel-oil consumption for family housing was being overestimated in order to get the DEIS data report to Fort Belvoir on time each month. Fort Monmouth had been estimating that 35% of the total fuel-oil consumption for the base was used by the family housing sector because MFH delivery data were not received in time to be included with the monthly DEIS report. Actual family housing fuel-oil consumption was substantially lower when delivery data were incorporated into the monthly totals, and MFH total energy consumption fell by 32% after the corrections were made. As a result of

this exercise, estimated data will be reviewed and corrected using actual delivery data, and the DEIS data will be updated. However, even with a 32% reduction, total energy consumption at Fort Monmouth is still too high.

3.4 DEIS ANALYSIS SUMMARY

We estimated that MFH consumes about 5–10% more energy on a square foot basis than the private sector when reported DEIS data are compared to 1987 RECS data. However, inconsistencies were found in the DEIS data for two of the three sites that we visited. We feel that the overall DEIS data for energy use at each base are accurate, but that the reported portions for family housing may not be sufficiently accurate to provide useful information about the present energy efficiency of housing units.

A database containing accurate energy consumption for the MFH sector at each military installation is necessary in order to make correct decisions regarding the implementation of projects designed to conserve energy in that sector. The accuracy of reported MFH consumption data at each installation can be evaluated from the ground up by implementing a review process that (1) determines how raw data are collected; (2) ensures that the appropriate meters are recording only the consumptions of the buildings or areas that they are supposed to be recording; (3) physically inspects the meters; (4) determines when the meters were last calibrated and verifies that they are on a regular calibration schedule; and (5) reviews how the data are processed (what assumptions are made and who does the data reduction) to develop the monthly report sent to the appropriate headquarters. Such reviews will ensure that the MFH consumption at each base is accurate and that the data gathering and reporting process is up to date and understood by all concerned.

4. ON-SITE INSPECTIONS OF MILITARY FAMILY HOUSING

We made in-depth inspections at two AFBs and one Army installation. We had also made a similar inspection at Shaw AFB prior to this study. Each house inspection took a team of three or four experienced inspectors about four hours to accomplish. The inspectors spent five days at each site and inspected a total of eight to ten houses. Appendix B contains the forms that were used on each house during the inspections.

4.1 INSPECTION OVERVIEW

4.1.1 House Survey

The house survey consisted of measuring and recording the physical dimensions of each inspected house, its windows and doors, and insulation levels in sufficient detail to determine energy flows and inefficiencies and to be able to model the house with a computer audit or energy load calculation program such as National Energy Audit (NEAT), Energy Economics of Design Options (EEDO), or DOE-2. In this manner, savings brought about by various retrofits could be predicted and the economics of recommended measures estimated.

4.1.2 Air-Leakage Measurements

We used a blower door to measure the air-leakage rate of each house to locate the major sources of leakage in each house. Air leakage increases heating and cooling loads and makes a house feel drafty and uncomfortable.

4.1.3 House Heating and Cooling Systems

Steady-state efficiencies were measured on heating systems to determine current operating conditions. The results of these tests were also used in our modeling effort. Settings of limit switches were checked to investigate optimum efficiency and safety settings. Flue gases were analyzed for carbon monoxide concentrations, which affect efficiency as well as safety. Flues were checked for structural integrity and functionality.

Air-conditioners were checked for refrigerant leaks and overall functionality. Outdoor condensing units were checked for siting location and heat-exchanger fin damage and blockage.

4.1.4 Distribution Systems

Forced-air distribution systems were checked for duct leakage using the blower door and a "Duct Blaster" (a specialized calibrated fan designed for this purpose) where necessary.* Ducts were inspected manually for insulation levels, for joint and structural integrity, and to locate major leakage areas. Duct leakage can be a very common problem in the private sector. Duct leakage in the supply side deposits conditioned air where it is not meant to go (sometimes in attics or crawl spaces). Duct leakage in the return side draws return air from attics, crawl spaces, the outside, and other unconditioned spaces for conditioning before supplying it to the house. Heating and cooling loads are therefore much higher than expected because of the extra energy consumed by the HVAC system to condition its "lower quality" inlet air.

Airflows were measured in return-air ducts of forced-air systems to ensure that sufficient air was being returned from the living space to the HVAC system. Air filters were checked for cleanliness to ensure that they were not blocking return air transport effectiveness, which can aggravate attic and other internal bypasses.

Houses with hydronic systems were checked to be sure that circulating pumps and zone valves were functional.

4.1.5 Infrared Scans

Houses underwent a scan with an infrared camera to identify any voids or unusual leaks in wall or attic insulation. Some duct leaks can be detected during the scan. The camera was also used in conjunction with the blower door to help identify air-leakage paths.

4.1.6 Safety Inspections

Safety inspections were performed to identify any problems that must be taken care of before any efficiency work is done. Much of the inspection was visual; a walk around the house, basement, attic, and garage was performed to search out potential problems.

House heating and cooling systems were inspected visually and with instruments to determine whether they were in safe operating condition, which quite often is also tied into efficient operation. The inspections involved visually checking for safety problems involving the electrical wiring, fuel-line plumbing, cutout switch settings, the presence of asbestos, components that were not functioning, flue and chimney integrity, and the presence of combustibles near the systems. Instruments were used to check for properly functioning flues (no backdrafts or leaks), carbon monoxide levels in flue gases, and the presence of carbon monoxide in the house.

*"Duct Blaster" is a trademark of The Energy Conservatory, Minneapolis, Minnesota.

Most of the water heaters we inspected were gas-fired, and they were inspected in the same manner as a gas-fired house heating system. Hot water delivery temperatures were measured and tank thermostats reset to 130°F if they were found to be set much higher. Gas heaters located in garages were carefully checked because they can be especially dangerous if precautions are not taken to keep pilot and burner flames out of the reach of gasoline and any other flammable chemicals stored nearby.

The house electrical system was inspected to be sure that ground wires in outlets were at ground potential, that the wiring was adequate, and that line voltage was proper.

4.1.7 Photographs

We documented problems that we found (and some solutions to problems that had been implemented) by photographing them with a still camera.

4.2 MALMSTROM AFB

A physical inspection of MFH at Malmstrom AFB, Great Falls, Montana, was conducted during May 17–21, 1993. The housing at Malmstrom is divided into six major groupings; these are shown in Table 4.1, along with additional housing information. The 544 buildings included have a total area of 1.679 million ft^2.

Table 4.1. Characteristics of housing at Malmstrom AFB

Housing group	No. of buildings	No. of units	Year built	Type of housing
On-base Capehart	76	150	1959	Duplex/single
Off-base Capehart	281	560	1949	Duplex
Lincoln Drive Wherry	43	400	1951	Multi
Malmstrom Drive Wherry	40	92	1949	Multi
Relocatable	100	200	1965	Duplex
Washington Circle	4	4	1960	Single
Totals	544	1406		

All space-heating systems at Malmstrom are forced-air gas-fired units, and all domestic hot water is heated with gas. There is no whole-house air-conditioning at Malmstrom, but it is being considered as an option in the revitalization process.

Measured data were taken in seven unoccupied units and one occupied unit during the week. We inspected two on-base Capeharts, two off-base Capeharts, one Lincoln Drive Wherry, two Malmstrom Drive Wherrys, and one relocatable. The types of houses we inspected were representative of almost all the housing types at Malmstrom. About a dozen other units were visually inspected while they were being repaired by contractor work crews.

Most houses are attractive and kept up very well. A great deal of energy-efficiency work has already been done to the base housing, such as adding attic and exterior wall insulation and steel siding and installing new high-efficiency furnaces. The revitalization process at Malmstrom should not have to address too many major energy-efficiency problems.

Insulation levels appear adequate in the nonbasement walls and in the attics of the Capeharts and the Wherrys. However, all Capehart houses have essentially heated basements containing ducts and water lines, and the basement walls are uninsulated. Losses from the basement walls, especially from the above-ground sections, and the uninsulated band joists are substantial. This means that the thermal boundary of these houses is not defined properly. The heated basements increase the total heated area of the thermal envelope and cause inconsistencies with reported DEIS data (the reported DEIS heated area is less than the actual heated area, so the reported energy intensity is higher than actual). The basements have a supply-air register but no return-air register. The lack of a return-air register causes the basements to be at a higher pressure than the rest of the house and the outside air when the furnace is operating. This increases infiltration losses.

One off-base Capehart had a foundation consisting of a partial basement and partial crawl space. Neither the crawl-space floor nor the ducts in the crawl space were insulated, and large gaps were present in the block walls separating the conditioned basement from the unconditioned crawl space where ducts passed through.

The relocatables could use more insulation. They have an enclosed duct and plumbing space under the floor and an unusual attic configuration that is caused by cathedral ceilings; both of these severely limit the amount of insulation that can be installed.

Most of the houses are sufficiently airtight (see Table 5.1). Only one had a blower-door air leakage over 2000 cfm50 (an air leakage rate of 1500–1800 cfm50 is usually considered tight). However, the Malmstrom Drive units were drafty. The occupants had many complaints about drafts, which led to the installation of new outside steel siding over rigid insulation board. Most complaints have subsided, but some outside air was still entering under the exterior siding and exiting from cracks or spaces in the tongue-and-groove wood paneling inside the house. Also, cutouts for piping, wiring, and duct passages through walls were often sealed inadequately, if at all. These factors form bypasses to the outside and to the attic and create drafts.

Significant duct leakage (> 200 cfm50) was found in all the Capehart houses we inspected (see Table 5.1). One supply leak was caused when an improperly nailed duct support strap in the

crawl space came loose from the joist and caused a supply-duct joint to fail (the nail was hammered into the bottom of the joist rather than to the side). This resulted in heated air being blown into the crawl space, which is a waste of energy. Because of its location, this particular leak was difficult to find even with our instrumentation and persistence.

The housing structure in the Capehart units was used as part of the return air duct system. This generally bad practice caused air bypasses to the attic, especially in one on-base Capehart where makeshift air filters (rolled-up fiberglass bats) located in the opening return passage under a closet seriously blocked the return airflow and opened a severe attic bypass via an interior wall at the rear of the closet. Figures 4.1 and 4.2 illustrate the location of the clogged opening and the source of attic air above the closet, respectively.

The gas furnaces are efficient. State-of-the-art high-efficiency condensing furnaces have been installed in the Capeharts, and replacement furnaces are planned for the Wherrys. Carbon monoxide levels were sufficiently low in water heaters and furnaces, except for one pulse combustion furnace that was emitting 88 ppm in its flue gas, a factor of 3 too high. The exhaust and combustion air plastic piping for basement furnaces exited the houses at a height of about two feet from the ground, making them accessible to children and blockage by drifting snow. Figure 4.3 shows an example of this common problem.

All domestic hot water heaters looked relatively new and operated well. We found dangerous hot water temperatures (greater than 150°F) coming from the faucets in several houses. Besides being dangerous, especially to children, water that is too hot wastes energy by increasing storage-tank and pipe losses. Low-flow showerheads (2.25 gpm or less) were not found in all units. Much energy ends up going down the drain with the combination of water that is too hot and flow rates that are too high.

Energy-efficient lighting was not present in any of the houses we inspected. Most of the refrigerators were about 10 years old and not as efficient as current models. The refrigerators are the most energy-using electric appliances in the houses at Malmstrom, typically using about 1200–1500 kWh annually. Newer models with the same capacity use about 800–1000 kWh annually.

4.3 ALTUS AFB

The family housing at Altus AFB, Oklahoma, was inspected during June 14–18, 1993. The housing at Altus is divided into two major groupings, shown in Table 4.2. All housing is slab-on-grade, and the total area is 1.11 million ft^2.

Fig. 4.1. Return air supply under closet.

Table 4.2. Characteristics of housing at Altus AFB

Housing group	No. of buildings	No. of units	Year built	Type of housing
On-base Capehart	665	700	1950s	630 Single 35 Duplex
Off-base Bicentennial	50	100	1977	Duplex
Totals	715	800		

Fig. 4.2. Attic bypass above closet shown in Fig. 4.1.

Measured data were taken in seven unoccupied and four occupied units over the course of the week. We inspected nine on-base Capeharts and two off-base Bicentennials. Our inspections covered housing types (floor plans) similar to 574 of the 800 housing units at Altus.

The houses were adequately maintained, and insulation levels generally appear adequate. However, repair work on furnaces and water pipes located in attics resulted in the existing insulation being randomly strewn about the attics of many houses. The insulation was not replaced properly or evenly. An example of this situation is shown in Fig. 4.4.

Attic venting was inadequate to vent moisture coming from the living area in winter. Attics should be sealed from the living area to reduce the flow of moisture. Some gable vents were "boarded" shut, as shown in Fig. 4.5. Occupants were advised to close slidingpanels over soffit vents in winter (to prevent water pipes located in attics from freezing) and to open them in summer. Often, the panels were not moved because they were stuck after being painted, because residents neglected to move them, or because they were also boarded shut. The panels

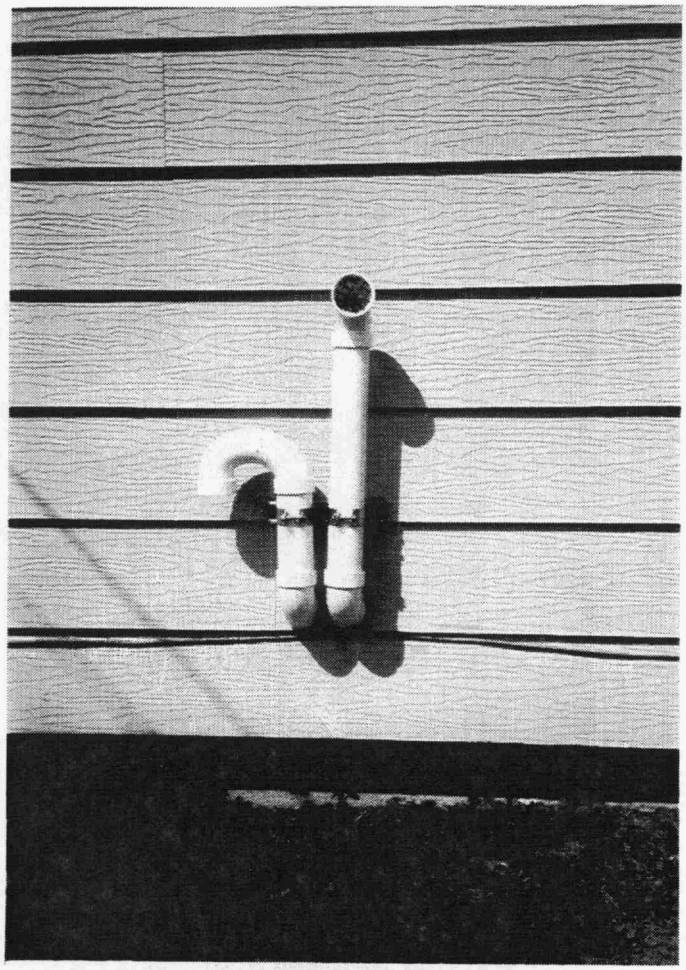

Fig. 4.3. Supply air to and exhaust air from condensing furnace.

should be removed and fixed soffit vents installed. Fiberglass insulation batts extended over the eaves on most houses and blocked off the soffit vents, as shown in Fig. 4.6.

The houses are adequately air-tight, except for duct leaks (see Table 5.1). Cutouts for piping, wiring, and duct passages through ceilings were often sealed inadequately, if at all. When combined with improperly sealed plumbing and duct chaseways and pocket doors, these practices open air paths through interior walls to the outside and to attics. Figures 4.7 and 4.8 illustrate this situation.

Significant duct leakage was found in most houses. Several cases of inadequately sealed/constructed return-air systems were found. Whenever the house structure (such as part of an interior wall) is used as part of the distribution system, access to attic air and its accompanying inefficiencies often result. Return-air systems in particular are susceptible to drawing in "energy-hungry" air from the attic because of poor design/construction or improper or nonlasting sealing techniques in the plenum. Dirty air filters at a return register (another common finding) amplify this problem because the increased pressure drop they present makes the energy-hungry attic air even more accessible.

Fig. 4.4. Attic insulation not replaced after repair work on water pipes.

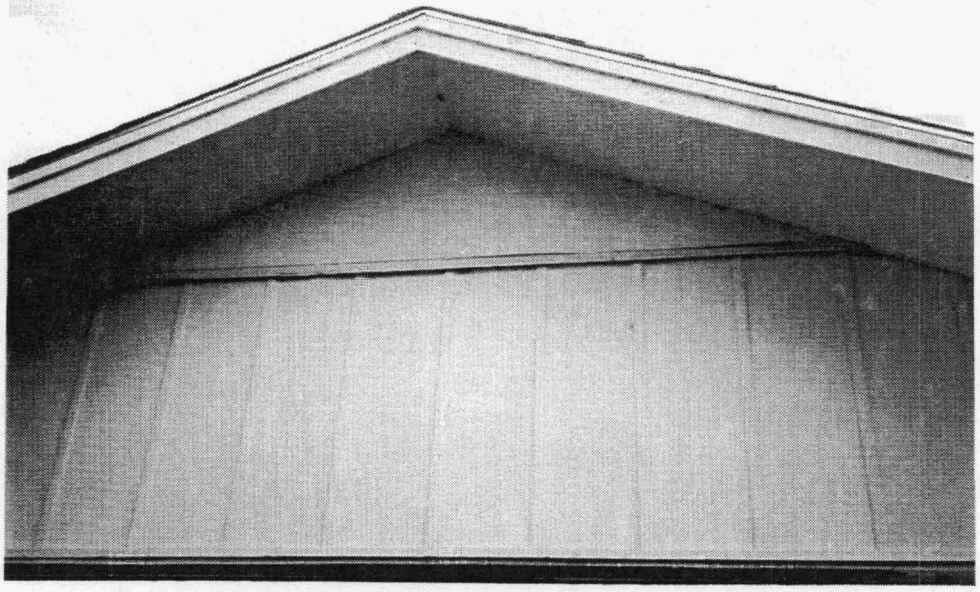

Fig. 4.5. Sealed off gable vent.

Fig. 4.6. Insulation covering soffit vents in attic.

Fig. 4.7. Access to outside air from refrigerant line entry.

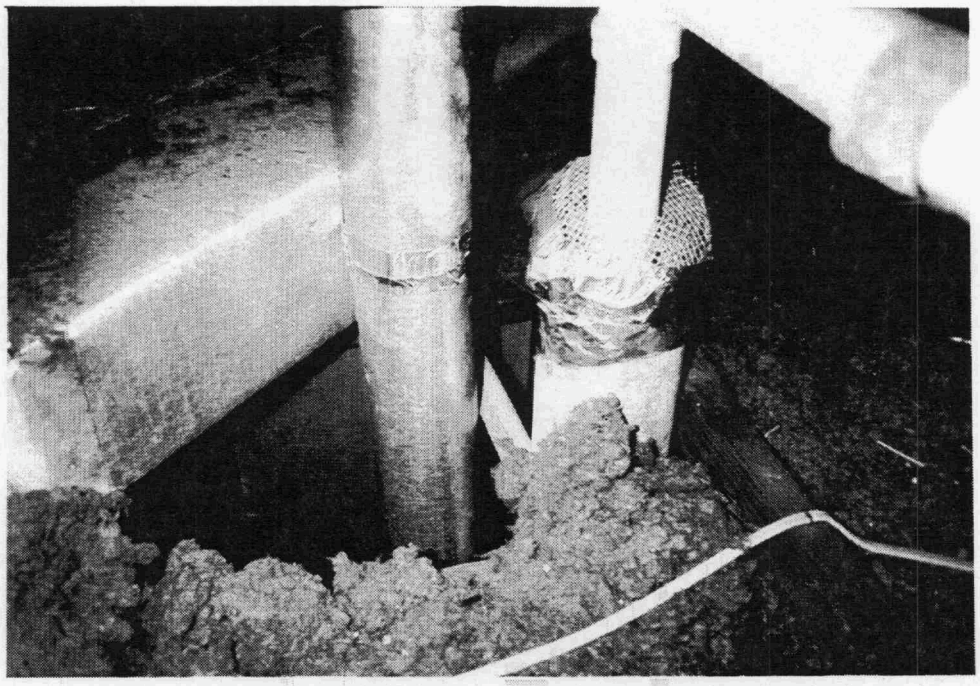

Fig. 4.8. Access to attic air from flue pipe chaseway.

All houses except the two-story Bicentennials have their distribution systems located in the attic, a nonideal but often necessary situation. Many instances of damaged duct insulation and joints were found. Figures 4.9–4.11 illustrate these conditions. We found damaged joints located on both supply and return sides of the HVAC system.

Much of the damage to ducts and duct joints was caused by human activity in the attics. To service furnaces and air handlers located in the attic, a technician must often step over ducts or straddle them while working. As a result of the limited space and often hostile thermal and breathing conditions, much damage is inadvertently caused to the ducts. Combined with duct joints that were usually sealed with duct tape (a short-lived measure at best) and duct hangers that were not meant to support a technician's weight, ducts were easily damaged.

Even revitalized houses had duct problems. One recently revitalized house with efficient HVAC equipment had easy access to attic air on the return side of the system. The HVAC system was built on a plenum in the garage. However, the return air plenum was not sealed properly from an interior wall, which allowed some of its return air to be drawn from the attic along with some accompanying dust. The same house also had supply-side air leaks in the attic because of large air gaps formed by improperly fastened transition boots to supply registers, which allowed spillage of conditioned air into the attic. Although the furnace and air-conditioner were of a high-efficiency

Fig. 4.9. Duct separation from trunk.

