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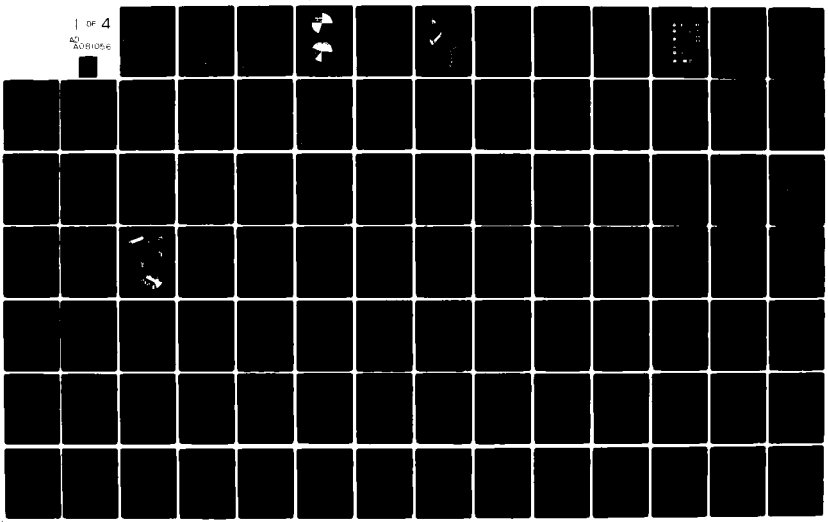

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REPORT TO THE CONGRESS

FAMILY HOUSING METERING TEST

A TEST PROGRAM TO DETERMINE THE FEASIBILITY OF INSTALLING UTILITY METERS IN MILITARY FAMILY HOUSING, DEVELOPING ENERGY CEILINGS, AND OPERATING A PENALTY BILLING SYSTEM FOR OCCUPANTS WHO OVERCONSUME ENERGY

Prepared by the Office of the Deputy Assistant Secretary of Defense (Installations and Housing)

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REPORT TO THE CONGRESS

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EXECUTIVE SUMMARY

Prepared by the Office of the Deputy Assistant Secretary of Defense (Installations and Housing)

1 March 1980

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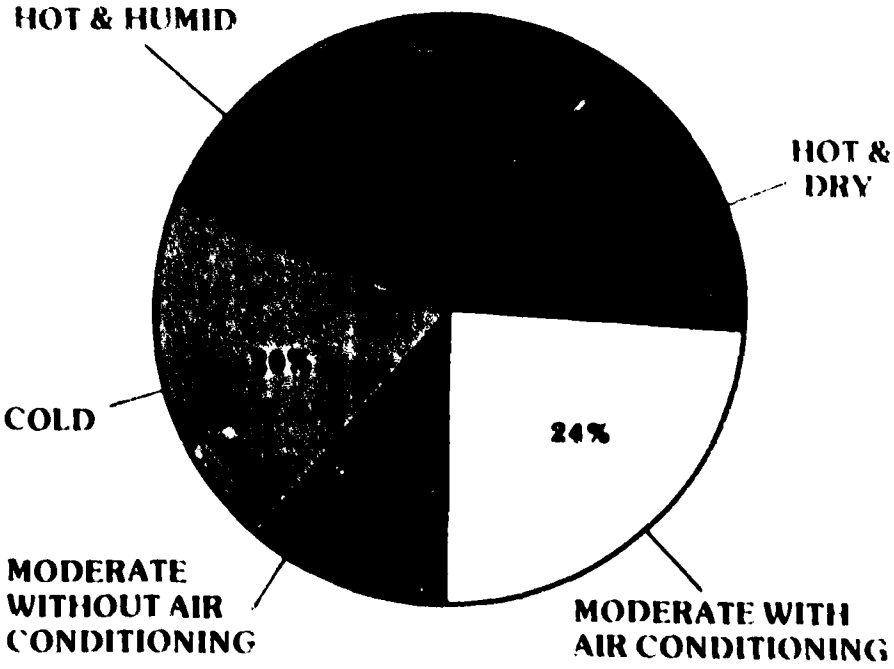
UNITS PROVIDED FOR TEST METERING

TOTAL 10,379 UNITS



TEST METERING UNITS BY CLIMATE

TOTAL 10,379 UNITS

FIGURE 1

EXECUTIVE SUMMARY

Executive Summary Organization

This executive summary presents an overview of the metering test; estimated costs of implementation; and potential impacts of the directed metering program, as well as several alternatives developed during the test.

Summary and Recommendations

The results of the metering test suggest that the legislation as now written should not be implemented. While retrofitting existing housing for metering and billing occupants is feasible, though extremely costly, the norm for determining appropriate energy allowances is not sufficiently accurate to bill individuals. The Department of Defense has concluded, based on results of tests, that the best approach to energy conservation in family housing is a combination of continuing aggressive consumer education coupled with increased emphasis on energy conservation facility improvement.