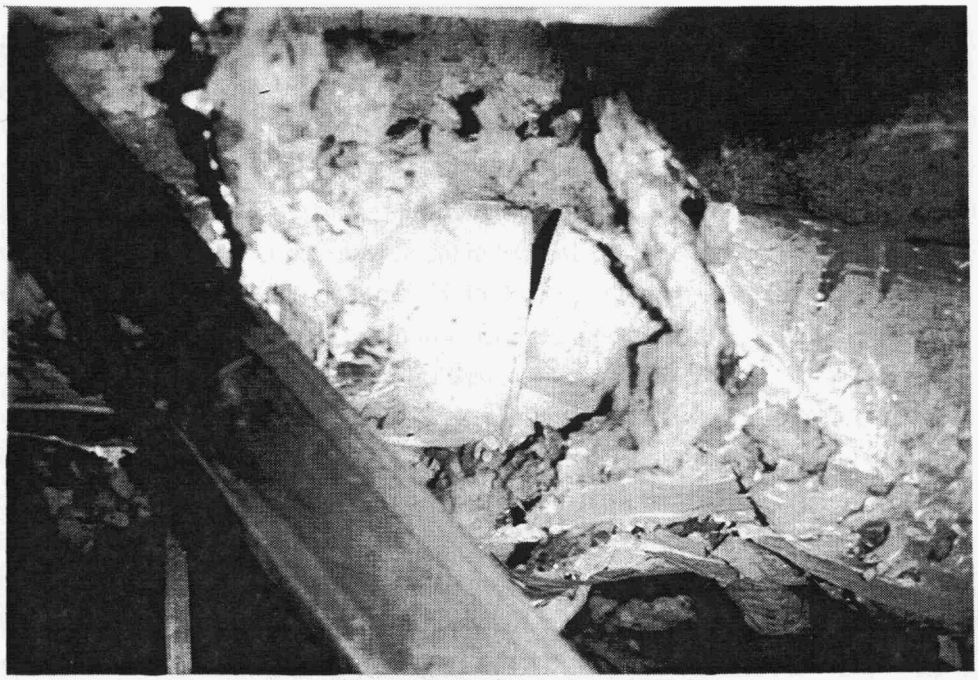

Fig. 4.10. Separated duct in attic.

Fig. 4.11. Damaged duct branch in attic.

design, when connected to the distribution system, the overall result was an inefficient system. Figures 4.12 and 4.13 illustrate poor attic supply boot connections.

One furnace in a Bicentennial had a humidifier installed on its A-coil that resulted in the coil not fitting on the furnace properly, leaving an approximate 0.5-in. gap at the base of the coil from which conditioned air was blown into the furnace closet enclosure (see Fig. 4.14). The furnace closet in turn had an intentional 3-in. diameter opening in its ceiling to the attic for a source of combustion air, so the attic also acted as a sink for conditioned air.

Many gas furnaces and air conditioners appeared to be 15–20 years old. They operate satisfactorily but are not overly efficient. Bad-fitting sheet metal covers on blowers and cooling coils were common. These led to dust and insulation being ingested onto cooling coils and heat exchangers, which detracted from heating and cooling delivered to the living area. Some occupants mentioned a funny smell like burning dust when the furnace was operating (it probably was burning dust). We found messy, unsafe HVAC electrical wiring in several houses, caused largely by equipment being located in attics.

We found two air-conditioning condensing units sitting side-by-side with a large, drooping tree hanging over them (see Fig. 4.15). This caused short circuiting of the condenser cooling air for which both units were competing (some of the heated exhaust air from the top of the units was being fed back into the inlet side). Also, pollen from the tree had clogged many of the condenser coil fins in both units, further degrading their performance.

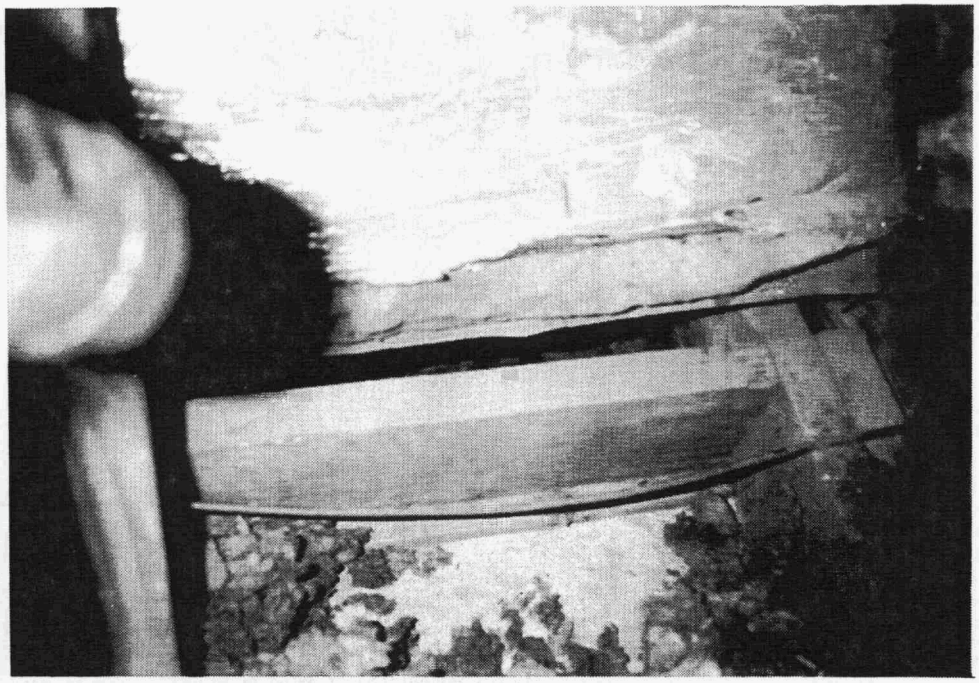

Fig. 4.12. Poorly sealed supply duct to register termination in attic.

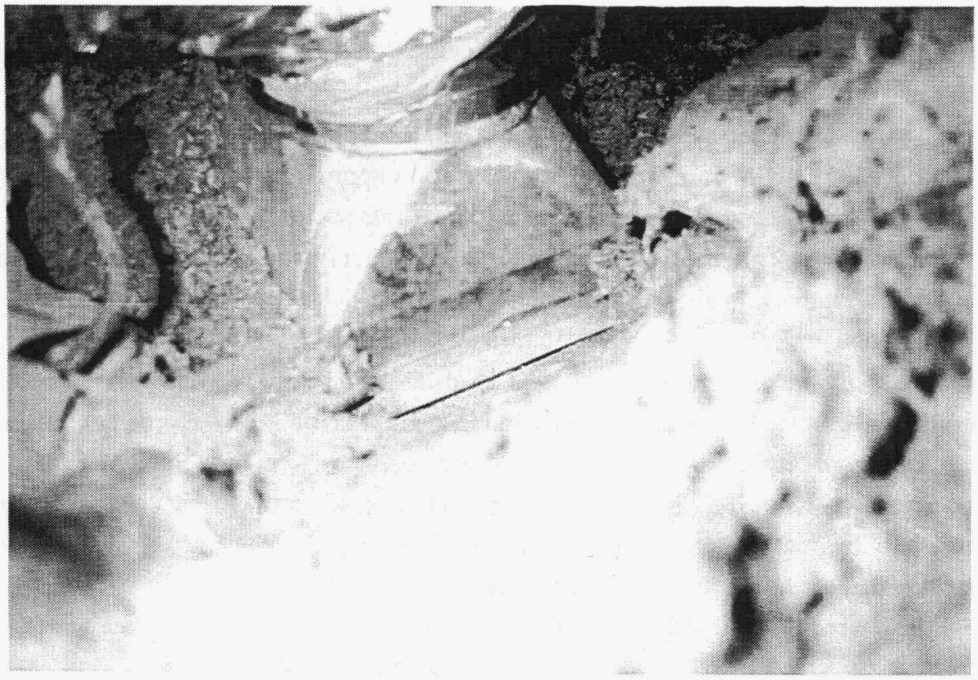

Fig. 4.13. Another poorly sealed supply duct to register termination in attic.

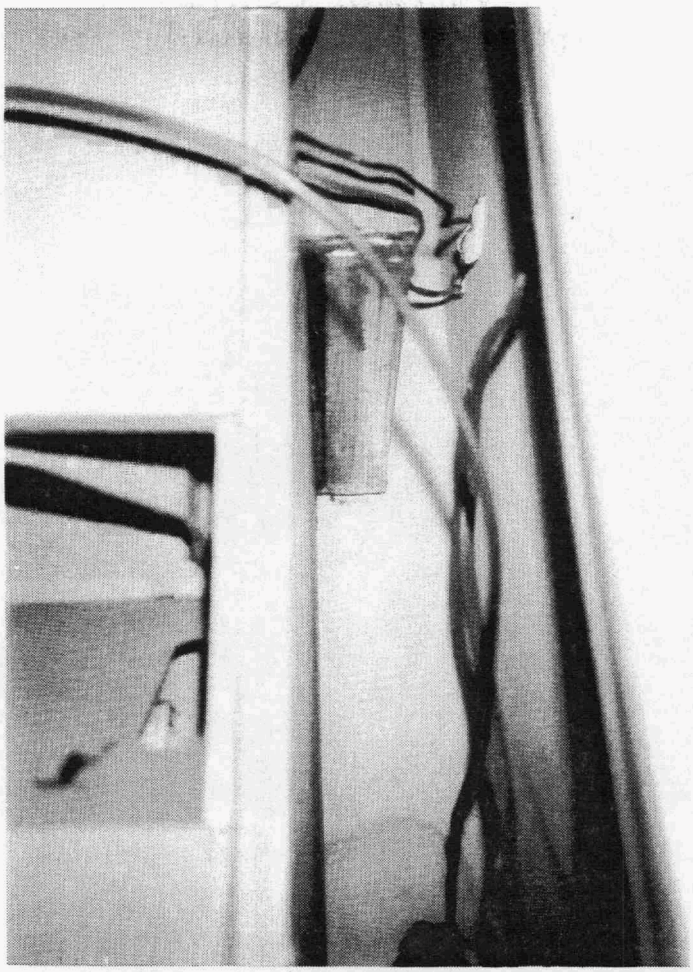

Fig. 4.14. Poorly fitting air-conditioner A-coil on gas furnace.

The domestic water heaters (all gas-fired) looked relatively new. We found dangerous hot water temperatures (greater than 150°F) coming from the faucets in several homes. Some water-heater safety problems were caused from the heaters being located in garages. The water heaters were encased in sheet-metal enclosures with a warning sign on the enclosure, but the enclosure sheet metal did not fit well enough or was sufficiently damaged at floor level to create a potential fire hazard from gasoline fumes being ignited by pilot or burner flames. Several water heaters were not connected to their flues properly (as shown in Fig. 4.16) and spilled some exhaust into the garages.

Carbon monoxide levels were low in water heaters and furnaces, except for one water heater emitting 140 ppm in its flue gas (about 10–15 ppm is normal).

Windows were single-pane with sliding storm windows. Several cases were noted of missing sliding storm windows in the frames.

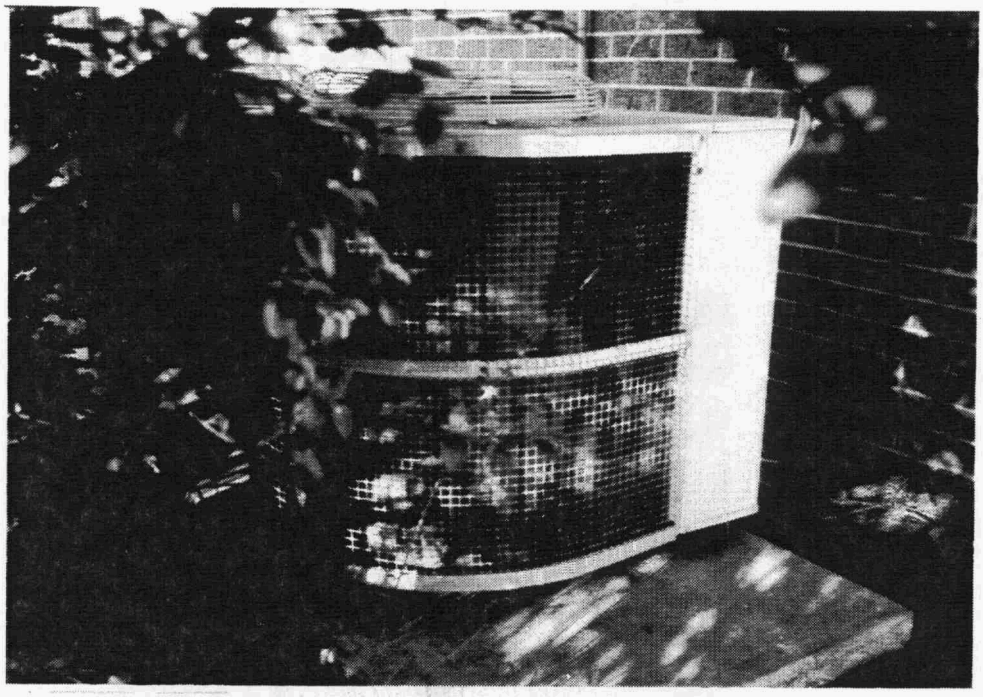

Fig. 4.15. Air-conditioner condensing unit covered by tree and pollen.

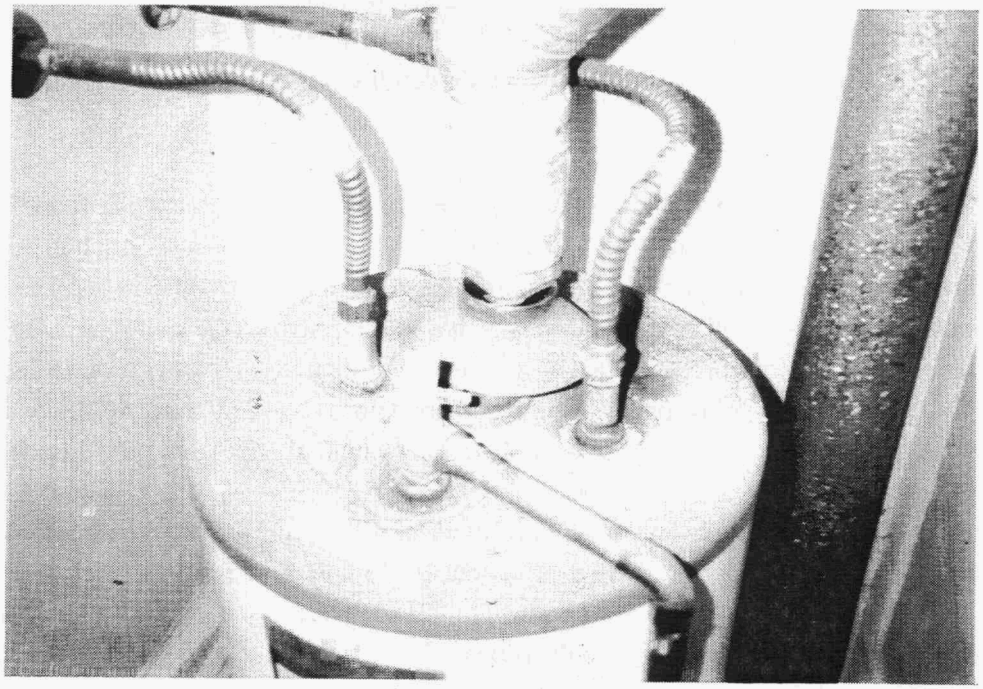

Fig. 4.16. Water-heater flue misaligned.

Energy-efficient lighting was not present in the houses. Low-flow showerheads (2.25 gpm or less) were not found in all units, and many showerheads were measured at 5 to 6 gpm. Most of the refrigerators were about 10–15 years old and relatively inefficient based on today's standards. We found a new side-by-side model in a revitalized house. Side-by-side refrigerators are usually not as efficient as top-freezer models.

4.4 FORT MONMOUTH

An inspection of family housing at Fort Monmouth, New Jersey, was conducted on November 1–5, 1993. As shown in Table 4.3, the housing at Fort Monmouth is divided into 17 different areas, but there are three major groupings.

Table 4.3. Family housing at Fort Monmouth

Housing group	Number of buildings	Number of units	Year built	Type of housing
On-post	54	120	1925–51	Duplex, multifamily
Charles Woods	118	536	1958–71	Multifamily
Howard Commons	52	486	1958	Multifamily
Totals	224	1142		

On-post housing units generally have basements and oil-fired hydronic heating systems, while Charles Woods and Howard Commons housing units have slab-on-grade or crawl-space foundations and have gas-fired, forced-air heating systems and central air-conditioners. Natural gas is used as the fuel for most domestic hot water heating and cooking. The total conditioned floor area is 1.643 million ft^2.

We gathered measured data from 11 unoccupied units over the course of the week, 4 on-post units, 5 Charles Woods units, and 2 Howard Commons units. Our inspections covered housing types (floor plans) similar to most of the 1142 housing units at Monmouth. The houses were adequately maintained, the surrounding grounds were well kept, and the housing looked attractive, especially the on-post segment.

Insulation levels were not adequate. None of the on-post housing had any wall insulation, and some lacked attic insulation. Enclosed porches attached to on-post housing were totally uninsulated, even though they were heated. There was no attic insulation in houses being revitalized in Howard Commons, nor was attic insulation scheduled to be installed during the revitalization. This last situation was attributed to a lack of funding for the project.

What appeared to be asbestos insulation (this should be verified) was on water heating system (hydronic) pipes in the on-post housing. Many ends of the insulation were trimmed off and not covered, so that loose asbestos (if that was in fact the insulation material) could be dislodged from the pipes.

The houses were only marginally air-tight (see Table 5.3) and contained many of the same problems that we found at Altus and Malmstrom AFBs. Cutouts for piping, wiring, duct passages through ceilings, and even bathroom medicine cabinets were often sealed inadequately, if at all. These situations enhance infiltration by providing direct access to attics and also open air paths through interior walls to attics. Cutouts and housings for old through-the-wall air-conditioners were commonly left in place in revitalized houses, also increasing infiltration and envelope losses. Outside-vented furnace rooms built inside the house shell, but physically separated from the house living area by a wall with no doorway, showed substantial air leakage into the living area through cutouts around the ducts. We feel that it is more efficient to include the furnace inside the house living area. Some of the houses we inspected did have this preferred layout.

Air leakage between multifamily units at Howard Commons and Charles Woods was common. Because old flooring was not removed, at least at Howard Commons, there was a buildup of the flooring to the extent that new drywall could not be nailed to the bottom wall plate, the top of which was at or below the new floor level. This allows air leakage between units and also leakage to outside wall cavities—another potential source of air bypasses to the outside and to attics.

Most of the forced-air systems had considerable duct leakage (see Table 5.3). Several cases of inadequately constructed and sealed return-air systems were found, with no airflow in one return and low airflow from the house in another. The house structure was used as part of the distribution system in many cases, a bad but common practice that allows furnace return air to be drawn from the attic or from the outside instead of from the living area. Many ducts were cut off short of the drywall (inside a wall cavity) and hence were poorly fastened to supply registers. This left them free to blow air into inside wall panels and into attics or any other area that was not adequately sealed from the interior wall panel. Figures 4.17 and 4.18 illustrate this problem.

The sources of several duct leaks could not be determined because they were located between the first and second floors, but we feel that damaged or inadequately fastened joints or registers could well be the problem.

The heating systems were on a regular maintenance schedule, which is good. Most gas furnaces appeared to be relatively new and operated satisfactorily. However, one was burning too rich and had an extremely high carbon monoxide concentration of 1200 ppm in the flue (November 1993). This particular unit had received a summer maintenance check in August 1993, so obviously the maintenance check was not performed very well. The oil-fired boilers were about 10–20 years old, had flame-retention burners (which is good), and were operating satisfactorily. However, many appeared to be substantially oversized.

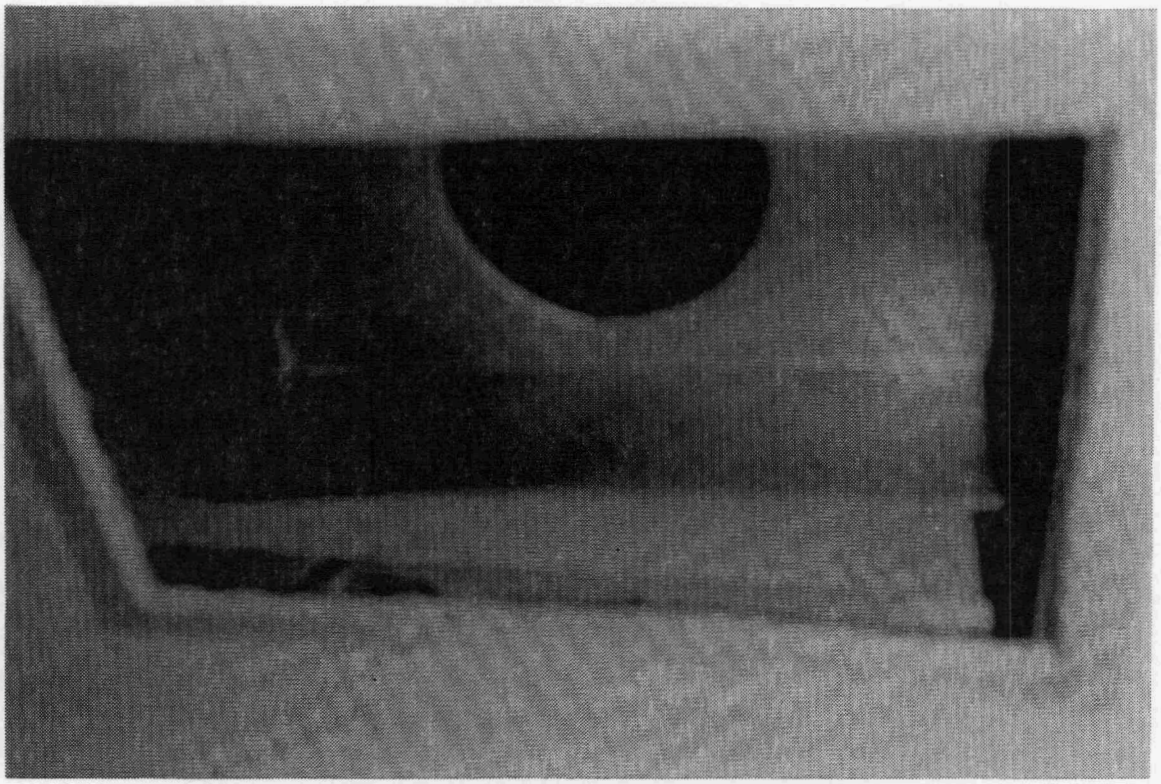

Fig. 4.17. Duct cut off too short at register, terminating inside interior wall.

Many of the outside air-conditioning condensing units had unprotected and exposed plate-type fins that were bent together and marked up with various initials, graffiti, and baseball impacts, presumably by the local children. This common problem creates an unsightly situation and reduces efficiency of the air conditioner. Condensing units should be fitted with outside housings to protect the fins. Several of the newer revitalized houses had such protected units. Figure 4.19 illustrates one example of damaged fins on an air conditioner.

The domestic water heaters (mostly gas-fired) looked relatively new. We found dangerous hot water temperatures (greater than 150°F) coming from the faucets in several houses. One stand-alone, oil-fired water heater with an 80-gal tank supplied a second nearby 150-gal storage tank with hot water. The second tank was not insulated and was presumably present to increase hot water storage. It was suggested that the tank may once have had asbestos insulation on it that had since been removed, but the tank had not been reinsulated. It was dumping much heat into the

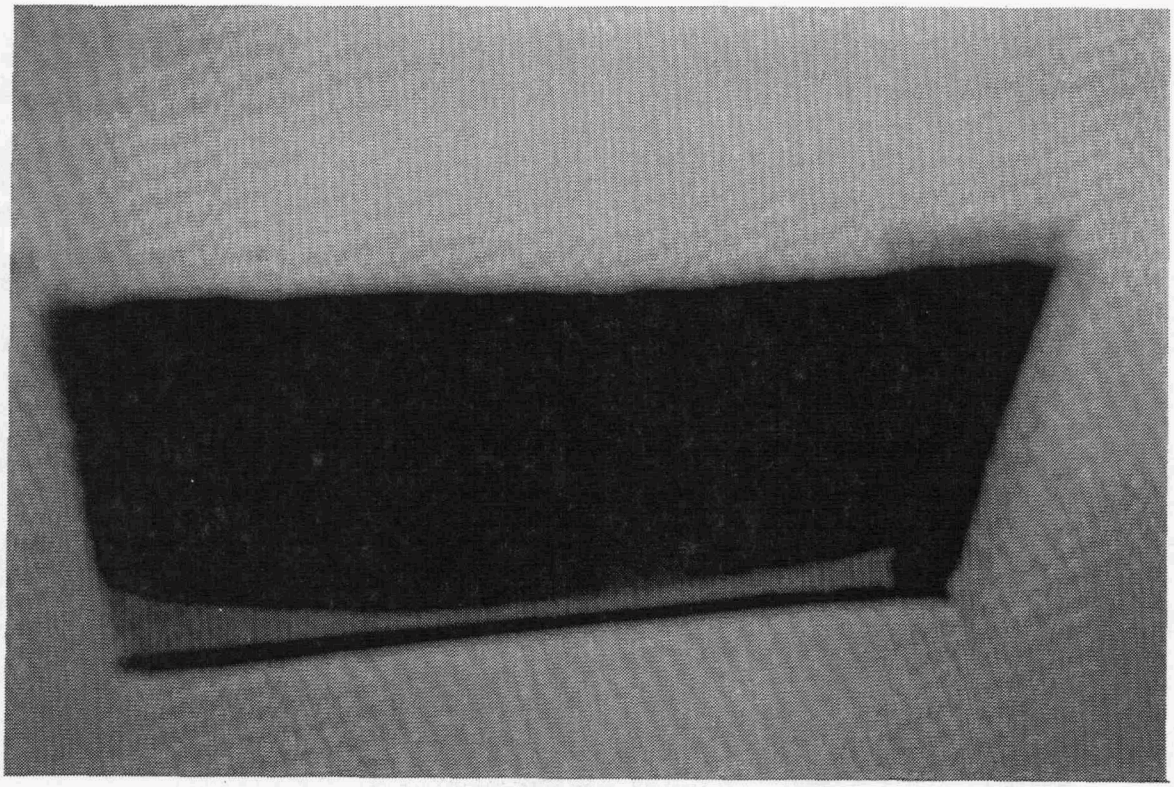

Fig. 4.18. Another duct cut off too short at register, terminating inside interior wall.

basement where it was located, which had an opened window to vent out an odor of fuel oil and natural gas. Natural gas lines ran within 15 ft of these tanks. We feel that separate gas-fired water heaters and a small vent fan to the outside would be a much better solution for this problem. Figure 4.20 illustrates the uninsulated 150-gal storage tank.

Carbon monoxide levels were generally acceptable in the flues of water heaters and furnaces, except for the previously mentioned gas furnace. No dangerous carbon monoxide levels were found inside any living spaces.

Energy-efficient lighting was not present in the houses. Most of the refrigerators were about 10 years old and operated satisfactorily. Low-flow showerheads were not found in all units. Several showerheads were measured at 5–6 gpm.

4.5 SITE INSPECTION SUMMARY

Our inspections of Malmstrom AFB, Altus AFB, and Fort Monmouth showed many of the same deficiencies, although the bases are spread apart geographically. These same deficiencies

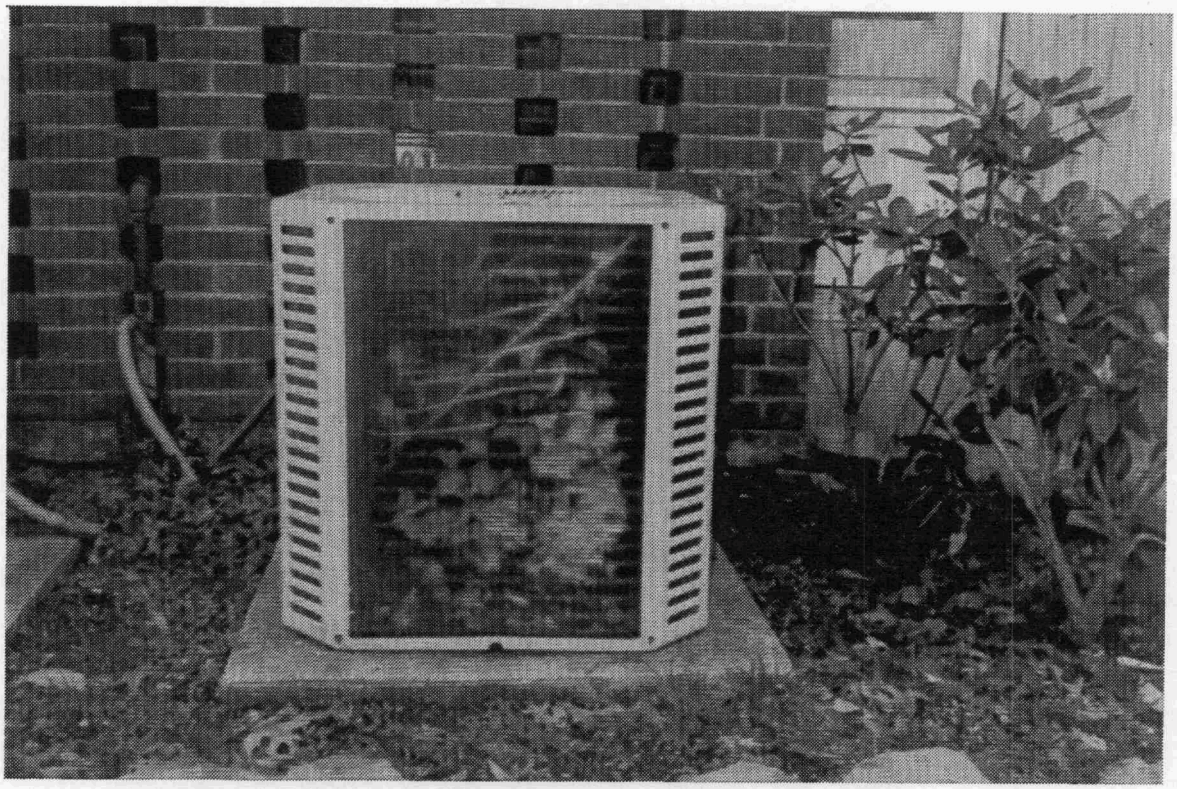

Fig. 4.19. Damaged fins on air-conditioner condensing unit.

were consistent with those found at Shaw AFB, which had been inspected before this study. Our experience in the private sector is no different from the military, with the same deficiencies showing up time and time again.

Duct leakage is a very common problem. Problems often showed up in duct joints because of faulty or poorly designed duct supports or human encounters with ducts. Ducts in attics can undergo extreme abuse and even separate when people enter the attics to perform tasks (e.g., furnace tune-ups, installing additional insulation). We found much of this at Altus AFB. To minimize the necessity of service people entering attics, HVAC equipment should not be placed in attics if at all possible. Attic locations for ducts should also be minimized where possible. We realize that sometimes it is extremely difficult to avoid locating HVAC equipment and especially ducts in attics. When it is necessary to use attic space, duct layouts should be designed with service access in mind, and ducts should be well insulated and installed carefully.

Duct supports were often inadequate; they should be more substantial than a piece of wire and should be securely fastened to a suitable surface. Duct joints should be sealed with a

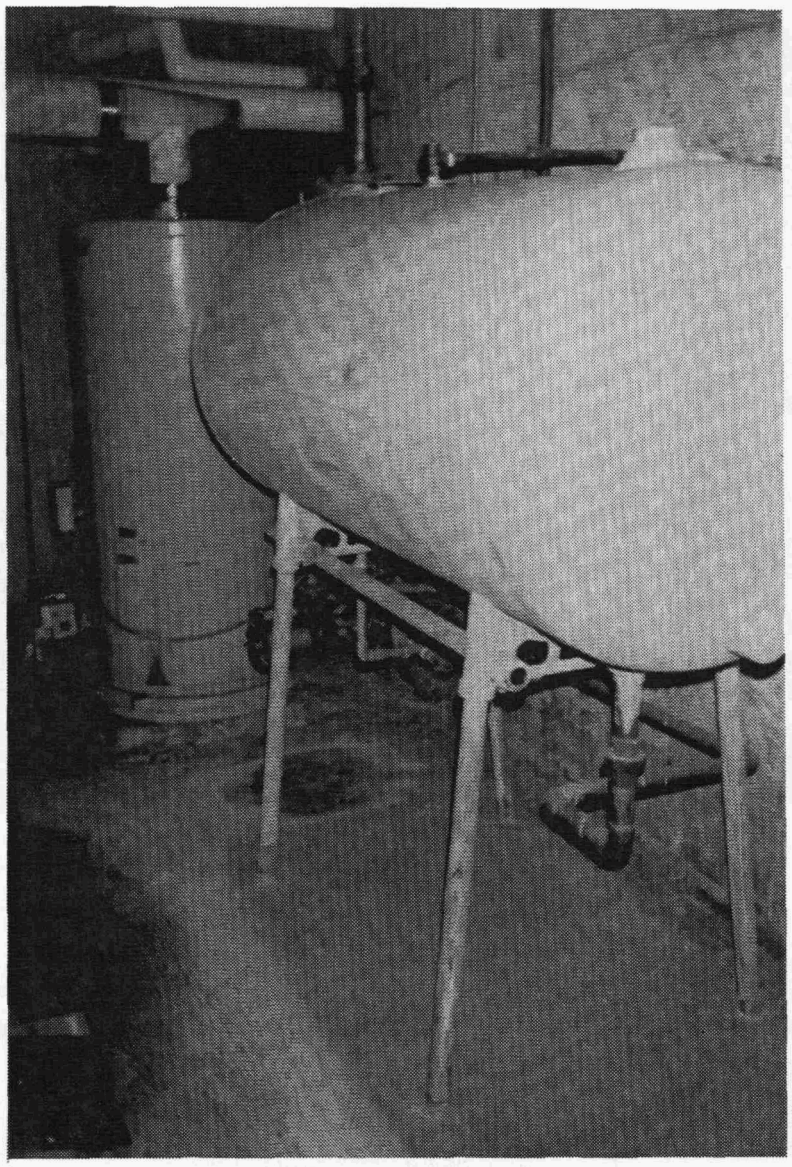

Fig. 4.20. Uninsulated 150-gal hot water storage tank.

mechanical fastener (e.g., sheet metal screws), covered with a fiberglass drywall-seam type of tape, and coated with a mastic compound made for that purpose. Cloth duct tape should be avoided, as it only forms a temporary seal at best.

Return-air systems, particularly plenums, were vulnerable to design and construction flaws that resulted in energy-efficient mechanical equipment being supplied with heating and cooling loads much higher than expected house design loads. The source of the increased loads is return air originating from places other than the house living area. The house structure should not be used as part of the duct system. When necessary, extreme care should be taken to permanently seal

plenums from interior walls. Dirty air filters at entrances to return-air registers aggravate such situations. Increased pressure drops across the dirty filters reduce airflows through the filters and increase amounts of attic or outside air in the return air to a furnace or air conditioner.

Locations where ducts join with air supply and return registers were often sources of duct leakage because of the use of improper materials or poor installation. The connections between register and duct should be secure and decoupled from the interior wall or attic spaces, with no air gaps remaining. Better-designed transition pieces or supply registers would help alleviate this common problem.

Bypasses are minimal-resistance, air-infiltration leakage paths to attics or the outside that allow relatively large quantities of conditioned air to easily exit a house by way of interior or exterior walls. Usual infiltration paths are small cracks and admit only small quantities of air, but a single bypass can short circuit the higher resistance paths and increase air infiltration significantly, often by more than 40%. Leakage paths to outside air and to attics can result any time ducts go through walls or whenever part of the house structure is used as part of the duct system. Cutouts in walls (including electrical outlets) should be properly sealed so the wall interior is decoupled from the room space. We found several cases of this at each of the three sites we visited.

Uninsulated overhang areas under a second or third story of a house or under bay windows are also sources of bypasses. We found several instances of uninsulated and partially insulated overhangs at Altus AFB and Fort Monmouth.

The thermal boundary of many houses is not truly defined at Malmstrom AFB and Fort Monmouth. Many houses at these locations have uninsulated basements that are essentially heated; they should be treated as conditioned areas of the houses and insulated appropriately. Some revitalized houses at Fort Monmouth had no attic insulation. All floors over crawl spaces and ducts in crawl spaces should also be insulated—we found several that were not.

Current HVAC systems are most likely oversized after any house shell, air infiltration, and duct improvements have been performed, and also because of initial oversizing. Replacement systems should properly sized. A slightly undersized air-conditioning system is often more comfortable to the occupants than an oversized system because it controls temperature and humidity more effectively due to longer run times. An oversized system usually costs more initially and is more expensive to operate because of the increased losses associated with more on/off cycling of the system. Keep HVAC systems out of attics if at all possible because of the many installation and service-related problems they cause.

Efficient HVAC systems, especially air conditioners, should be installed at Altus during revitalization. When existing furnaces are replaced at Altus, we do not necessarily recommend state-of-the-art condensing furnaces as replacements. Medium-efficiency (80% AFUE) furnaces may be more cost-effective replacements in the Altus climate, which has moderate winters. However, we believe that high-efficiency air conditioners are cost effective at Altus because of the long and hot summers. A recently revitalized Altus house had such an HVAC combination, which we think is a good choice, but the furnace was oversized for the house. These recommendations should be checked out more closely, as discounts from quantity purchases, any available utility

incentives, and the use of plastic pipe for venting exhausts of condensing furnaces (instead of building a conventional flue through the roof) may change the situation.

There is presently no central air-conditioning at Malmstrom AFB, but it is being considered during revitalization. This option should be considered very carefully, as it is an expensive installation that will only be used a few times during the year. Whole-house fans may be a suitable and effective substitute there. The potential safety hazards caused by the exit points of condensing furnace flues and supply pipes at Malmstrom should be looked into to see if a suitable and effective solution can be found. Perhaps a small wire fence around the area would suffice.

The boarded-up gable vents and covered soffit vents at Altus do not supply enough venting to the attics in winter for dissipation of moisture that migrates there from the living area. The living area should be sealed from the attic. Adding ridge vents and removing the sliding covers on soffit vents should be considered for all houses at Altus. The problem of freezing water pipes in winter should be readdressed. If windows are to be replaced, consideration should be given to installing energy-efficient double-pane windows with low-E glass and argon filling. However, single-pane windows with storm windows will suffice, and replacements cannot be justified on a cost-effectiveness basis.

Many cases of hot water delivery temperatures in excess of 145°F were found at all installations, as were shower flow rates of 5–6 gpm. All hot water temperatures should be set to a maximum of 130°F, and inlet and exit water piping should be insulated to a distance of about 12–24 in. back from the water heater tank. Low-flow showerheads (2.25 gpm) should be installed in all houses. Low-flush toilets (1.7 gal per flush) should also be considered.

We found a potential safety problem at Altus AFB where gas-fired water heaters were located in garages inside sheet metal housings with poor-fitting sheet metal. Gas-fired water heaters in garages should be located 24 in. off the floor (or follow local building code guidelines) and away from flammable substances such as gasoline vapors.

We found no energy-efficient lighting at any installations. Energy-efficient lighting should be considered for all permanent wall and ceiling lighting fixtures. When the existing refrigerators are replaced, high-efficiency nonchlorofluorocarbon (CFC) (R134a refrigerant) replacements should be purchased. Replacement dishwashers should use low amounts of hot water in their cycles. Occupants should be made aware that energy-efficient washing machines and dryers are available in the marketplace and should be urged to consider them when making such a purchase.

5. RESULTS OF ENERGY MODELING

ORNL developed an energy audit computer program under contract from DOE that estimates the present energy usage of a house based on its geographic location and measurements of its structural and thermal characteristics. The audit program is called the National Energy Audit (commonly referred to as NEAT). NEAT also estimates what can be done to a house to improve its energy efficiency, how much energy is saved, and which of those measures are cost-effective. The program has been available for a few years and is still being updated (mostly in the areas of cosmetics and user convenience) as user comments are received.

NEAT was applied to most of the houses we visited during our inspections. A summary of some of the data from the housing inspections is contained in Table 5.1 for the Air Force houses and in Table 5.3 for the Army houses. A summary of the NEAT energy use analyses is contained in Table 5.2 for the Air Force houses and in Table 5.4 for the Army houses. More detailed summaries for each house, along with specific cost-effective measures and their estimated savings, are contained in the Appendix, Tables A.6–A.29. Table 5.5 contains a summary of the NEAT-estimated preheating and precooling energy usage along with 1992 DEIS reported thermal and electric consumptions for the three sites we inspected. A summary of the measures recommended by NEAT for each installation is contained in Table 5.6.

5.1 COMPARISON OF NEAT ESTIMATES AND DEIS DATA

Table 5.5 includes a rough comparison of the results of our NEAT heating and cooling usage pre-retrofit estimates with adjusted DEIS data for thermal and electric usages for the same installations. Keep in mind that DEIS thermal data contain water heating and cooking usages as well as house heating usage, and that DEIS electric data contain a base consumption for lighting and electrical appliances such as refrigerators, freezers, clothes dryers, and entertainment equipment, as well as house cooling usage. NEAT does not address water heating or noncooling electric measures, such as low-flow showerheads, efficient refrigerators and lighting, or duct leakage losses. We would therefore expect raw DEIS thermal and electric usages to be higher than NEAT estimates for heating and cooling because of these factors—and they are.

To better compare DEIS data and NEAT estimates for each base, we adjusted DEIS consumptions by assuming an annual base thermal load for water heating of 15 Mbtu/kSF and a base electrical noncooling usage of 20 MBtu/kSF (reasonable values to expect for these quantities). Another assumption is that our inspections at each site were representative of site housing types and in the same numerical proportion. We realize that these assumptions are very approximate, but they are probably good enough for our purposes.

Table 5.1. Summary data from Air Force family housing inspections

ID[a]	House type	Address	Foundation type	Story	Conditioned Area (ft^2)	Conditioned Volume (ft^3)	Air Leakage House (cfm50)	Air Leakage Ducts (cfm50)
A01	W	108a Ridley St.	Slab	1	903	7,648	1,111	251
A02	Bicen	180 Liberty St.	Slab	2	1,369	10,952	981	108
A03	R	339 Birch St.	Slab	1	1,176	9,408	1,544	235
A04	$S_{renovated}$	165 Woodring St.	Slab	1	1,219	9,752	1,606	190
A05	H	439 Jasmine St.	Slab	1	1,601	12,808	1,828	406
A06	E	76 So. Gum St.	Slab	1	1,385	11,080	2,201	650
A07	$I_{renovated}$	534 Alpha St.	Slab	1	1,250	10,000	2,322	808
M01	Off-Cap	4930B Locust St.	Basement	1	2,904	23,232	1,802	348
M02	Off-Cap	4201A Elder St.	Basement	1	2,386	19,088	2,132	560
M03	Reloc	5223B Pecan St.	Crawl space	1	1,170	9,775	1,460	201
M04	Wherry	932 Lincoln Dr.	Slab	2	1,039	8,677	1,532	88
M06	Malm	174 Malmstrom Dr.	Slab	2	1,350	11,475	1,754	0
M08	On-Cap	8 Birch St.	Basement	1	1,988	15,904	3,061	522

[a]A = Altus Air Force Base; M = Malmstrom Air Force Base.

Table 5.2. Summary of NEAT energy analysis for Air Force housing inspections[a]

	Heating energy (MBtu/year)			Cooling energy (MBtu/year)		
ID[b]	Pre	Post	Save	Pre	Post	Save
A01	24	24	0	12	8	4
A02	27	32	-5	13	7	6
A03	28	27	-1	11	9	2
A04	26	31	-5	15	9	6
A05	30	26	4	15	14	1
A06	34	38	-4	14	10	4
A07	30	25	5	11	11	0
M01	93	59	34	—	—	—
M02	81	48	33	—	—	—
M03	45	35	10	—	—	—
M04	28	26	2	—	—	—
M06	118	51	67	—	—	—
M08	83	69	14	—	—	—
Total	647	491	154	91	68	23

[a]NEAT = National Energy Audit Computer Program (U.S. Department of Energy.

[b]A = Altus Air Force Base; M = Malmstrom Air Force Base.

Table 5.3. Summary data from Army family housing inspections

ID[a]	House type	Address	Foundation type	Story	Conditioned Area (ft^2)	Conditioned Volume (ft^2)	Air leakage House (cfm50)	Air leakage Ducts (cfm50)
FM01	On-Base	15 Gosselin Ave.	Basement	2	1,265	10,645	2,500	NA
FM02	On-Base	9 Gosselin Ave.	Basement	2	1,265	10,645	2,236	NA
FM03	On-Base	16 Carty Ave.	Basement	2	2,296	—	—	NA
FM04	On-Cap	5 Allen Ave.	Basement	2	2,138	17,457	3,509	NA
FM05	Off-Cap	54 Olangapo Rd.	Slab	2	1,147	9,827	2,457	305
FM06	Off-Cap	64 Wake Rd.	Slab	2	988	8,466	2,529	770
FM07	Off-Whe	408 Pine Brook Rd.	Crawl space	2	1,001	7,728	2,790	464
FM08	Off-Whe	51 Mitchell Ln.	Crawl space	2	1,001	7,728	2,681	432
FM09	Off-Cap	13 Guam Ct.	Slab	2	1,154	9,229	2,062	38
FM10	Off-Cap	118 Wake Ct.	None	2	950	7,600	2,163	174
FM11	Off-Cap	41 Mariveles Rd.	Slab	2	1,091	8,797	1,979	30

[a]FM = Fort Monmouth.

Table 5.4. Summary of NEAT energy analysis for Army housing inspections[a]

ID[b]	Heating energy (MBtu/year)			Cooling energy (MBtu/year)		
	Pre	Post	Save	Pre	Post	Save
FM01	64	32	32	—	—	—
FM02	59	30	29	—	—	—
FM04	96	63	33	—	—	—
FM05	81	52	29	8	7	1
FM06	86	62	24	8	7	1
FM07	60	25	35	5	4	1
FM08	64	29	35	5	4	1
FM09	19	21	-2	9	5	4
FM10	19	17	2	7	7	0
FM11	47	34	16	8	8	0
Total	595	365	233	50	42	8

[a]NEAT = National Energy Audit computer program (U.S. Department of Energy).
[b]FM = Fort Monmouth.

Table 5.5. Summary of NEAT heating and cooling estimates and comparison with adjusted DEIS data

Location	DEIS 92 Thermal use adjusted for base load[a]	NEAT annual heating estimate (MBtu/kSF)			DEIS 92 electric use adjusted for base load[b]	NEAT annual cooling estimate (MBtu/kSF)		
		Pre	Post	Percent saved		Pre	Post	Percent saved
Altus AFB	49.3	22.3	22.8	-2.2	14.7	10.2	7.6	25.3
Malmstrom AFB	58.9	62.2	40.0	35.7	4.6	—	—	—
Fort Monmouth	114.0	41.6	25.5	39.1	2.5	3.4	2.9	14.7

[a]AFB = Air Force Base; DEIS = Defense Energy Information System; NEAT = National Energy Audit computer program (U.S. Department of Energy). Reported DEIS thermal consumption was reduced by 15 MBtu/kSF to account for water heating, cooking, etc.
[b]Reported DEIS electric consumption was reduced by 20 MBtu/kSF to account for lighting, appliances, etc.

Table 5.6. Summary of cost-effective measures recommended by National Energy Audit (NEAT) audit program

Measure	Number of inspected houses requiring measure at			Total houses requiring measure	Percent of houses requiring measure
	Altus Air Force Base (total 7 houses)	Malmstrom Air Force Base (total 6 houses)	Fort Monmouth (total 10 houses)		
Attic insulation		4	9	13	48%
Sill box insulation		3	3	6	22%
Foundation insulation		3	3	6	22%
Floor insulation		2	2	4	15%
Wall insulation	1		1	2	7%
Duct insulation	5	1		6	22%
Smart thermostat	7	2	8	17	63%
Furnace tune-up			3	3	11%
Louvered sun screen	4		1	5	19%
Low-E storm window	1			1	4%
Storm window	1			1	4%

The first thing that stands out in Table 5.5 is that the reported thermal DEIS data for Altus are about a factor of two higher than the NEAT heating estimates. DEIS electric data are about 35% higher than NEAT estimates at Altus. Because we think that DEIS data are being measured properly at Altus, something is causing MFH consumptions to be higher than expected. This might well be duct leakage, which we know is high at Altus. This rough comparison suggests that much savings are possible at Altus AFB.

The NEAT preheating usage estimate for Malmstrom AFB is 62.2 MBtu/kSF (not including basement areas), which agrees quite well with the adjusted Malmstrom DEIS value of 58.9 MBtu/kSF. This implies that the Malmstrom DEIS data may be valid, even though we suspect it is high. Because Malmstrom has no air-conditioning equipment, the adjusted electrical usage of 4.6 MBtu/kSF seems high by about 23% but may be reasonable considering that it includes the base hospital usage. NEAT suggests that substantial heating savings (36%) are possible at Malmstrom.

NEAT heating estimates for Fort Monmouth of 41.6 MBtu/kSF are one-third of the adjusted DEIS value of 114 MBtu/kSF. We know that Fort Monmouth DEIS data are high, and this comparison supports that. The adjusted DEIS electric usage of 2.5 MBtu/kSF is not too different numerically from the NEAT cooling estimate of 3.4 MBtu/kSF. Nevertheless, NEAT estimates that a cooling savings is possible at Fort Monmouth.

5.2 MEASURES SUGGESTED BY NEAT

Table 5.6 lists the cost-effective measures recommended by NEAT for the 23 houses that we inspected. These measures are listed in more detail for each house along with the estimated savings for the measure in Appendix A, Tables A.6–A.29. Keep in mind that NEAT does not currently recognize duct leakage nor recommend its repair.

The most common recommended measure is a smart thermostat (used for heating only) for 63% of the homes. Most of the houses at Malmstrom AFB already have smart thermostats, but they were noticeably absent at Altus and Monmouth. One thing that NEAT does not guarantee, however, is that smart thermostats will be regularly used by the occupants. Smart thermostats must be used regularly to be effective, so an educational measure must be included with smart thermostats.

Additional or new attic insulation was the second most recommended measure and appeared 48% of the time. Sill box (band joist) insulation, duct insulation, and foundation (basement wall) insulation all were recommended 22% of the time.

The primary recommendation for cooling-load reduction was louvered sun screens at an occurrence level of 19%. Only two cases of adding a storm window (not whole-house storm windows) were recommended.

5.3 NEAT MODELING SUMMARY

Comparisons of NEAT pre-retrofit heating and cooling estimates with DEIS data (after adjusting them with estimates for thermal and electric base load consumptions) suggest that

- Altus AFB heating and cooling DEIS data are high. Duct leakage could be a major cause of this.
- Malmstrom AFB heating DEIS data could be correct, but DEIS electric data may be slightly high.
- Fort Monmouth DEIS heating data are high, but electric consumption is correct.

NEAT suggested that there is still a great deal of energy to be saved in the houses that we inspected, upwards of 20% without considering duct leakage, and these savings can probably be attained throughout the entire MFH spectrum, because many common problem areas exist.

Although smart thermostats for heating and additional insulation in attics, sill boxes, and basements are the most commonly recommended cost-effective measures to save energy, we feel that the attainable savings would be much higher if the widely present duct leakage we encountered could be considered by NEAT. The repair of duct leaks and the proper installation and sealing of ducts will save significant amounts of energy.

6. FAMILY HOUSING COMMUNITY PLAN REVIEW

Each AFB has a Family Housing Community Plan that describes in detail what is planned in the revitalization of its MFH and why. The site-specific plans were written for the bases by separate A&E firms after they had inspected the family housing at that site. The plans cover neighborhood development, landscaping, traffic control, and housing revitalization based on the projected needs of the particular site. We reviewed the Family Housing Community Plans for Malmstrom and Altus AFBs (Fort Monmouth did not have one) before and after visiting those sites. A brief critical review of the plans for Malmstrom and Altus follow, concentrating on energy-efficient items.

6.1 MALMSTROM AFB

The Malmstrom AFB plan contains examples of not specifying efficiency ratings of new equipment to be installed during revitalization. New street lighting is recommended here, but the plan does not say that it should be high-efficiency lighting. Because these lights will operate for long hours each day, they should be high-efficiency lights. New interior lighting fixtures recommended for high-use areas (e.g., kitchens) should also be of the high-efficiency type (fluorescent lighting with electronic ballasts).

New gas-fired furnaces were recommended for the Lincoln Drive units at Malmstrom AFB without specifying any efficiency levels. Because the units in the interior of each building have little exposed envelope area and hence have relatively low heating requirements, it may be more cost-effective to install an 80% efficient furnace rather than a condensing furnace.

The replacement of single-pane windows that have interior storm windows with double-pane windows will most likely not prove to be cost-effective but is planned to take place for architectural reasons. The windows should be of high-quality, double-gazing with argon-filled, low-E coating glass. If sliding-glass or French doors are added to any houses, they should also mimic the windows in quality. Such doors and windows will be less leaky and more energy efficient and will last longer than standard models.

The plan for Malmstrom also recommends moving the Relocatable housing to another location on base, an act that will surely increase air infiltration and duct leakage in these houses. The housing should be inspected after the move, and additional floor and duct insulation should be added if a crawl-space foundation is used.

Many basements need joist insulation, and basement wall insulation should also be considered, especially because most basements are conditioned. Any new walls or additions that are recommended should be properly insulated and the ductwork sealed using mastic and fiberglass tape. Standard cloth duct tape should not be used for sealing joints.

The plan recommends planting new trees in the yards. They should be located to maximize summer house shading within reasonable limits. This might alleviate the need for air conditioning.

The furnace return air plenums located under closets in the Capehart housing are prime sources of dilution of furnace return air with attic air. Care should be taken not to couple the plenums to the house structure.

6.2 ALTUS AFB

The Altus plan recognizes energy efficiency and addresses it in a short section (3.1.3 in the plan) entitled "Energy-Efficient Design." The plan says that all new envelope additions or exterior walls "if exposed during renovation" be insulated to meet or exceed minimum Air Force standards for heat transfer and that accessible heated (conditioned) spaces be insulated from unheated (unconditioned) spaces. We feel that all deficient envelope areas should be insulated, as modern insulation-blowing techniques can handle almost any situation.

The plan also recommends high-efficiency windows where replacements are to be made. Low-E glass, argon filling, window films, and shading are not mentioned. High-quality exterior storm doors are recommended to be added "as appropriate" (what is not appropriate?).

The plan recommends replacing all older less-efficient HVAC equipment and appliances with new equipment meeting ASHRAE 90A-1980. New equipment should meet the current federal standards as stated in ASHRAE 90.2. Most likely, condensing furnaces will not be cost-effective in a moderate Altus heating season.

Low-flow showerheads should be installed in all houses and not just considered for installation. The stated 1.5-gpm flow rate showerhead may not be as satisfactory as one with a 2.25-gpm flow rate. This should be checked out, because occupants may replace unsatisfactory energy-efficient showerheads with more satisfactory energy-inefficient ones.

A vague energy management program is mentioned that monitors energy usage and establishes guidelines based on the data collected. This sounds like a good idea, even though it will be difficult to implement. It may also irk many occupants, as the military does not currently charge occupants for utilities.

The following comments concern parts of the plan outside of the section on energy efficiency. Ridge vents should be considered when any attic ventilation work is to be done. They are more effective than gable vents at ventilating attics. Pocket doors usually result in the formation of air-leakage paths to attics. If used, they should be installed carefully and isolated from the interior wall space. Any walls added in the garage to form a laundry room should be insulated and dryer vents should exit outdoors. Makeup air for the dryer should ideally come from the house in winter (because it is cheaper to heat air with a gas furnace than with a dryer's electric heating element) and from the outside air in summer.

We totally agree that furnaces should be removed from the attics. However, our inspections revealed that if the job is not done properly, the gain is not as great as it should be from an energy viewpoint. Ductwork must be installed properly and isolated from interior walls.

New interior doors are to be installed. One point often overlooked is that interior doors should be undercut sufficiently to allow return air to flow freely from all rooms to the (usually only one) centrally located return air grill. Pressure balancing with the distribution system operating should be checked after the installation.

Whenever exterior siding is to be installed, uninsulated wall cavities should be insulated. The addition of rigid exterior wall insulation should also be considered.

Whenever new air conditioners are installed, the existing refrigerant lines should be replaced with new properly insulated lines. The wiring and breakers should also be checked.

All outside street lighting should be high-efficiency lighting.

6.3 SUMMARY OF FAMILY HOUSING PLANS

The Family Housing Plans for Malmstrom and Altus were all-encompassing and, as expected, tended to emphasize matching military square-footage requirements with rank and family size, aesthetics, outside facilities, and landscaping. Energy efficiency is not ignored in the plans, but it is not emphasized nearly as much as it should be.

The shortcomings of the Family Housing Plans in energy-efficiency areas accentuate the need for a guidebook to promote energy efficiency. The Family Housing Community Plans are very useful documents and can be extended in scope when used with our energy-efficiency guidebook.

7. CONCLUSIONS AND RECOMMENDATIONS

We estimate that MFH consumes about 5–10% more energy on a square-foot basis than the private sector when DEIS data are compared to 1987 RECS data. However, inconsistencies found in the DEIS MFH data for two of the three sites we visited indicate that these data may not be sufficiently accurate to make correct decisions regarding the implementation of projects designed to conserve energy in the MFH sector. The accuracy of DEIS MFH data can be evaluated through a thorough review process.

Many of the same energy deficiencies in the private sector are present in MFH. Forced-air distribution system problems are widespread. Duct leakage is common with duct joints failing because of faulty or poorly designed duct supports and because of human encounters with ducts. Locating HVAC equipment outside of attics will minimize the necessity of service people entering attics and reduce the human contribution to duct damage. Locating ducts in attics should also be minimized where possible. Duct joints should be sealed with mechanical fasteners such as sheet metal screws, covered with a fiberglass drywall-seam type of tape, and coated with a suitable mastic compound. Avoid cloth duct tape, which only forms a temporary seal. Duct supports should be more substantial than a piece of wire and should be securely fastened to a suitable surface.

We found that return-air plenums often contain design and construction flaws that result in mechanical equipment being supplied with heating and cooling loads much higher than should be. The problem is caused by return air being drawn from the attic and the outside. Air from these sources requires much more energy to condition than that from the living area. The house structure should not be used as part of the duct system, because any areas not permanently sealed from interior walls are prime sources of attic and outside return air. Dirty air filters at the entrance to a return-air register will aggravate this situation.

Locations where ducts connect with air supply and return registers are often sources of leakage and should be decoupled from the interior wall or attic spaces, with no air gaps remaining. Better-designed transition pieces or supply registers would help alleviate this problem.

Uninsulated overhang areas and those under bay windows are sources of energy-wasting bypasses.

Many houses with basements have improperly defined thermal boundaries. These usually uninsulated basements are essentially heated, and the area should be treated as a conditioned area and insulated appropriately. All attics should be adequately insulated. Floors over crawl spaces and ducts in crawl spaces should be insulated.

Most original HVAC systems are probably oversized after revitalization improvements have been performed. Replacement systems should be properly sized.

High-efficiency air conditioners should be installed at Altus during revitalization, but medium-efficiency (80% AFUE) furnaces may be most the cost-effective replacements for the moderate winters there. Adding ridge vents and removing the sliding covers on soffit vents

will improve attic ventilation at Altus. The problem of freezing water pipes in winter should be readdressed. Replacement windows should be energy-efficient, double-pane windows with low-E glass and argon filling, even though single-pane windows with storm windows will suffice.

Whole-house fans may be a more suitable and effective substitute than installing central air-conditioning at Malmstrom. A small wire fence around the area where condensing furnace flue and supply pipes exit each house at Malmstrom may reduce the potential safety hazards there.

Attic and wall insulation are needed at Fort Monmouth, as well as general air and distribution system tightening.

All hot water temperatures should be set to a maximum of 130°F, low-flow showerheads (2.25 gpm) should be installed in all houses, and low-flush toilets (1.7 gal per flush) should also be considered.

All replacement street lighting and permanent interior wall and ceiling lighting fixtures should be energy efficient. High-efficiency non-CFC (R134a refrigerant) refrigerators should be purchased at replacement time. Replacement dishwashers should use low amounts of hot water. Occupants should be made aware that efficient washing machines and dryers are available and should be urged to consider them when purchasing one.

NEAT suggested that there is upwards of 20% of energy to be saved in the houses we inspected, even though duct leakage is not considered by NEAT. We estimate that about 35% of the present energy can be saved when distribution systems are considered.

The shortcomings of the Family Housing Plans in the area of energy efficiency accentuate the need for a guidebook to promote energy efficiency.

8. REFERENCES

1. M. P. Ternes and S. Scully, *Energy-Efficiency Evaluation of the Housing Community Plan Developed for Shaw Air Force Base*, ORNL/TM-12033, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 1992.
2. *Household Energy Consumption and Expenditures 1987*, Part 1, DOE/EIA-0321/1(87), October 1989.
3. *Facility Design and Planning Engineering Weather Data*, AFM 88-29, TM 5-785, NAVFAC P-89, July 1978.

APPENDIX A

U.S. AIR FORCE AND U.S. ARMY FAMILY HOUSING DEIS DATA AND NEAT ENERGY ANALYSIS SUMMARY REPORTS

Table A.1. U.S. Air Force family housing data from DEIS database (1)

		FISCAL YEAR 1992								FISCAL YEAR 1985							
Name of Base	St	1992 CDD	1992 HDD	Area kSF	MB/kSF Total	MB/kSF Elec	MB/kSF Tot-El	B/SF/CD Elec	B/SF/HD Tot-El	1985 CDD	1985 HDD	Area kSF	MB/kSF Total	MB/kSF Elec	MB/kSF Tot-El	B/SF/CD Elec	B/SF/HD Tot-El
ALTUS AFB	OK	1962	2797	1110	98.9	34.6	64.2	17.6	22.9	2616	3213	1080	120.4	42.6	77.7	16.3	24.2
ANDREWS AFB	MD	841	4042	2992	109.1	49.9	59.1	59.4	14.6	1207	4030	2999	107.1	47.4	59.7	39.2	14.8
BARKSDALE AFB	LA	1945	622	790	129.2	56.2	73.0	28.9	117.4	2437	2222	1540	97.2	40.8	56.3	16.7	25.3
BEALE AFB*	CA	2129	737	2567	86.7	86.7	0.0	40.7	0.0	1187	3226	2266	98.2	98.2	0.0	82.7	0.0
BERGSTROM AFB	TX	2873	1540	856	104.7	57.7	46.9	20.1	30.5	3355	1709	844	137.0	55.7	81.2	16.6	47.5
BOLLING AFB	DC	841	4042	2112	71.7	50.4	21.3	59.9	5.2	1207	4030	2112	87.9	71.1	16.7	58.9	4.1
CANNON AFB	NM	674	3907	1387	97.7	23.0	74.7	34.2	19.1	1180	4160	1413	108.1	20.2	87.9	17.1	21.1
CARSWELL AFB	TX	2156	1789	1139	59.3	23.2	36.0	10.8	20.1	2777	2382	1068	117.6	43.9	73.7	15.8	30.9
CASTLE AFB	CA	2067	670	1326	85.6	35.5	50.1	17.2	74.8	1172	3060	999	117.9	37.9	80.0	32.4	26.1
CHANUTE AFB	IL	928	5035	2085	106.8	26.3	80.4	28.4	15.9	1206	5177	2069	116.3	18.5	97.8	15.4	18.8
CHARLESTON AFB	SC	2293	1821	1171	108.8	44.6	64.2	19.4	35.2	2466	1945	1140	125.7	49.7	75.9	20.1	39.0
COLUMBUS AFB*	MS	1843	2424	1076	56.9	56.9	0.0	30.8	0.0	2002	2760	1054	62.1	62.1	0.0	31.0	0.0
DAVIS MONTHAN AF	AZ	3186	1473	1644	89.0	36.3	52.7	11.3	35.7	2808	1792	1374	100.9	33.8	67.0	12.0	37.4
DOVER AFB	DE	919	4554	2092	94.1	33.0	61.1	35.9	13.4	1201	4152	2090	96.0	32.4	63.5	27.0	15.3
DYESS AFB	TX	1700	935	1450	53.6	29.7	23.9	17.5	25.5	2503	2756	1172	114.2	43.1	71.1	17.2	25.8
EAKER AFB	AR	70	795	1463	60.0	19.1	40.9	273.5	51.4	1837	3556	1292	108.8	32.9	75.8	17.9	21.3
EDWARDS AFB	CA	1517	2667	2575	117.1	22.0	95.0	14.5	35.6	1593	346	2952	115.5	30.2	85.3	18.9	246.5
EGLIN AFB	FL	2279	1554	3355	66.0	36.1	29.8	15.8	19.2	2579	1463	3355	95.8	54.0	41.8	20.9	28.5
ELLSWORTH AFB	LA	224	3736	2999	96.5	29.1	67.3	130.3	18.0	715	7190	2471	93.4	18.7	74.7	26.2	10.3
ENGLAND AFB	LA	1102	1665	816	81.4	27.8	53.5	25.3	32.1	2398	1776	797	118.6	43.8	74.7	18.3	42.0
F E WARREN AFB	WY	159	6538	1879	125.3	10.0	115.3	63.1	17.6	270	7924	1477	105.1	13.7	91.4	50.7	11.5
FAIRCHILD AFB	WA	394	6489	2102	90.6	36.0	54.6	91.4	8.4	457	7508	1875	118.9	38.5	80.3	84.3	10.7
GEORGE AFB	CA	2042	2561	1997	57.3	18.4	38.9	9.0	15.2	1674	3033	1997	105.8	24.2	81.7	14.4	26.9
GRAND FORKS AFB	ND	180	9261	3987	71.8	34.0	37.8	189.2	4.0	228	9362	4214	91.5	32.6	58.8	143.3	6.2
GRIFFISS AFB	NY	249	2830	1024	110.7	24.0	86.7	96.6	30.6	404	6687	1073	118.5	20.6	97.8	51.0	14.6
GRISSOM AFB	IN	578	5732	1545	121.8	17.1	104.7	29.6	18.2	950	5419	1498	124.0	13.6	110.4	14.3	20.3
HILL AFB	UT	652	5516	1487	99.9	22.3	77.5	34.3	14.0	1047	6654	1487	130.3	24.7	105.6	23.6	15.8
HOLLOMAN AFB	NM	1053	1788	2105	103.2	20.6	82.5	19.6	46.1	1659	3381	2087	149.3	23.4	125.9	14.1	37.2
HOMESTEAD AFB*	FL	2567	65	2124	60.5	60.5	0.0	23.6	0.0	3988	413	2127	63.2	63.2	0.0	15.8	0.0
K I SAWYER AFB	MI	73	8870	3308	87.5	31.1	56.4	426.4	6.3	69	9055	3336	94.8	34.2	60.5	496.1	6.6
KEESLER AFB	MS	2576	1495	2576	66.3	38.2	28.1	14.8	18.8	2811	1361	2495	87.6	40.6	46.9	14.4	34.4
KELLY AFB	TX	2845	1406	741	37.8	28.1	9.7	9.8	6.9	3224	1002	715	62.7	40.4	22.2	12.5	22.1
KIRTLAND AFB	NM	1179	4058	3405	94.7	23.5	71.1	19.9	17.5	1189	4547	3009	98.6	11.2	87.3	9.4	19.2
L G HANSCOM AFB	MA	731	5328	1158	126.5	26.0	100.4	35.6	18.8	627	5785	947	112.4	21.1	91.3	33.6	15.7
LACKLAND AFB	TX	2844	1406	1046	79.8	32.9	46.9	11.5	33.3	3357	1479	1042	88.7	29.3	59.3	8.7	40.1
LANGLEY AFB	VA	1280	3571	2674	74.3	40.2	34.0	31.4	9.5	1840	3033	2631	100.0	44.3	55.7	24.1	18.3
LAUGHLIN AFB	TX	3151	1013	794	79.2	30.3	48.9	9.6	48.2	3009	1652	798	98.7	34.5	64.2	11.4	38.9
LITTLE ROCK AFB*	AR	2131	2546	2094	54.8	54.8	0.0	25.7	0.0	1806	3198	1694	66.6	66.6	0.0	36.8	0.0
LORING AFB	ME	101	9713	3421	78.2	11.5	66.6	114.6	6.8	131	9184	2964	113.4	13.2	100.1	101.1	10.9
LOS ANGELES AFS	CA	928	830	1075	29.8	10.9	18.8	11.8	22.7	747	95	384	46.9	13.9	32.9	18.6	346.7
LOWRY AFB	CO	426	5868	1350	112.3	19.1	93.2	44.9	15.8	557	6457	1306	127.1	15.8	111.3	28.4	17.2
LUKE AFB	AZ	3430	1159	1262	70.5	40.9	29.6	11.9	25.6	3352	1452	1266	86.5	42.4	44.1	12.6	30.4
MACDILL AFB	FL	3718	432	1175	57.3	33.1	24.2	8.9	56.1	3488	626	1058	65.8	43.1	22.6	12.3	36.2
MALMSTROM AFB	MT	326	6420	2115	98.4	24.5	73.8	75.4	11.5	477	7957	2060	143.1	22.7	120.4	47.6	15.1
MARCH AFB	CA	1960	818	1177	85.7	29.3	56.4	14.9	69.0	1114	2567	979	115.2	17.7	97.5	15.9	37.9
MATHER AFB	CA	1684	2335	1711	84.9	33.8	51.0	20.1	21.8	1129	2961	1647	94.0	25.9	68.0	22.9	22.9
MAXWELL AFB	AL	2040	2227	1164	73.2	30.7	42.5	15.0	19.1	2479	1909	1224	79.3	33.6	45.6	13.5	23.9
MCCHORD AFB	WA	196	4495	1212	116.6	110.0	6.5	561.7	1.4	147	5730	1203	93.8	70.1	23.6	477.3	4.1
MCCLELLAN AFB	CA	2171	1938	879	105.0	36.3	68.6	16.7	35.4	1462	2542	882	119.7	26.6	93.1	18.1	36.6
MCCONNELL AFB	KS	1408	3802	1308	52.4	16.2	36.2	11.5	9.5	1695	4677	1329	72.3	20.8	51.5	12.2	11.0
MCGUIRE AFB	NJ	795	4909	2224	139.9	36.1	103.8	45.4	21.1	1060	4783	2042	135.0	31.1	103.8	29.4	21.7
MINOT AFB	ND	259	8603	5151	82.9	14.4	68.4	55.6	7.9	160	9585	4550	111.1	16.9	94.2	105.6	9.8
MT HOME AFB	ID	962	5010	2187	82.2	34.9	47.3	36.3	9.4	850	6931	2155	111.3	31.9	79.3	37.6	11.4
MYRTLE BEACH AFB*	SC	1731	2409	1078	58.2	58.2	0.0	33.6	0.0	1898	2257	1111	67.0	65.0	1.9	34.2	0.8
NELLIS AFB	NV	3027	2099	1949	88.3	51.4	36.9	16.9	17.6	3209	2170	2040	97.6	48.2	49.4	15.0	22.7
OFFUTT AFB	NE	925	5309	4949	75.8	12.5	63.3	13.5	11.9	963	5840	4371	100.1	19.8	80.2	20.6	13.7
PLATTSBURGH AFB	NY	11	8290	2606	147.7	14.4	133.3	1310.8	16.0	265	7394	2561	159.7	17.5	142.2	66.0	19.2
POPE AFB	NC	1435	2920	729	37.7	29.3	8.3	20.4	2.8	1870	2842	707	93.1	35.1	58.0	18.8	20.4
RANDOLPH AFB	TX	2959	1423	1592	54.2	23.4	30.7	7.9	21.6	2538	1736	1392	98.7	56.7	42.0	22.3	24.1
ROBINS AFB	GA	2026	1606	1838	106.9	45.3	61.6	22.3	38.3	2415	2126	1838	117.5	46.7	70.8	19.3	33.3
SCOTT AFB	IL	1337	4248	2632	99.7	35.2	64.4	26.3	15.1	1258	4734	2647	115.4	42.6	72.7	33.9	15.3
SEYMOUR JOHNSON	NC	1810	2860	2169	58.7	53.2	5.4	29.4	1.9	1682	2792	2173	65.2	57.6	7.6	34.2	2.7
SHAW AFB	SC	1874	1730	2464	63.5	43.8	19.6	23.4	11.3	1930	2146	2462	76.7	46.5	30.2	24.1	14.1
SHEPPARD AFB	TX	2115	2751	1531	100.7	34.3	66.4	16.2	24.1	2274	3170	1531	95.7	44.6	51.0	19.6	16.1
TINKER AFB	OK	1527	2697	1090	83.6	26.5	57.1	17.3	21.1	2159	3481	1014	91.5	31.2	60.2	14.4	17.3
TRAVIS AFB	CA	1402	2600	3051	69.8	19.2	50.6	13.7	19.4	969	2933	2663	118.8	21.6	97.2	22.2	33.1
TYNDALL AFB	FL	2310	1538	1427	69.6	46.1	23.4	19.9	15.2	2655	1020	1352	73.2	49.0	24.1	18.4	23.6
USAF ACADEMY	CO	127	7459	2345	74.9	15.5	59.3	122.4	7.9	80	7951	2345	83.5	13.3	70.1	167.1	8.8
WHITEMAN AFB	MO	980	4490	1939	71.8	20.8	51.0	21.2	11.3	1277	4903	1802	84.7	17.0	67.6	13.3	13.8
WILLIAMS AFB	AZ	2812	1022	953	55.3	32.6	22.7	11.6	22.2	3381	1392	1031	61.2	37.1	24.1	10.9	17.3
WRIGHT PATTERSON	OH	592	5431	3408	75.4	28.4	46.9	48.0	8.6	985	5235	3408	89.1	38.0	51.1	38.6	9.7
WURTSMITH AFB	MI	334	7952	6233	30.1	5.8	24.2	17.6	3.0	387	7331	2565	78.8	25.9	52.8	67.1	7.2
AVERAGES PER BASE		1472	3398	1978	82.5	31.2	51.2	21.2	15.0	1640	3908	1842	101.5	35.1	66.4	21.4	17.0

Notes: * = Electric Heat; CDD, CD = Cooling Degree Days; HDD, HD = Heating Degree Days; kSF, SF = (Thousand) Square Feet
MB, B = (Million) Btu; Total, Tot = Total Consumption from All Fuels; Elec, El = Electrical Consumption in MBtu

Table A.2. U.S. Air Force family housing data from DEIS database (2)

Name of Base	St	RATIOS BETWEEN FISCAL YEARS 1992/1985						
		Total MBtu/kSF	Elec MBtu/kSF	Tot-Elec MBtu/kSF	CDD 85/92	HDD 85/92	Elec B/SF/CDD	Tot-Elec B/SF/HDD
ALTUS AFB	OK	0.822	0.813	0.827	1.333	1.149	1.083	0.950
ANDREWS AFB	MD	1.018	1.054	0.990	1.435	0.997	1.512	0.987
BARKSDALE AFB	LA	1.330	1.376	1.296	1.253	3.572	1.724	4.631
BEALE AFB*	CA	0.883	0.883	1.000	0.558	4.377	0.492	---
BERGSTROM AFB	TX	0.764	1.035	0.578	1.168	1.110	1.209	0.642
BOLLING AFB	DC	0.815	0.708	1.269	1.435	0.997	1.016	1.265
CANNON AFB	NM	0.904	1.138	0.850	1.751	1.065	1.993	0.905
CARSWELL AFB	TX	0.504	0.530	0.489	1.288	1.331	0.683	0.651
CASTLE AFB	CA	0.726	0.936	0.627	0.567	4.567	0.531	2.862
CHANUTE AFB	IL	0.918	1.420	0.823	1.300	1.028	1.845	0.846
CHARLESTON AFB	SC	0.866	0.896	0.846	1.075	1.068	0.964	0.903
COLUMBUS AFB*	MS	0.915	0.915	0.000	1.086	1.139	0.994	---
DAVIS MONTHAN AF	AZ	0.882	1.072	0.786	0.881	1.217	0.945	0.956
DOVER AFB	DE	0.980	1.017	0.962	1.307	0.912	1.329	0.877
DYESS AFB	TX	0.470	0.690	0.337	1.472	2.948	1.016	0.992
EAKER AFB	AR	0.552	0.581	0.539	26.243	4.473	15.238	2.412
EDWARDS AFB	CA	1.014	0.731	1.114	1.050	0.130	0.768	0.145
EGLIN AFB	FL	0.689	0.669	0.715	1.132	0.941	0.757	0.673
ELLSWORTH AFB	LA	1.033	1.556	0.901	3.192	1.925	4.967	1.734
ENGLAND AFB	LA	0.687	0.635	0.717	2.176	1.067	1.383	0.765
F E WARREN AFB	WY	1.192	0.732	1.260	1.698	1.212	1.244	1.528
FAIRCHILD AFB	WA	0.762	0.935	0.680	1.160	1.157	1.084	0.787
GEORGE AFB	CA	0.542	0.761	0.477	0.820	1.184	0.624	0.565
GRAND FORKS AFB	ND	0.785	1.042	0.643	1.267	1.011	1.320	0.650
GRIFFISS AFB	NY	0.935	1.167	0.886	1.622	2.363	1.893	2.093
GRISSOM AFB	IN	0.982	1.257	0.948	1.644	0.945	2.066	0.897
HILL AFB	UT	0.766	0.904	0.734	1.606	1.206	1.451	0.885
HOLLOMAN AFB	NM	0.691	0.882	0.656	1.575	1.891	1.390	1.240
HOMESTEAD AFB*	FL	0.958	0.958	0.000	1.554	6.354	1.488	---
K I SAWYER AFB	MI	0.923	0.909	0.931	0.945	1.021	0.859	0.951
KEESLER AFB	MS	0.757	0.939	0.599	1.091	0.910	1.025	0.545
KELLY AFB	TX	0.604	0.695	0.439	1.133	0.713	0.788	0.313
KIRTLAND AFB	NM	0.960	2.088	0.815	1.008	1.121	2.106	0.913
L G HANSCOM AFB	MA	1.125	1.234	1.100	0.858	1.086	1.058	1.194
LACKLAND AFB	TX	0.900	1.123	0.790	1.180	1.052	1.325	0.831
LANGLEY AFB	VA	0.743	0.908	0.612	1.438	0.849	1.305	0.520
LAUGHLIN AFB	TX	0.802	0.879	0.761	0.955	1.631	0.839	1.241
LITTLE ROCK AFB*	AR	0.823	0.823	0.000	0.847	1.256	0.697	---
LORING AFB	ME	0.690	0.874	0.665	1.297	0.946	1.134	0.629
LOS ANGELES AFS	CA	0.636	0.787	0.572	0.805	0.114	0.633	0.066
LOWRY AFB	CO	0.884	1.209	0.838	1.308	1.100	1.581	0.922
LUKE AFB	AZ	0.816	0.965	0.672	0.977	1.253	0.943	0.842
MACDILL AFB	FL	0.872	0.768	1.068	0.938	1.449	0.721	1.547
MALMSTROM AFB	MT	0.688	1.082	0.613	1.463	1.239	1.583	0.760
MARCH AFB	CA	0.744	1.651	0.579	0.568	3.138	0.938	1.817
MATHER AFB	CA	0.904	1.305	0.750	0.670	1.268	0.875	0.951
MAXWELL AFB	AL	0.924	0.914	0.931	1.215	0.857	1.111	0.798
MCCHORD AFB	WA	1.243	1.569	0.277	0.750	1.275	1.177	0.353
MCCLELLAN AFB	CA	0.877	1.367	0.737	0.673	1.312	0.921	0.967
MCCONNELL AFB	KS	0.725	0.780	0.703	1.204	1.230	0.939	0.865
MCGUIRE AFB	NJ	1.037	1.160	1.000	1.333	0.974	1.546	0.974
MINOT AFB	ND	0.746	0.853	0.726	0.618	1.114	0.527	0.809
MT HOME AFB	ID	0.739	1.094	0.596	0.884	1.383	0.967	0.824
MYRTLE BEACH AFB*	SC	0.869	0.895	0.000	1.096	0.937	0.982	---
NELLIS AFB	NV	0.905	1.066	0.748	1.060	1.034	1.130	0.773
OFFUTT AFB	NE	0.758	0.630	0.790	1.041	1.100	0.656	0.869
PLATTSBURGH AFB	NY	0.925	0.824	0.937	24.091	0.892	19.839	0.836
POPE AFB	NC	0.405	0.836	0.144	1.303	0.973	1.089	0.140
RANDOLPH AFB	TX	0.549	0.413	0.733	0.858	1.220	0.354	0.894
ROBINS AFB	GA	0.909	0.969	0.869	1.192	1.324	1.155	1.151
SCOTT AFB	IL	0.864	0.826	0.886	0.941	1.114	0.777	0.987
SEYMOUR JOHNSON	NC	0.900	0.925	0.711	0.929	0.976	0.860	0.694
SHAW AFB	SC	0.828	0.943	0.650	1.030	1.240	0.971	0.806
SHEPPARD AFB	TX	1.053	0.769	1.301	1.075	1.152	0.826	1.499
TINKER AFB	OK	0.914	0.849	0.948	1.414	1.291	1.200	1.223
TRAVIS AFB	CA	0.588	0.891	0.521	0.691	1.128	0.616	0.588
TYNDALL AFB	FL	0.951	0.940	0.972	1.149	0.663	1.080	0.645
USAF ACADEMY	CO	0.897	1.163	0.846	0.630	1.066	0.733	0.902
WHITEMAN AFB	MO	0.848	1.220	0.754	1.303	1.092	1.590	0.823
WILLIAMS AFB	AZ	0.903	0.877	0.943	1.202	1.362	1.055	1.285
WRIGHT PATTERSON	OH	0.846	0.748	0.919	1.664	0.964	1.244	0.886
WURTSMITH AFB	MI	0.383	0.226	0.459	1.159	0.922	0.262	0.424
AVERAGES PER BASE		0.831	0.962	0.762	1.114	1.150	1.072	0.876

Notes: * = Electric Heat; CDD = Cooling Degree Days; HDD = Heating Degree Days; kSF, SF = (Thousand) Square Feet
MB, B = (Million) Btu; Total, Tot = Total Consumption from All Fuels; Elec = Electrical; Consumption in MBtu

Table A.3. U.S. Army installations energy use from DEIS database

Installation Name	Region	En Use Budget (MB/kSF)	Degree Days		Total Energy (MBtu/kSF)					Thermal Energy (MBtu/kSF)					Electric Energy (MBtu/kSF)				
			Heat	Cool	1985	1990	1991	1992	92/85	1985	1990	1991	1992	92/85	1985	1990	1991	1992	92/85
FT DRUM	5	55	7601	452	72	90	86	94	1.294	41	71	68	75	1.828	31	19	19	18	0.591
FT MCCOY	5	55	7558	573	98	90	76	86	0.885	84	76	64	67	0.797	14	14	11	20	1.413
FITZSIMONS AMC	6	45	6016	625	122	98	83	84	0.687	109	85	70	71	0.651	13	13	13	13	0.985
FT BEN HARRISON	6	45	5577	974	103	102	88	93	0.908	80	78	64	69	0.858	23	23	24	25	1.081
FT CARSON	6	45	6373	692	117	113	110	101	0.863	104	102	99	87	0.840	14	11	12	14	1.041
FT DEVENS	6	45	6475	560	123	98	78	82	0.666	96	80	66	72	0.753	27	19	12	10	0.360
FT SHERIDAN	6	45	6068	826	122	138	131	78	0.644	107	121	114	72	0.669	14	17	17	7	0.457
WEST POINT	6	45	5753	830	74	79	76	84	1.137	60	64	62	69	1.155	13	14	14	14	1.056
ABERDEEN PROV GND	7	45	5184	1076	118	82	76	81	0.692	96	44	37	41	0.424	21	38	39	40	1.909
CARLISLE BARRACKS	7	45	5269	995	127	118	114	139	1.094	111	98	93	121	1.094	16	20	21	18	1.092
FT BELVOIR	7	45	4891	1120	78	89	84	82	1.043	47	53	49	49	1.035	31	36	35	33	1.054
FT CAMPBELL	7	45	4290	1472	77	69	71	70	0.902	31	25	28	27	0.887	47	44	43	43	0.912
FT DIETRICK	7	45	5059	948	103	95	85	94	0.910	76	68	63	69	0.911	27	26	22	24	0.907
FT DIX	7	45	5139	983	127	124	123	116	0.912	111	106	99	82	0.735	16	19	24	34	2.135
FT GEORGE MEADE	7	45	4733	1039	110	118	104	108	0.982	88	85	77	82	0.933	22	33	28	26	1.174
FT HAMILTON	7	45	5184	861	103	125	108	116	1.121	96	115	97	105	1.104	8	10	11	11	1.335
FT KNOX	7	45	4616	1360	120	121	115	113	0.943	92	86	79	79	0.858	28	34	36	34	1.222
FT LEAVENWORTH	7	45	4822	1292	108	72	70	54	0.499	88	56	54	38	0.428	20	16	16	16	0.819
FT LEONARD WOOD	7	45	4707	1314	111	109	110	111	1.004	83	76	74	75	0.908	28	33	36	36	1.287
FT LEWIS	7	45	5339	110	99	80	82	71	0.722	69	52	55	45	0.655	30	29	27	26	0.877
FT MCNAIR	7	45	4153	1517	85	118	113	80	0.938	62	76	68	73	1.171	23	42	45	7	0.307
FT MONMOUTH	7	45	5128	770	122	148	124	151	1.243	99	126	102	129	1.307	23	22	22	23	0.971
FT MYER	7	45	4211	1415	92	87	68	72	0.791	80	72	53	58	0.726	11	15	15	14	1.249
FT RILEY	7	45	5306	1503	73	81	79	74	1.013	39	43	41	39	1.012	35	38	38	35	1.015
WALTER REED AMC	7	45	4483	1217	88	80	71	65	0.741	54	39	36	33	0.610	35	41	35	33	0.945
FT BRAGG	8	45	3105	1760	71	58	59	62	0.869	38	19	16	18	0.481	32	39	43	43	1.330
FT EUSTIS	8	45	3752	1585	80	82	73	68	0.846	37	34	27	28	0.750	43	47	46	40	0.929
FT GORDON	8	45	2547	1995	49	45	58	53	1.065	18	13	24	20	1.105	31	32	34	33	1.042
FT HUACHUCA	8	45	2551	1573	104	81	80	91	0.876	76	67	66	77	1.008	28	13	14	14	0.517
FT LEE	8	45	3939	1353	95	63	58	50	0.531	57	36	31	29	0.512	37	27	27	21	0.562
FT MCCLELLAN	8	45	2806	1886	98	83	74	83	0.850	70	57	46	57	0.819	28	26	28	26	0.927
FT MCPHERSON	8	45	3095	1589	72	48	39	40	0.549	58	18	12	12	0.204	15	29	27	28	1.925
FT MONROE	8	45	3623	1539	92	74	61	65	0.701	54	58	44	49	0.913	38	16	17	15	0.401
FT ORD	8	45	3818	37	85	65	75	64	0.756	72	52	61	51	0.712	13	12	13	13	1.005
MC WESTERN AREA	8	45	3080	39	74	84	91	81	1.089	53	58	64	54	1.024	21	26	27	27	1.251
PRESIDIO OF SF	8	45	3080	39	74	86	81	64	0.866	64	73	68	55	0.863	10	13	13	9	0.889
FT BUCHANAN	10	50	0	4982	47	83	92	--	---	0	0	0	0	---	47	83	92	0	---
FT HOOD	10	50	1959	2792	74	70	69	69	0.941	41	36	36	36	0.876	33	34	33	33	1.023
FT POLK	10	50	1889	2666	50	45	43	44	0.865	6	3	3	3	0.527	44	43	40	40	0.911
FT RUCKER	10	50	1968	2386	85	83	82	79	0.934	50	51	49	52	1.034	35	32	33	28	0.790
FT SAM HOUSTON	10	50	1570	2994	78	73	69	66	0.848	45	39	37	36	0.803	33	34	32	30	0.908
FT STEWART	10	50	1713	2414	59	58	56	57	0.970	21	16	14	13	0.604	38	42	43	44	1.169
FT BENNING	11	55	2406	2203	60	83	76	80	1.327	33	41	37	44	1.316	27	42	39	36	1.340
FT BLISS	11	55	2432	2253	114	88	83	90	0.793	97	73	69	76	0.780	17	14	14	15	0.868
FT IRWIN	11	55	2547	2272	85	66	63	51	0.598	70	44	39	22	0.306	15	21	24	29	1.967
FT JACKSON	11	55	2598	2087	89	77	78	57	0.635	57	48	47	30	0.523	32	29	31	27	0.835
FT SILL	11	55	3367	2217	108	79	77	81	0.750	79	53	52	59	0.749	30	25	25	22	0.750
WHITE SANDS MR	11	55	2526	2243	61	57	54	58	0.955	43	39	36	39	0.911	18	18	18	19	1.059
Averages of Installations			4048	1446	91	86	82	80	0.876	65	59	54	54	0.823	26	28	28	24	0.944

Notes: MB/kSF = MBtu/kSF = Million Btu/1000 Square Feet at Location of use
En Use Budget = Energy Use Budget for New Construction as Proposed in September, 1992
Degree Days = Heating and Cooling Degree Days as in Air Force Manual 88-29 "Engineering Weather Data"
92/85 = Ratio of 1992/1985 for an item

Table A.4. U.S. Army installations energy costs from DEIS database

Installation Name	Region	En Use Budget (MB/kSF)	Degree Days		Total Energy Cost ($/kSF)					Thermal Energy Cost($/kSF)					Elec. Energy Cost ($/kSF)				
			Heat	Cool	1985	1990	1991	1992	92/85	1985	1990	1991	1992	92/85	1985	1990	1991	1992	92/85
FT DRUM	5	55	7601	452	824	742	737	824	1.000	235	373	347	390	1.658	589	369	390	434	0.737
FT MCCOY	5	55	7558	573	677	494	484	705	1.042	463	294	317	361	0.781	214	200	166	344	1.608
FITZSIMONS AMC	6	45	6016	625	523	389	388	345	0.660	322	204	197	158	0.489	201	186	191	188	0.935
FT BEN HARRISON	6	45	5577	974	722	595	550	545	0.754	481	368	310	273	0.569	242	227	240	271	1.121
FT CARSON	6	45	6373	692	636	583	563	534	0.841	504	446	423	356	0.706	132	137	140	179	1.355
FT DEVENS	6	45	6475	560	1232	854	661	641	0.520	716	458	420	445	0.622	516	395	240	196	0.379
FT SHERIDAN	6	45	6068	826	777	914	857	446	0.573	519	515	507	318	0.612	258	399	350	128	0.496
WEST POINT	6	45	5753	830	622	518	576	587	0.945	297	251	283	296	0.995	324	267	293	291	0.898
ABERDEEN PROV GND	7	45	5184	1076	969	744	888	847	0.874	649	185	245	199	0.306	320	559	643	648	2.028
CARLISLE BARRACKS	7	45	5269	995	1009	820	889	937	0.928	755	493	535	623	0.826	255	327	354	314	1.232
FT BELVOIR	7	45	4891	1120	792	753	929	806	1.017	323	234	303	221	0.683	469	519	626	585	1.248
FT CAMPBELL	7	45	4290	1472	734	752	739	735	1.001	125	72	88	89	0.710	609	680	651	646	1.061
FT DIETRICK	7	45	5059	948	856	636	501	547	0.639	593	378	283	303	0.511	264	259	218	245	0.928
FT DIX	7	45	5139	983	973	813	1040	816	0.839	587	441	546	379	0.647	386	373	494	436	1.130
FT GEORGE MEADE	7	45	4733	1039	870	925	770	744	0.855	527	415	316	323	0.612	343	510	453	421	1.228
FT HAMILTON	7	45	5184	861	944	811	995	992	1.051	643	492	699	534	0.830	301	319	296	458	1.521
FT KNOX	7	45	4616	1360	770	722	666	639	0.831	415	327	259	254	0.612	355	395	408	386	1.086
FT LEAVENWORTH	7	45	4822	1292	727	487	464	434	0.597	374	220	199	181	0.483	354	267	265	253	0.716
FT LEONARD WOOD	7	45	4707	1314	868	723	967	874	1.008	480	264	475	390	0.814	388	459	492	484	1.249
FT LEWIS	7	45	5339	110	581	506	473	441	0.760	458	264	254	224	0.489	122	242	219	217	1.776
FT MCNAIR	7	45	4153	1517	892	1160	1174	588	0.659	440	493	428	464	1.054	452	667	745	124	0.275
FT MONMOUTH	7	45	5128	770	1332	1139	1222	1232	0.925	689	596	692	678	0.983	643	543	530	555	0.863
FT MYER	7	45	4211	1415	673	501	507	443	0.658	478	299	297	249	0.520	195	202	210	194	0.995
FT RILEY	7	45	5306	1503	658	648	629	597	0.908	133	151	137	145	1.090	525	498	492	453	0.862
WALTER REED AMC	7	45	4483	1217	979	868	797	793	0.810	380	239	197	217	0.570	599	629	600	576	0.962
FT BRAGG	8	45	3105	1760	775	768	931	931	1.201	249	92	105	82	0.328	525	676	827	849	1.615
FT EUSTIS	8	45	3752	1585	859	871	925	759	0.884	253	144	184	131	0.519	606	727	741	628	1.036
FT GORDON	8	45	2547	1995	564	563	641	605	1.073	104	71	129	107	1.024	460	492	511	498	1.084
FT HUACHUCA	8	45	2551	1573	817	622	665	737	0.901	389	314	315	373	0.958	428	307	351	364	0.850
FT LEE	8	45	3939	1353	845	536	466	378	0.448	293	166	89	89	0.305	552	370	376	289	0.523
FT MCCLELLAN	8	45	2806	1886	842	620	591	613	0.728	395	240	189	237	0.600	447	380	403	376	0.842
FT MCPHERSON	8	45	3095	1589	582	614	541	541	0.930	346	131	90	92	0.267	236	484	451	449	1.903
FT MONROE	8	45	3623	1539	944	480	532	468	0.496	358	238	253	226	0.631	585	242	279	242	0.414
FT ORD	8	45	3818	37	763	569	686	617	0.809	457	316	408	334	0.731	306	254	278	283	0.924
MC WESTERN AREA	8	45	3080	39	893	1049	1046	1131	1.266	338	336	301	296	0.876	555	713	744	834	1.503
PRESIDIO OF SF	8	45	3080	39	799	679	760	598	0.748	497	394	476	380	0.766	303	284	285	217	0.717
FT BUCHANAN	10	50	0	4982	1398	2385	2486	---	---	0	0	0	---	---	1398	2385	2486	---	---
FT HOOD	10	50	1959	2792	688	617	631	646	0.938	167	144	146	149	0.893	521	473	484	496	0.952
FT POLK	10	50	1889	2666	652	739	730	687	1.054	28	13	15	15	0.521	624	726	715	672	1.078
FT RUCKER	10	50	1968	2386	771	619	643	589	0.763	233	177	192	206	0.884	538	442	451	383	0.711
FT SAM HOUSTON	10	50	1570	2994	681	589	603	571	0.838	238	134	152	139	0.584	443	454	451	432	0.974
FT STEWART	10	50	1713	2414	730	732	746	715	0.979	129	84	89	84	0.652	601	648	657	630	1.049
FT BENNING	11	55	2406	2203	545	743	727	654	1.200	161	137	155	164	1.017	384	606	572	490	1.277
FT BLISS	11	55	2432	2253	776	498	479	563	0.725	394	238	214	233	0.593	383	261	265	330	0.862
FT IRWIN	11	55	2547	2272	818	660	819	930	1.137	488	183	293	119	0.244	330	477	526	811	2.460
FT JACKSON	11	55	2598	2087	800	636	648	511	0.639	282	270	269	184	0.651	518	366	379	328	0.633
FT SILL	11	55	3367	2217	710	474	377	385	0.542	375	233	191	205	0.547	335	241	186	180	0.536
WHITE SANDS MR	11	55	2526	2243	462	487	463	500	1.083	192	146	123	132	0.689	270	342	340	368	1.364
Averages of Installations			4048	1446	799	722	742	664	0.831	374	264	274	256	0.685	425	458	468	408	0.960

Notes: MB/kSF = MBtu/kSF = Million Btu/1000 Square Feet at Location of use
En Use Budget = Energy Use Budget for New Construction as Proposed in September, 1992
Degree Days = Heating and Cooling Degree Days as in Air Force Manual 88-29 "Engineering Weather Data"
$/kSF = Annual Cost of Energy in Dollars/1000 Square Feet
92/85 = Ratio of 1992/1985 for an item

Table A.5. U.S. Army installations family housing data from DEIS database

Installation Name	Region	En Use Budget (MB/kSF)	Degree Days		Total Base Population (People)					MFH Conditioned Area (kSF)				
			Heat	Cool	1985	1990	1991	1992	92/85	1985	1990	1991	1992	92/85
FT DRUM	5	55	7601	452	8200	31317	40687	27249	3.32	563	5806	5966	5966	10.60
FT MCCOY	5	55	7558	573	3010	7319	7399	8114	2.70	252	252	252	150	0.60
FITZSIMONS AMC	6	45	6016	625	5542	4850	4850	4703	0.85	467	467	467	474	1.01
FT BEN HARRISON	6	45	5577	974	9397	5950	5700	4960	0.53	566	598	615	606	1.07
FT CARSON	6	45	6373	692	25844	23800	23800	23500	0.91	2870	2816	2806	2591	0.90
FT DEVENS	6	45	6475	560	11561	13995	13220	12359	1.07	2972	3021	2976	2976	1.00
FT SHERIDAN	6	45	6068	826	5794	6848	4686	250	0.04	986	976	976	976	0.99
WEST POINT	6	45	5753	830	9975	10800	12629	9811	0.98	3276	3276	3276	3276	1.00
ABERDEEN PROV GND	7	45	5184	1076	14047	67212	70809	70619	5.03	1876	2476	2462	2462	1.31
CARLISLE BARRACKS	7	45	5269	995	1720	1749	1778	1802	1.05	642	642	642	642	1.00
FT BELVOIR	7	45	4891	1120	16453	0	0	0	0.00	3068	3068	3068	3068	1.00
FT CAMPBELL	7	45	4290	1472	35277	31361	34126	30968	0.88	5990	5991	5991	5991	1.00
FT DIETRICK	7	45	5059	948	3760	4503	4585	4673	1.24	249	244	244	244	0.98
FT DIX	7	45	5139	983	23556	25006	20459	17177	0.73	2839	2768	2610	2610	0.92
FT GEORGE MEADE	7	45	4733	1039	42174	38001	37241	25	0.00	3861	3799	3857	3704	0.96
FT HAMILTON	7	45	5184	861	4293	3715	3715	3715	0.87	1741	1266	1266	1266	0.73
FT KNOX	7	45	4616	1360	34697	28310	27406	32003	0.92	6260	6262	6262	6262	1.00
FT LEAVENWORTH	7	45	4822	1292	10326	13965	12878	12878	1.25	3392	3324	3306	3387	1.00
FT LEONARD WOOD	7	45	4707	1314	27410	24801	22340	22271	0.81	3552	3552	3552	3552	1.00
FT LEWIS	7	45	5339	110	35351	48300	48300	32756	0.93	5991	6007	5920	5920	0.99
FT MCNAIR	7	45	4153	1517	2337	1626	1645	1531	0.66	238	166	166	166	0.70
FT MONMOUTH	7	45	5128	770	11000	13400	13497	13376	1.22	1610	1601	1649	1646	1.02
FT MYER	7	45	4211	1415	5203	3216	3250	3481	0.67	415	382	382	382	0.92
FT RILEY	7	45	5306	1503	25174	25852	26569	24052	0.96	5314	5329	5329	5329	1.00
WALTER REED AMC	7	45	4483	1217	9715	8107	9447	8994	0.93	348	347	347	345	0.99
FT BRAGG	8	45	3105	1760	57993	63874	63957	64536	1.11	7288	7357	7373	7373	1.01
FT EUSTIS	8	45	3752	1585	13102	15280	13266	13609	1.04	1816	1869	1851	1851	1.02
FT GORDON	8	45	2547	1995	17764	16150	17198	16149	0.91	1269	1269	1269	1269	1.00
FT HUACHUCA	8	45	2551	1573	11439	13235	10051	9142	0.80	3291	3290	3280	3281	1.00
FT LEE	8	45	3939	1353	11792	9733	10268	10264	0.87	2135	2122	2119	2120	0.99
FT MCCLELLAN	8	45	2806	1886	11990	11699	8646	7675	0.64	858	858	858	858	1.00
FT MCPHERSON	8	45	3095	1589	14553	6720	6221	6218	0.43	333	338	338	338	1.02
FT MONROE	8	45	3623	1539	1850	1813	2405	2405	1.30	583	583	583	583	1.00
FT ORD	8	45	3818	37	48433	21616	23224	23224	0.48	7085	9082	9304	9304	1.31
MC WESTERN AREA	8	45	3080	39	1996	1887	1877	1671	0.84	157	157	157	157	1.00
PRESIDIO OF SF	8	45	3080	39	14679	16207	15707	13565	0.92	2736	2736	2736	2736	1.00
FT BUCHANAN	10	50	0	4982	4232	5800	5680	0	0.00	507	507	507	0	0.00
FT HOOD	10	50	1959	2792	62262	58314	63161	50833	0.82	8222	8736	8723	8597	1.05
FT POLK	10	50	1889	2666	20824	30200	29971	29971	1.44	5410	8059	7835	7835	1.45
FT RUCKER	10	50	1968	2386	14905	13983	14091	15561	1.04	2072	2072	2010	2010	0.97
FT SAM HOUSTON	10	50	1570	2994	17505	18261	14872	14023	0.80	2307	2307	2307	2307	1.00
FT STEWART	10	50	1713	2414	40000	30648	30319	28182	0.70	3861	4098	4098	4098	1.06
FT BENNING	11	55	2406	2203	47901	49280	43269	41556	0.87	6473	6482	6482	6482	1.00
FT BLISS	11	55	2432	2253	29002	31289	39885	29520	1.02	4806	4804	5305	5305	1.10
FT IRWIN	11	55	2547	2272	8696	13719	13800	13800	1.59	1452	2950	2950	2950	2.03
FT JACKSON	11	55	2598	2087	23303	19372	19337	18935	0.81	1700	1847	1847	1847	1.09
FT SILL	11	55	3367	2217	30528	26281	19818	20129	0.66	2508	2512	2512	2511	1.00
WHITE SANDS MR	11	55	2526	2243	0	9780	9780	10196	0.00	1290	1252	1252	1252	0.97
Averages of Installations			4048	1446	18470	19357	19330	16926	0.92	2656	2911	2918	2897	1.09

Notes: MB/kSF = MBtu/kSF = Million Btu/1000 Square Feet at Location of use.
En Use Budget = Energy Use Budget for New Construction as Proposed in September, 1992.
Degree Days = Heating and Cooling Degree Days as in Air Force Manual 88-29 "Engineering Weather Data".
92/85 = Ratio of 1992/1985 for an item.
Total Base Population includes all people working on base, not just Family Housing sector.

NEAT ENERGY ANALYSIS SUMMARY REPORT

Table A.6. The A01 house on 108A Ridley in the Oklahoma City weather region

108a Ridley St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	903	903
Conditioned House Volume (Cu Ft)	7,224	7,224
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft^2/Yr)	39,867	35,437
Heating Load @ 9°F Design Conditions (Btu/Hr)	28,000	26,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	24.0	24.0	0.0
Space Cooling System	12.0	8.0	4.0
Totals	36.0	32.0	4.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Sun screen, louvered	Windows	370.00	-19.2%	34.5%	0.0%	0.0%
Smart thermostat	HVAC	65.00	10.0%	0.0%	0.0%	0.0%
Wall insulation	HVAC	88.00	8.8%	0.1%	0.0%	0.0%
Duct insulation	HVAC	11.00	0.4%	0.0%	0.0%	0.0%
TOTALS		534.00	0.0%	34.6%	0.0%	0.0%

Table A.7. The A02 house on 180 Liberty in the Oklahoma City weather region

180 Liberty St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	1369	1369
Conditioned House Volume (Cu Ft)	10,952	10,952
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft^2/Yr)	29,219	28,488
Heating Load @ 9°F Design Conditions (Btu/Hr)	31,000	31,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	27.0	32.0	-5.0
Space Cooling System	13.0	7.0	6.0
Totals	40.0	39.0	1.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	9.6%	0.0%	0.0%	0.0%
Sun screen, louvered	Windows	609.00	-27.0%	41.0%	0.0%	0.0%
Duct insulation	HVAC	11.00	0.7%	0.0%	0.0%	0.0%
TOTALS		685.00	-16.7%	41.0%	0.0%	0.0%

Table A.8. The A03 house on 339 Birch in the Oklahoma City weather region

339 Birch St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1176	1176
Conditioned House Volume (Cu Ft)	9,408	9,408
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	33,163	30,612
Heating Load @ 9°F Design Conditions (Btu/Hr)	31,000	30,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	28.0	27.0	1.0
Space Cooling System	11.0	9.0	2.0
Totals	39.0	36.0	3.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	3.8%	0.0%	0.0%	0.0%
Low-E windows	Windows	100.00	11.6%	1.9%	0.0%	0.0%
Sun screen, louvered	Windows	328.00	-18.4%	20.1%	0.0%	0.0%
Totals		493.00	-3.0%	22.0%	0.0%	0.0%

Table A.9. The A04 house on 165 Woodring in the Oklahoma City weather region

165 Woodring St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1219	1219
Conditioned House Volume (Cu Ft)	9,752	9,752
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	33,634	32,813
Heating Load @ 9°F Design Conditions (Btu/Hr)	31,000	31,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	26.0	31.0	-5.0
Space Cooling System	15.0	9.0	6.0
Totals	41.0	40.0	1.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	10.0%	0.0%	0.0%	0.0%
Sun screen, louvered	Windows	631.00	-31.1%	36.6%	0.0%	0.0%
Duct insulation	HVAC	13.00	0.8%	0.0%	0.0%	0.0%
TOTALS		709.00	-20.3%	36.6%	0.0%	0.0%

Table A.10. The A05 house on 439 Jasmine in the Oklahoma City weather region

439 Jasmine St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1601	1601
Conditioned House Volume (Cu Ft)	12,808	12,808
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	28,107	18,738
Heating Load @ 9°F Design Conditions (Btu/Hr)	36,000	35,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	30.0	26.0	4.0
Space Cooling System	15.0	14.0	1.0
Totals	45.0	30.0	5.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	9.7%	0.0%	0.0%	0.0%
Duct insulation	HVAC	51.00	2.7%	0.9%	0.0%	0.0%
TOTALS		116.00	12.4%	0.9%	0.0%	0.0%

Table A.11. The A06 house on 76 So. Gum in the Oklahoma City weather region

76 So. Gum St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1385	1385
Conditioned House Volume (Cu Ft)	11,080	11,080
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	34,657	34,657
Heating Load @ 9°F Design Conditions (Btu/Hr)	36,000	36,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	34.0	38.0	-4.0
Space Cooling System	14.0	10.0	4.0
Totals	48.0	48.0	0.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	9.4%	0.0%	0.0%	0.0%
Sun screen, louvered	Windows	515.00	-22.9%	32.1%	0.0%	0.0%
Duct insulation	HVAC	13.00	0.6%	0.0%	0.0%	0.0%
Totals		593.00	-13.2%	32.1%	0.0%	0.0%

Table A.12. The A07 House on 534 Alpha in the Oklahoma City weather region

534 Alpha St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	1250	1250
Conditioned House Volume (Cu Ft)	10,000	10,000
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage ($Btu/Ft^2/Yr$)	32,800	28,800
Heating Load @ 9°F Design Conditions (Btu/Hr)	37,000	36,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	30.0	25.0	6.0
Space Cooling System	11.0	11.0	0.0
Totals	41.0	36.0	6.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	10.0%	0.0%	0.0%	0.0%
Storm windows	Windows	102.00	4.0%	1.5%	0.0%	0.0%
TOTALS		167.00	14.0%	1.5%	0.0%	0.0%

NEAT ENERGY ANALYSIS SUMMARY REPORT

Table A.13. The M01 House on 4930B Locust in the Helena weather region

4930B Locust St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	2904	2904
Conditioned House Volume (Cu Ft)	23,232	23,232
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	32,024	20,316
Heating Load @ -21°F Design Conditions (Btu/Hr)	42,000	32,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	93.0	59.0	34.0
Space Cooling System	0.0	0.0	0.0
Totals	93.0	59.0	34.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Sillbox insulation	General	45.00	5.6%	0.0%	0.0%	0.0%
Attic insulation	General	117.00	2.5%	0.0%	0.0%	0.0%
Foundation insulation	General	1607.00	28.9%	0.0%	0.0%	0.0%
TOTALS		1769.00	37.0%	0.0%	0.0%	0.0%

Table A.14. The M02 house on 4201A Elder in the Helena weather region

4201A Elder St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	2386	2386
Conditioned House Volume (Cu Ft)	19,088	19,088
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	33,948	20,117
Heating Load @ -21°F Design Conditions (Btu/Hr)	39,000	30,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	81.0	48.0	33.0
Space Cooling System	0.0	0.0	0.0
Totals	81.0	48.0	33.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Sillbox insulation	General	38.00	5.3%	0.0%	0.0%	0.0%
Attic insulation	General	128.00	3.2%	0.0%	0.0%	0.0%
Foundation insulation	General	1529.00	31.1%	0.0%	0.0%	0.0%
Totals		1695.80	39.6%	0.0%	0.0%	0.0%

Table A.15. The M03 house on 5223B Pecan in the Helena weather region

5223B Pecan St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1170	1170
Conditioned House Volume (Cu Ft)	9,735	9,735
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	38,462	29,914
Heating Load @ -21°F Design Conditions (Btu/Hr)	28,000	25,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	45.0	35.0	10.0
Space Cooling System	0.0	0.0	0.0
Totals	45.0	35.0	10.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic insulation	General	450.00	21.6%	0.0%	0.0%	0.0%
TOTALS		450.00	21.6%	0.0%	0.0%	0.0%

Table A.16. The M04 house on 932 Lincoln in the Helena weather region

932 Lincoln Dr. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1039	1039
Conditioned House Volume (Cu Ft)	8,677	8,677
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	26,949	25,024
Heating Load @ -21°F Design Conditions (Btu/Hr)	21,000	21,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	28.0	26.0	2.0
Space Cooling System	0.0	0.0	0.0
Totals	28.0	26.0	2.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart thermostat	HVAC	65.00	6.4%	0.0%	0.0%	0.0%
TOTALS		65.00	6.4%	0.0%	0.0%	0.0%

Table A.17. The M06 house on 174 Malmstrom in the Helena weather region

174 Malmstrom Dr. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1350	1350
Conditioned House Volume (Cu Ft)	11,475	11,475
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	87,404	37,777
Heating Load @ -21°F Design Conditions (Btu/Hr)	51,000	25,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	118.0	51.0	67.0
Space Cooling System	0.0	0.0	0.0
Totals	118.0	51.0	67.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Sillbox insulation	General	26.00	3.0%	0.0%	0.0%	0.0%
Smart thermostat	HVAC	65.00	6.6%	0.0%	0.0%	0.0%
Foundation insulation	General	1133.00	37.9%	0.0%	0.0%	0.0%
Attic insulation	General	406.00	9.5%	0.0%	0.0%	0.0%
Totals		1630.00	57.0%	0.0%	0.0%	0.0%

Table A.18. The M08 house on 8 Birch in the Helena weather region

8 Birch St. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1988	1988
Conditioned House Volume (Cu Ft)	15,904	15,904
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75	75
House Heating & Cooling Usage (Btu/Ft²/Yr)	41,750	34,708
Heating Load @ -21°F Design Conditions (Btu/Hr)	38,000	34,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	83.0	69.0	14.0
Space Cooling System	0.0	0.0	0.0
Totals	83.0	69.0	14.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Duct insulation	HVAC	66.00	3.6%	0.0%	0.0%	0.0%
Floor insulation	General	330.00	16.3%	0.0%	0.0%	0.0%
TOTALS		396.00	19.9%	0.0%	0.0%	0.0%

Table A.19. The FM01 house on 15 Gosselin Lane in the Newark weather region

15 Gosselin Lane Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1265	1265
Conditioned House Volume (Cu Ft)	10,645	10,645
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	--	--
House Heating & Cooling Usage (Btu/Ft²/Yr)	50,593	25,296
Heating Load @ 10°F Design Conditions (Btu/Hr)	51,000	45,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	64.0	32.0	32.0
Space Cooling System	0.0	0.0	0.0
Totals	64.0	32.0	32.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic Insulation, R-38	House	386.00	16.4%	0.0%	0.0%	0.0%
Smart Thermostat	HVAC	65.00	7.8%	0.0%	0.0%	0.0%
Sillbox Insulation	House	28.00	1.7%	0.0%	0.0%	0.0%
Foundation Insulation	Foundation	852.00	21.3%	0.0%	0.0%	0.0%
Furnace Tuneup	HVAC	45.00	4.5%	0.0%	0.0%	0.0%
Totals		1376.00	51.7%	0.0%	0.0%	0.0%

Table A.20. The FM02 house on 9 Gosselin Lane in the Newark weather region

9 Gosselin Lane Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1265	1265
Conditioned House Volume (Cu Ft)	10,645	10,645
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	--	--
House Heating & Cooling Usage (Btu/Ft²/Yr)	46,640	23,715
Heating Load @ 10°F Design Conditions (Btu/Hr)	48,000	41,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	59.0	30.0	29.0
Space Cooling System	0.0	0.0	0.0
Totals	59.0	30.0	29.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic Insulation, R-38	House	386.00	18.0%	0.0%	0.0%	0.0%
Smart Thermostat	HVAC	65.00	7.8%	0.0%	0.0%	0.0%
Sillbox Insulation	House	28.00	1.9%	0.0%	0.0%	0.0%
Foundation Insulation	Foundation	852.00	22.9%	0.0%	0.0%	0.0%
Totals		1331.00	50.6%	0.0%	0.0%	0.0%

Table A.21. The FM04 house on 5 Allen Ave. in the Newark weather region

5 Allen Ave. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	2138	2138
Conditioned House Volume (Cu Ft)	17,457	17,457
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	--	--
House Heating & Cooling Usage (Btu/Ft²/Yr)	44,902	29,467
Heating Load @ 10°F Design Conditions (Btu/Hr)	56,000	53,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	96.0	63.0	33.0
Space Cooling System	0.0	0.0	0.0
Totals	96.0	63.0	33.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart Thermostat	HVAC	65.00	7.5%	0.0%	0.0%	0.0%
Sillbox Insulation	House	35.00	1.6%	0.0%	0.0%	0.0%
Furnace Tuneup	HVAC	45.00	7.3%	0.0%	0.0%	0.0%
Attic Insulation, R-38	House	514.00	6.7%	0.0%	0.0%	0.0%
Foundation Insulation	Foundation	1198.00	12.9%	0.0%	0.0%	0.0%
Totals		1887.00	36.0%	0.0%	0.0%	0.0%

Table A.22. The FM05 house on 54 Olangapo Road in the Newark weather region

54 Olangapo Road Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1147	1147
Conditioned House Volume (Cu Ft)	9,827	9,827
Thermostat Set Point Heating (°F)	70/70	70/70
Thermostat Set Point Cooling (°F)	75/75	75/75
House Heating & Cooling Usage (Btu/Ft²/Yr)	77,594	57,439
Heating Load @ 10°F Design Conditions (Btu/Hr)	44,000	36,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	81.0	52.0	29.0
Space Cooling System	8.0	7.0	1.0
Totals	89.0	59.0	30.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic Insulation, R-38	House	320.00	35.7%	12.5%	0.0%	0.0%
Totals		320.00	35.7%	12.5%	0.0%	0.0%

Table A.23. The FM06 house on 64 Wake Road in the Newark weather region

64 Wake Road Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	988	988
Conditioned House Volume (Cu Ft)	8,466	8,466
Thermostat Set Point Heating (°F)	70/70	70/70
Thermostat Set Point Cooling (°F)	75/75	75/75
House Heating & Cooling Usage (Btu/Ft^2/Yr)	95,142	69,838
Heating Load @ 10°F Design Conditions (Btu/Hr)	48,000	40,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	86.0	62.0	24.0
Space Cooling System	8.0	7.0	1.0
Totals	94.0	69.0	25.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic Insulation, R-38	House	267.00	28.5%	12.5%	0.0%	0.0%
Totals		267.00	28.5%	12.5%	0.0%	0.0%

Table A.24. The FM07 house on 408 Pine Brook Road in the Newark weather region

408 Pine Brook Rd. Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	1001	1001
Conditioned House Volume (Cu Ft)	7,728	7,728
Thermostat Set Point Heating (°F)	70/70	70/70
Thermostat Set Point Cooling (°F)	75/75	75/78
House Heating & Cooling Usage (Btu/Ft^2/Yr)	64,935	28,971
Heating Load @ 10°F Design Conditions (Btu/Hr)	45,000	21,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	60.0	25.0	35.0
Space Cooling System	5.0	4.0	1.0
Totals	65.0	29.0	36.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic Insulation, R-38	House	298.00	43.0%	20.0%	0.0%	0.0%
Smart Thermostat	HVAC	65.00	4.7%	0.0%	0.0%	0.0%
Floor Insulation, R-19	Floor	265.00	10.7%	0.0%	0.0%	0.0%
Totals		330.00	58.4%	20.0%	0.0%	0.0%

Table A.25. The FM08 house on 51 Mitchell Road in the Newark weather region

51 Mitchell Road Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1001	1001
Conditioned House Volume (Cu Ft)	7,728	7,728
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75/75	75/75
House Heating & Cooling Usage (Btu/Ft²/Yr)	68,931	32,967
Heating Load @ 10°F Design Conditions (Btu/Hr)	47,000	24,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	64.0	29.0	35.0
Space Cooling System	5.0	4.0	1.0
Totals	69.0	33.0	36.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Attic Insulation, R-38	House	298.00	40.5%	14.0%	0.0%	0.0%
Smart Thermostat	HVAC	65.00	5.0%	0.0%	0.0%	0.0%
Floor Insulation, R-19	Floor	265.00	10.0%	-5.2%	0.0%	0.0%
Totals		628.00	55.5%	9.8%	0.0%	0.0%

Table A.26. The FM09 house on 13 Guam Court in the Newark weather region

13 Guam Court Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft²)	1154	1154
Conditioned House Volume (Cu Ft)	9,229	9,229
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75/75	75/75
House Heating & Cooling Usage (Btu/Ft²/Yr)	24,263	22,530
Heating Load @ 10°F Design Conditions (Btu/Hr)	25,000	24,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	19.0	21.0	-2.0
Space Cooling System	9.0	5.0	4.0
Totals	28.0	26.0	2.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Louvered Sun Screen	Windows	518.00	-25.3%	46.0%	0.0%	0.0%
Smart Thermostat	HVAC	65.00	8.9%	0.0%	0.0%	0.0%
Attic Insulation, R-30	House	43.00	3.2%	0.2%	0.0%	0.0%
Totals		330.00	-13.1%	46.2%	0.0%	0.0%

Table A.27. The FM10 house on 118 Wake Court in the Newark weather region

118 Wake Court Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	9501	950
Conditioned House Volume (Cu Ft)	7,600	7,600
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75/75	75/75
House Heating & Cooling Usage (Btu/Ft^2/Yr)	27,369	25,263
Heating Load @ 10°F Design Conditions (Btu/Hr)	20,000	20,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	19.0	17.0	2.0
Space Cooling System	7.0	7.0	0.0
Totals	26.0	24.0	2.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart Thermostat	HVAC	65.00	8.4%	0.0%	0.0%	0.0%
Totals		65.00	8.4%	0.0%	0.0%	0.0%

Table A.28. The FM11 house on 41 Mariveles Road in the Newark weather region

41 Mariveles Road Summary House Specifications	Original	Retrofit
Conditioned House Area (Ft^2)	1091	1091
Conditioned House Volume (Cu Ft)	8,797	8,797
Thermostat Set Point Heating (°F)	70/70	70/68
Thermostat Set Point Cooling (°F)	75/75	75/75
House Heating & Cooling Usage (Btu/Ft^2/Yr)	50,412	38,497
Heating Load @ 10°F Design Conditions (Btu/Hr)	33,000	28,000

ANNUAL ENERGY USE BY COMPONENT	Original (MBtu/Yr)	Retrofit (MBtu/Yr)	Change (MBtu/Yr)
Space Heating System	47.0	34.0	13.0
Space Cooling System	8.0	8.0	0.0
Totals	55.0	42.0	13.0

SUMMARY OF COST AND SAVINGS ESTIMATES OF RECOMMENDED RETROFITS

DESCRIPTION OF RETROFIT	AREA	COST ($) TO IMPLEMENT	RETROFIT SAVINGS OVER ORIGINAL VALUES			
			HEATING	COOLING	WATER HEATER	ELECTRIC
Smart Thermostat	HVAC	65.00	8.1%	0.0%	0.0%	0.0%
Wall Insulation	Windows	143.00	10.6%	1.7%	0.0%	0.0%
Attic Insulation, R-30	House	274.00	9.4%	0.8%	0.0%	0.0%
Totals		482.00	28.1%	2.5%	0.0%	0.0%

APPENDIX B

FORMS USED DURING INSPECTIONS

Version: May 11, 1993

Auditor: _____

Date: _____

MILITARY BASE HOUSE ENVELOPE SURVEY

IDENTIFICATION

Base name: _____ House ID: _____

House address: _____

Picture taken _____ (Y,N)

GENERAL

Type: _____ SFD - single-family detached MFS - small (2-4 units) multifamily
SFA - single-family attached MFL - large (>4 units) multifamily
MH - manufactured of mobile home

A single-family housing unit is a structure that provides living space for one household or family. The structure may be detached, attached on one side, or attached on two sides. Attached houses are considered single-family houses as long as the house itself is not divided into more than one housing unit and has an independent outside entrance. A single-family house is contained within walls that go from the basement (or ground floor, if there is no basement) to the roof. A mobile home with one or more rooms added is a single-family home. Row houses and side-by-side duplexes (twins) are typically single-family houses.

A small multifamily house or building is a structure that is divided into living quarters for two, three, or four families or households. This category also includes houses originally intended for occupancy by one family (or for some other use) that have since been converted to separate dwellings for two to four families. Typical arrangements in these types of living quarters are separate apartments downstairs and upstairs, or one apartment on each of three or four floors. Over-and-under duplexes are typically in this category.

A mobile or manufactured home is a structure that has all the facilities of a dwelling unit but is built on a movable chassis. It may be placed on a permanent or temporary foundation and may contain one room or more. If rooms are added to the structure, it is considered a single-family home.

Are the following systems shared with other housing units: space-heating system _____ (Y,N)
space-cooling system _____ (Y,N)
water-heating system _____ (Y,N)

If SFA, number of attached housing units: _____ (NA, 1, 2, ...) (typically 2 or less)

If MFA, Number of units Beside: _____,
Above : _____,
Below : _____

House ID: _____

FLOOR AREAS AND VOLUMES

Floor	Total area (ft^2)	Intentionally heated area (ft^2)	Intentionally air-conditioned (ft^2)	Ceiling Height (ft)	Volume (ft^3)
Basement					
First floor					
Second floor					
All other floors					
Totals					

An intentionally conditioned space is one with equipment and/or distribution outlets designed to maintain a desired temperature in the space.

An unintentionally conditioned space is one that is conditioned primarily from equipment jacket and/or distribution losses (there is little control over the resulting temperature).

A space is not conditioned if there is no source to alter the natural temperature of the space. For example, a basement heated primarily from equipment jacket and/or distribution system losses is not considered to be an intentionally heated space.

A window air conditioner cools only the room the unit is installed in, not adjacent rooms.

If a space was designed to be intentionally conditioned but is maintained by the occupant in an unconditioned state (by closing registers and doors, for example), the space should still be considered a conditioned space with one exception:

> an unfinished basement or other unfinished room with a distribution system that is always shut off should be considered unintentionally conditioned.

Floor heights used to calculate volume are floor to floor except for the top floor, which is floor to ceiling. For cathedral ceilings use average of maximum and minimum heights.

Number of intentionally heated stories: _____ (1, 1.5, 2, 2.5, 3, 3.5, 4 or more)

Number of intentionally cooled stories: _____ (1, 1.5, 2, 2.5, 3, 3.5, 4 or more)

House ID: _____

EXTERIOR WALLS

Wall code	Wall facing	Wall exposure	Exterior			Wall type	Gross wall area (ft²)	Existing insulation		
			Type	Color	Shade			Insulated sheathing	Type	Depth (in.)

Shared walls found in duplexes and row houses are not exterior walls.

The type of load bearing structure is the wall type.

Wall facing:
N - north, NE - northeast, E - east, SE - southeast, S - south, SW - southwest, W - west, NW - northwest
Wall exposure:
O - outside, N - non-conditioned attic space, B - buffered space (garage, etc.)
Exterior type:
WO - wood or masonite, AL - aluminum, steel, or vinyl, ST - stucco, BR - brick or stone, AS - asphalt shingle, WS - wood shingle, RA - rolled asphalt, X - other, N - none
Exterior color:
W - white, Y - yellow, O - orange, PI - pink, R - red, GN - green, BL - blue, GR - grey, PU - purple, BR - brown, X - other
Exterior shade:
L - light, M - medium, D - dark
Wall type:
PF - platform frame, BF - balloon frame, BL - block, ST - stone or masonry, X - other
Insulated sheathing:
Y - yes (present), N - not present, U - unknown
Insulation type:
BC - blown cellulose, BF - blown fiberglass, FB - fiberglass batt, BRW - blown rock wool, RWB - rock wool batt, RB - rigid board or foam, X - other, N - none

House ID: _____

WINDOWS AND GLASS DOORS

Wall code	Window glazing type	Frame type	Exterior window treatment	Storm window	Height (inches)	Width (inches)	Window Area (sq ft)	Overhang width (inches)

Overhang width is the width of the eave that shades the window.

Window glazing type:
SP - single pane, DP - double pane, TP - triple pane, GB - glass block, TE - temporary (cardboard, plastic, etc.), X - other
Frame type:
W - wood, M - metal, V - vinyl, X - other, N - none
Exterior window treatment:
A - awning, F - film, S - solar screen, X - other, N - none
Storm window:
W - wood, M - metal, X - other, N - none

House ID: _____

EXTERNAL DOORS

Wall code	Door type	Number	Height (inches)	Width (inches)	Color	Shade	Storm door (Y,N)

Door type:
H - hollow core wood, S - solid core wood, P - paneled wood, M - metal, X - other
Color:
W - white, Y - yellow, O - orange, PI - pink, R - red, GN - green, BL - blue, GR - grey, PU - purple, BR - brown, X - other
Shade:
L - light, M - medium, D - dark

House ID: _____

FOUNDATION SPACES

Type	Space status	Joist area (ft²)	Joist insulation thickness (inches)	Perimeter (band joist)		Wall height		Existing wall insulation	
				Length (ft)	Percent exposed	Total (ft)	Percent above ground	Type	Thickness (inches)
US									

Joist area - For slab-on-grade, the area of the intentionally conditioned slab floor.
Perimeter length - Do not include perimeter bordering another foundation space.
Percent exposed - For basements and crawlspaces, the percent of band joist length that is exposed to the outside and not insulated.
Total wall height - Height of basement or crawlspace wall; an estimated average if the height is not uniform.

Foundation type:
B - basement, C - crawlspace, US - uninsulated slab, IS - insulated slab

Foundation space status:
NC - non-conditioned space, IC - intentionally conditioned space, UC - unintentionally conditioned space, NA - slab

Existing insulation type:
BC - blown cellulose, BF - blown fiberglass, FB - fiberglass batt, BRW - blown rock wool, RWB - rock wool batt, RB - rigid board or foam, V - vermiculite, X - other, N - none

House ID: _____

ATTICS

UNFINISHED ATTIC AREAS				
Attic type	Floor area (ft²)	Existing insulation		Radiant barrier present (Y,N)
		Type	Depth (inches)	

FINISHED ATTIC AREAS					
	Attic type	Area (ft²)	Existing insulation		Radiant barrier present (Y,N)
			Type	Depth (inches)	
Outer ceiling joist					
Collar beam					
Kneewall					
Roof rafter					

Finished attic areas are defined in the figures on the following page.

Areas must be adjacent to intentionally or unintentionally conditioned spaces only. The area above an unconditioned garage should not be included.

Attic type:
F - floored, U - unfloored, C - cathedral, F - flat roof

Existing insulation type:
BC - blown cellulose, BF - blown fiberglass, FB - fiberglass batt, BRW - blown rock wool, RWB - rock wool batt, RB - rigid board or foam, V - vermiculite, X - other, N - none

House ID: _____

ATTIC VENTILATION

Type	Number	Length (in)	Width (in)	Comment
Soffit register				
Continuous soffit				
Gable				
Ridge				
Mushroom				
Turbine				
Dormer				
Power fan				

ROOF

Type: _____ (G - gable, H - hip and mansard, GM - gambrel, F - flat, X - other)

Material: _____ (AS - asphalt shingle, T - tile, S - slate, CS - cedar shake, M - metal, BU - built up, X - other)

Color: _____ (W - white, Y - yellow, O - orange, PI - pink, R - red, GN - green, BL - blue, GR - grey, PU - purple, BR - brown, X - other)

Shade: _____ (L - light, M - medium, D - dark)

	Space-heating	Water-heating
Chimney extends > 2 ft above roof (Y,N,NA)		
Clearance at chimney top > 10 ft (Y,N,NA)		

Picture of Roofs

House ID: _____

CENTRAL DISTRIBUTION SYSTEM (If Present)

Duct Function	Duct Type	Duct Size	Insulated (Y/N)	Location	Structural Integrity	Length (ft)
Supply Plenum						
Supply Trunk 1						
Supply Trunk 2						
Supply Runs						
Return Plenum						
Return Trunk 1						
Return Trunk 2						
Other						

Duct type:
DB=duct board, SM=sheet metal, FD=flex duct, HS=Uses house structure, X=other

Location:
A=attic, H=hallway, C=crawlspace, B=basement, G=garage, IC=interior closet, X=other

Also add:
IH=intentionally heated, IC=intentionally cooled,
UH=unintentionally heated, UC=unintentionally cooled,
NH=not heated, NC=not cooled

Structural Integrity:
G=good, L=minor leaky seams or junctions, NG=major leaks

Any asbestos present on distribution system? _____ (Y,N)

House ID: _____

APPLIANCES

Appliance	Fuel	Quantity	Age	Location
Stove top				
Conventional oven				
Microwave oven	E			
Refrigerator	E			
Dishwasher	E			
Freezer	E			
Clothes washer	E			
Clothes dryer				
Whole house fan	E			
Attic ventilation fan	E			
Fireplace				
Other _____				

Fuel:

NG - natural gas, P - propane, O - oil, K - kerosene, E - electricity, W - wood, C - coal, S - solar, X - other, N - none

Location:

(NC - non-conditioned space, IC - intentionally conditioned space, UC - unintentionally conditioned space)

House ID: _____

LIGHTING SURVEY

Room	Location (Wall,Ceiling,Floor)	Number of Bulbs	Type (I or F)	Wattage per Bulb

House ID: _____

COMMENTS:

Version: June 7, 1993

Auditor: _____

Date: _____

MILITARY BLOWER DOOR INSPECTION

IDENTIFICATION

Base name: _____ House ID: _____

House address: _____

BLOWER DOOR DATA

Procedures to prepare house for test: _____

Test equipment: _____ Basement Door (Open/Closed)

Indoor temperature (°F)		Outdoor temperature (°F)		Wind condition[1]	High wind gusts? (Y/N)	Local shielding class[2]
Ducts open	Duct sealed	Ducts open	Ducts sealed			

Ducts Open

Pressure station		Fan pressure (Pa)	Flow ring (N,A, B)	Flow-rate (cfm)
Goal (Pa)	Actual (Pa)			
60				
50				
40				
30				
20				
*				

Ducts Sealed

Pressure station		Fan pressure (Pa)	Flow ring (N,A, B)	Flow-rate (cfm)
Goal (Pa)	Actual (Pa)			
60				
50				
40				
30				
20				
*				

[1]Wind conditions: 1= calm (0-5 MPH); 2= moderate (5-10 MPH); 3= high (> 10 MPH)

[2]Local Shielding Class

1 - No obstructions or local shielding
2 - Light local shielding: few obstructions, a few trees, or small shed
3 - Moderate local shielding: some obstructions within two house heights; thick hedge, solid fence, or one neighboring house
4 - Heavy shielding: obstructions around most of perimeter; building or trees within 30 ft in most directions; typical suburban shielding
5 - Very heavy shielding: large obstructions surrounding perimeter within two house heights; typical downtown shielding.

House ID: _____

HOUSE AIR LEAKAGE

Conditioned volume	ft^3
Air leakage rate	cfm50
Natural house air change rate (cfm50 x 3)/volume	ACH
House too tight for _____ bedrooms? (Y,N) ACH < 0.35 OR cfm50 <1500 OR cfm50 < (300 x # of bedrooms)	

DESCRIPTION OF HOUSE LEAKAGE SITES

_____

_____

_____

_____

DUCT AIR LEAKAGE

Ducts open	cfm50
Ducts closed	cfm50
Duct leakage	cfm50
Duct Blaster (50 Pa)	
Fan pressure	Pa
Flow ring (???)	
Duct leakage (from table)	cfm50
Duct Blaster (25 Pa)	
Fan pressure	Pa
Flow ring (???)	
Duct leakage (from table)	cfm25

House ID: _____

DESCRIPTION OF DUCT LEAKAGE SITES

Room	Floor	Duct pressure (Pa)		Comments
		Supply	Return	
Foyer				
Living				
Family				
Dining				
Kitchen				
Master bedroom				
Bedroom 2				
Bedroom 3				
Bedroom 4				
Bathroom 1				
Bathroom 2				
Bathroom 3				
Hallway 1				
Hallway 2				
Utility				

Floor:
F - first, S - second, T - third, B - basement

Duct pressure:
If more than one register, list data in clockwise rotation from main entrance to room.

House ID: _____

PRESSURE DISTRIBUTION AND CFM50 AT 50 PASCALS DEPRESSURIZED

House Setup	Pressure difference[1] (Pa): House to			Pressure difference[1] (Pa): Combustion room to		CFM50 House
	Exterior	Combustion room	Return plenum	Exterior	Return plenum	
Blower door on @ 50 Pa depressurized. Turn air handler fan off. Turn exhaust fans off. Open all interior doors. Close combustion room door to main body. Close all exterior doors & windows in combustion room.						
Open exterior door or window in combustion room.						
Open combustion room door to main body. Close all exterior doors & windows in combustion room.						
Seal off all supply & return ducts.						
Close combustion room door to main body.						
Open exterior door or window in combustion room.						

[1] Reference Pressure - House or Combustion Room.

House ID: _____

PRESSURE BALANCING

House Setup	Pressure difference[1] (Pa): House to								Pressure difference (Pa): Combustion room to	
	Exterior	MBR	BR 2	BR 3	BR 4	Combustion room	Supply duct	Return duct	Exterior	Return duct
Turn air handler fan on. Turn exhaust fans off. Open all interior doors. Close combustion room door.										
Close master bedroom door.										
Close all bedroom and bathroom doors.										
Turn on all exhaust fans.										
Open combustion room door.										

[1] Reference pressure - house or combustion room

Version: June 7, 1993

Inspector: _____

Date: _____

MILITARY HVAC SYSTEM INSPECTION

IDENTIFICATION

Base name: _____ House ID: _____

Address : _____

DISTRIBUTION SYSTEM

Forced-air or gravity systems		
Condition of air filters (N-none, C-clean, D-dirty, P-plugged)		
Circulating fan operating (Y,N,NA)		
Grill height		in.
Grill width		in.
Grill type (S - stamp-face, B - bar type)		
Test equipment ID number: _____	Filter in	Filter out
Horizontal velocity	fpm	fpm
Vertical velocity	fpm	fpm
Average velocity	fpm	fpm
Air flow rate	cfm	cfm

Boilers	
Circulating pump operating (Y,N,NA)	
Zone valves operating (Y,N,NA)	
Any leaks present (Y,N)	
Any asbestos present on distribution system (Y,N)	

Air flow rate = Average velocity x Height x Width x 0.00486 for "S" type grill
Air flow rate = Average velocity x Height x Width x 0.00590 for "B" type grill

House ID: _____

SPACE-HEATING SYSTEM GENERAL INFORMATION

PRIMARY SYSTEM	
System type	
Fuel type	
System age	years
Location	
Manufacturer:	
Model:	
Input rating	
Output rating	
Efficiency (rated)	%
Pilot light (Y,N,NA)	
Pilot light on over summer (Y,N,NA)	
Smart thermostat (Y,N)	
Other efficiency measures	

AUXILIARY SYSTEMS		
Type	Fuel	Number

Space-heating system types:

Central systems:
1 - forced air furnace, 2 - gravity furnace, 3 - steam boiler, 4 - hot water boiler with radiators/convectors, 5 - hot water boiler for slab heating, 6 - heat pump

Fossil fueled in-space heaters:
7 - room heater, 8 - forced air wall furnace, 9 - gravity wall furnace, 10 - forced air floor furnace, 11 - gravity floor furnace, 12 - vaporizing pot heater (oil and kerosene), 13 - portable kerosene

Electric in-space heaters:
14 - wall, 15 - floor, 16 - baseboard, 17 - ceiling radiant (imbedded cable), 18 - wall or floor radiant (imbedded cable), 19 - portable (cord-connected), 20 - window heat pump

Other:
21 - wood or coal stove, 22 - fireplace, 23 - stove top or oven, 24 - other, 25 - none

Fuel:
NG - natural gas, P - propane, O - oil, K - kerosene, E - electricity, W - wood, C - coal, S - solar, X - other, N - none

Location:
NC - non-conditioned space, IC - intentionally conditioned space, UC - unintentionally conditioned space

Other efficiency measures:
V - vent damper, I - intermittent ignition device, F - flame retention, O - outdoor temperature reset (boilers only), G - gas power burner, X - other, N - none

House ID: _____

SPACE-HEATING SYSTEM SAFETY INFORMATION

Thermostat operating (Y,N)	
Electrical cutoff switch present (Y,N)	
Wiring secure (Y,N)	
Furnace fan on/off temperature switches present (Y,N,NA)	
If yes: Upper setting _____ °F Lower setting _____ °F	
If Boiler: Operating temperature	°F
High limit switch settings (none, °F, psi)	
Combustible materials near flue (Y,N)	
Asbestos insulation present on system (Y,N)	
Combustion air adequate (Y,N)	

FUEL-OIL SPACE-HEATING SYSTEM ONLY - FUEL LEAKS

Is a filter and shutoff valve in supply line (Y,N)	
Leaks in space-heating system supply line (Y,N,NA)	
Leaks in water-heating system supply line (Y,N,NA)	
Leaks in above ground storage tank (Y,N,NA)	

House ID: _____

SPACE-HEATING SYSTEM FLUE AND CHIMNEY INSPECTION

Structurally sound (Y,N,NA)	
Leaks exist (Y,N,NA)	
Thick debris present (Y,N,NA)	
Flue liner present (Y,N,NA)	
Barometric Damper Exist (Y,N)	
Barometric Damper Function OK (Y,N,NA)	

SPACE-HEATING SYSTEM HEAT EXCHANGER

Cracks observed visually (Y,N,NA)	
Test equipment ID number	
Percent oxygen reading before blower turns on	%
Percent oxygen reading after blower turns on	%
Flue gas odor noticed in house (Y,N,NA)	
Flame change when air handler turned on (Y,N)	
Flame rollout (Y,N)	

House ID: _____

SPACE-HEATING SYSTEM DRAFT

Test set-up (door positions, fan operation, etc.): _____

_____

Outdoor temperature	°F
Power vent present (Y,N)	
Test equipment ID number	
Draft with system off	in. water
Time to stop spilling	seconds
Draft with system on	
30 seconds	in. water
1 minute	in. water
2 minutes	in. water
3 minutes	in. water

SPACE-HEATING SYSTEM STEADY-STATE EFFICIENCY ANALYSIS

Test Equipment ID Number	
Percent Oxygen Reading	%
Net Stack Temperature	°F
Unadjusted Steady-State Efficiency	%
Smoke No. (Fuel-Oil System Only)	
Adjusted Steady-State Efficiency	%
Exit temperature of supply air	°F
Temperature rise	°F
Carbon monoxide reading in flue gas	ppm

If Smoke No. Is	1	2	3	4	5	6	7	8	9
Subtract from SSE	0	0	0	1	2	3	4	6	7

House ID: _____

DOMESTIC WATER-HEATING SYSTEM GENERAL AND SAFETY INFORMATION

Manufacturer	
Model	
Type (SA-stand alone, T-tankless, X-Other, N-none)	
Fuel (NG-natural gas, P-propane, O-oil, E-electricity, S-solar, X-other, N-none)	
Location (NC-non-conditioned, IC-intentionally conditioned, UC-unintentionally conditioned)	
Capacity	gallons
Age	years
Upper heating rate (KW, Btu/h)	
Lower heating rate (Electric systems only)	kW
Upper temperature setting	°F
Lower temperature setting (Electric systems only)	°F
External blanket insulation (Y,N,NA)	
Combustion air adequate (Y,N,NA)	
Combustible materials near flue (Y,N,NA)	
Pressure relief valve present (Y,N)	
Pipes insulated (Y,N)	
Hot water temperature at far faucet	°F
Cold water flow at showerhead number 1	gpm
Cold water flow at showerhead number 2 (or NA)	gpm

DOMESTIC WATER-HEATING SYSTEM FLUE AND CHIMNEY INSPECTION

Structurally sound (Y,N,NA)	
Leaks exist (Y,N,NA)	
Thick debris present (Y,N,NA)	
Flue liner present (Y,N,NA)	

House ID: _____

DOMESTIC WATER-HEATING SYSTEM DRAFT (NON-ELECTRIC ONLY)

Test set-up (door positions, fan operation, etc.): _____

_____

_____

Outdoor temperature	°F
Power vent present (Y,N)	
Test equipment ID number	
Draft with system off	in. water
Time to stop spilling	seconds
Draft with system on	
30 seconds	in. water
1 minute	in. water
2 minutes	in. water
3 minutes	in. water
Flame rollout (Y,N)	
Carbon monoxide reading in flue gas	ppm

House ID: _____

CARBON MONOXIDE TESTING

Test set-up (door positions, fan operation, etc.): _____

_____

_____

Furnace Blower/Boiler Operating with --->	Doors Open	Doors Closed
Ambient	ppm	ppm
Five feet from space-heating system	ppm	ppm
Five feet from water-heating system	ppm	ppm
Kitchen	ppm	ppm
Living room	ppm	ppm
Register (or NA)	ppm	ppm
Were the following operating during the test:		
Gas stove top (Y,N)		
Gas oven (Y,N)		
Fossil-fuel space-heater (Y,N)		

House ID: _____

AIR CONDITIONER/HEAT PUMP NAMEPLATE INFORMATION

ID	Unit Type	Location	Maker	Model	Age (yrs)	Filter Cond.	Refrig Leaks	Input (Watts)	Output (Btu/hr)	Compressor FLA

[1]Unit type: CACS - central A/C split unit
CHPS - central heat pump split unit
WAC - window A/C, WHP - window heat pump
GP - gas pack
CACP - central A/C package unit
CHPP - central heat pump package unit
EC - evaporative cooler
X - other

[2]Filter: C - clean, D - dirty, P - plugged, N - none

Air flow per ton of cooling capacity = Air flow rate _____ / Capacity _____ = _____ cfm/ton

Exit temperature of supply air: _____°F

Inlet temperature of return air: _____°F

House ID: _____

AIR CONDITIONER/HEAT PUMP OPERATING DATA

ID	Operating Mode (H or C)	Suction Side		Discharge Side		Super Heat (F°)	Sub Cool (F°)	Unit Watts	Compres-sor (Amps)
		Press (psig)	Temp (°F)	Press (psig)	Temp (°F)				

Measure suction temperature (ST) just before suction-line accumulator (if present)
Measure discharge temperature (DT) just before expansion device (after condenser)
Superheat = Saturation suction temperature (from pressure reading) - measured ST
Subcool = Saturation discharge temperature (from pressure reading) - measured DT

ID	Operating Mode	Outdoor Air Temp	Indoor Air System					Sens Load	Total Load
			Flow (cfm)	Temp In DB	Temp In WB	Temp Out DB	Temp Out DB		

House ID: _____

COMMENTS

INTERNAL DISTRIBUTION

1-50. W. P. Levins
51-52. M. P. Ternes
53. M. M. Abraham
54. J. B. Cannon
55. J. E. Christian
56. G. E. Courville
57. P. D. Fairchild
58. W. Fulkerson
59. M. B. Gettings
60. J. O. Kolb
61. M. A. Kuliasha
62. J. M. MacDonald
63. H. A. McLain
64. W. R. Mixon
65-67. R. R. Parks
68. A. C. Schaffhauser
69. T. R. Sharp
70. R. B. Shelton
71. R. L. Wendt
72. K. E. Wilkes
73-76. Central Research Library
77. Document Reference Section
78-81. Laboratory Records
82. Laboratory Records-RC
83. ORNL Patent Office

EXTERNAL DISTRIBUTION

84. T. Adams, HQ AFCESA/EN, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32403-5319
85. R. Baker, HQ AF CESA/EN, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32403-5319
86. F. Beason, HQ AFCESA/EN, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32403-5319
87. Dr. Douglas R. Bohi, Director, Energy and Natural Resources Division, Resources for the Future, 1616 P Street, N.W., Washington DC 20036
88. R. Castellanos, U.S. Air Force, Housing Technical Branch, HQ USAF/LEEHT, Pentagon, Room 5D-440, Washington, D.C. 20330-5140
89. J. W. Cooke, DOE, Field Office, Post Office Box 2008, Oak Ridge, TN 37831-6269
90. L. Davis, 97 CES/CEC, 41 L Avenue, Building 357, Altus AFB, OK 75323-5138
91. Dr. T. E. Drabek, Professor, Department of Sociology, University of Denver, Denver, CO 80208-0209
92. C. Fields, 97 CES/CEC 41 L Avenue, Building 357, Altus AFB, OK 7523-5138
93. G. Fitzmaier, Directorate of Public Works, ATTN: SELFM-TW-EP, Building 167, Fort Monmouth, NJ 07703-5108
94. M. Ginsberg, Office of Federal Energy Management Program, EE-44, 5E-080/Forrestal Building, 1000 Independence Avenue, Washington, D.C. 20585
95. P. Goutos, Chief Army Housing Facilities Division, U.S. Army Engineering & Housing Support Center (CEHSC-HF), Room 102 Casey Building, Fort Belvoir, VA 22060-5516

96. M. M. Herbert, Directorate of Engineering and Housing, Building 270/ATTN: SELF-EH-H, Fort Monmouth, NJ 07703-5109
97. Dr. Stephen G. Hildebrand, Director, Environmental Sciences Division, Oak Ridge National Laboratory, P. O. Box 2008, Oak Ridge, Tennessee, 37831-6037
98. A. Houtzager, Army Housing Facilities Division, U.S. Army Engineering & Housing Support Center (CEHSC-HF), Room 102 Casey Building, Fort Belvoir, VA 22060-5516
99. G. James, USAF, HQ AETC/CEPH, 266 F. St. West, Randolph AFB, TX 78150-4321
100. Richard H. Karney, Department of Energy, EE-421, 5E-098/FORS, 1000 Independence Avenue, S.W., Washington, D.C. 20585
101. T. Ketchum, Army Housing Facilities Division, U.S. Army Engineering & Housing Support Center (CEHSC-HF), Room 102 Casey Building, Fort Belvoir, VA 22060-5516
102. L. Layton, Army Housing Facilities Division, U.S. Army Engineering & Housing Support Center (CEHSC-HF), Room 102 Casey Building, Fort Belvoir, VA 22060-5516
103. Mr. Calvin D. MacCraken, President, Calmac Manufacturing Corporation, P.O. Box 710, Englewood, NJ 07631
104. J. McCarty, Army Housing Facilities Division, U.S. Army Engineering & Housing Support Center (CEHSC-HF), Room 102 Casey Building, Fort Belvoir, VA 22060-5516
105. 1st Lt. M. Mongold, 97 CES/CEOE, 501 L Avenue, Building 362, Altus AFB, OK 75323
106. R. Moretti, Deputy of Civil Engineering, 43 CES/CECR, Building 470, Malmstrom AFB, MT 59402
107. R. Nader, Post Office Box 19367, Washington, D.C. 20036
108. J. Ott, Directorate of Public Works, Building 167, ATTN: SELSM-PW, Fort Monmouth, NJ 07703-5000
109. S. Scully, NAHB Research Center, 400 Prince George Blvd., Upper Marlboro, MD 20772
110. J. B. Shrago, Director, Office of Technology Transfer, 405 Kirkland Hall, Vanderbilt University, Nashville, TN 37240
111. G. F. Sowers, P.E., Senior Vice President, Law Companies Group, Inc., 114 Townpark Drive, Suite 250, Kennesaw, GA 30144-5599
112. C. M. Walton, Department of Civil Engineering, College of Engineering, The University of Texas, Cockrell Hall, Suite 4.2, Austin, TX 78712
113. G. Willems, Assistant for Family Housing and Facility Maintenance, Deputy Assistant Secretary for Installations, SAF/RI, Pentagon, Suite 4C940, Washington, D.C. 20330-1000
114. Office of Assistant Manager for Energy Research and Development, DOE Oak Ridge Field Office, P.O. Box 2008, Oak Ridge, TN 37831-6269

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