Full-Service Metering Costs (Chapter 1)

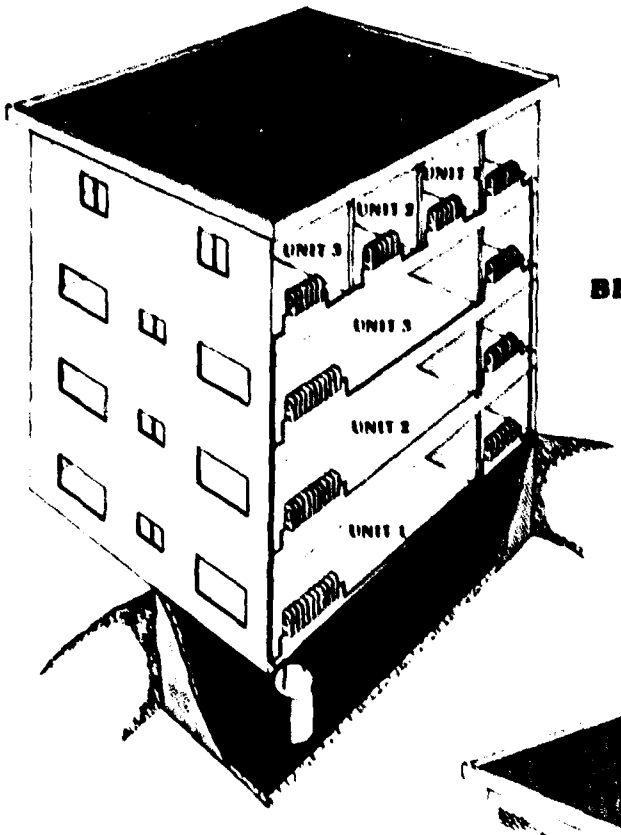
The estimated cost of metering the remaining approximately 300,000 units of DoD housing in the 50 States and U.S. possessions is $415,000,000 in 1981 dollars, although actual expenditure will be spread over several years. Actual installation of meters, if directed, would require a significant period of time. The total implementation of a DoD-wide metering program is estimated to require between 5 and 6 years. The estimated cost for procurement of necessary minicomputers and software to perform the norm calculation and produce the bills is $25,000,000 in 1981 dollars, bringing the total initial cost to $465,000,000, including individual house norm data collection costs.

Costs of operating and maintaining a metering system and billing occupants are significant and must include meter maintenance, norm data base maintenance, meter reading and consumption data input, and collection and accounting for funds. These functions are estimated to have an annual cost of over $32,000,000 in FY 1987 dollars and to require a minimum of 487 additional employees for meter reading alone. Related costs of occupant education and response to increased occupant-generated maintenance service calls would raise this annual operating cost to over $55,000,000.

Estimated Energy Savings (Chapter 8)

It is estimated that a norm and penalty billing system as prescribed in Public Law 95-82, if technologically feasible, might result in a 6 percent energy consumption reduction in DoD family housing, or an annual saving of approximately 4,860,000 MBtu. The estimated 1987 value of the energy saved would be

SIMPLIFIED CUTAWAY DRAWING OF BEFORE-AND-AFTER PIPING FOR HOT WATER HEATING ONLY



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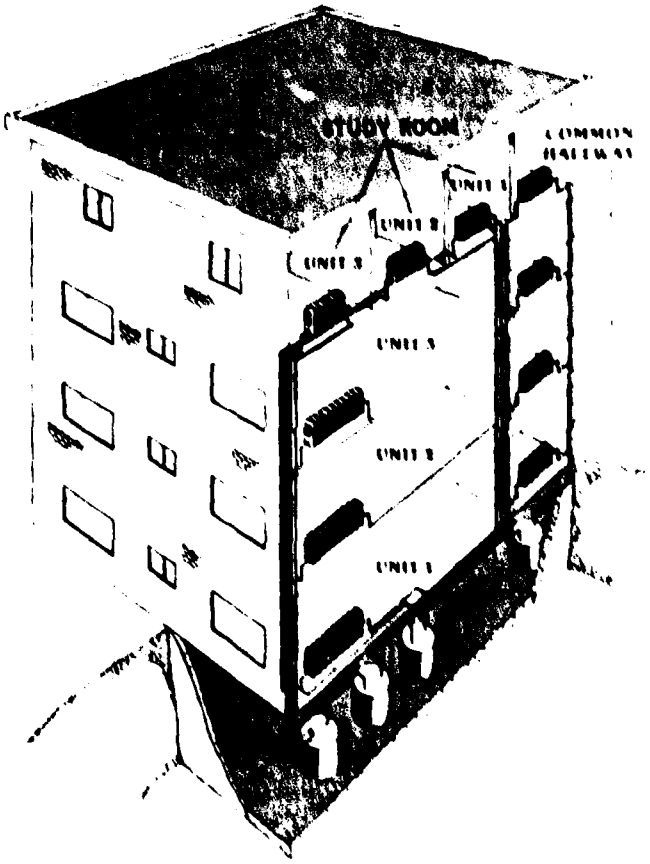

AFTER

FIGURE 2

about $32,000,000. Because of the high annual system operating cost of $55,000,000, there would be a $23,000,000 annual operating loss. If amortization of the initial costs was carried out over 25 years, the total annual loss would be $42,000,000.

Meter Installation (Chapter 1)

Prior to the actual passage of Public Law 95-82, a Department of Defense Metering Task Force established the basic concepts and ground rules for conduct of the test, selected ten test locations, and established certain basic energy consumption criteria for the test. Selected test and service units are shown in Figure 1. Harry Diamond Laboratory, White Oak, Maryland, was the central computer service location for the test. A total of 19,279 meters were installed at a cost of $5,407,575, for an average installation cost per unit metered of $496. There was, however, considerable variation in the cost of metering individual units from a low of $129 to a high of $5,536 per unit. It was estimated that, for certain units dropped from the test, costs to install necessary meters would have exceeded $35,000 per unit.

Meter Installation Problems (Chapter 1)

Many DoD family housing units are multifamily structures. At the time of construction no consideration was given to layout of internal utility systems to facilitate system isolation. Electric, gas, steam, chilled and heated water and domestic hot-water lines were usually run within the building in the most effective manner possible from a construction and first-cost view. Metering of such buildings required that all systems for each unit be isolated. System isolation was one of the most prevalent and difficult problems to overcome in terms of time and expense. Figure 2 illustrates this problem. Such work would have severely impacted on the livability of the house, and, in some cases, a vacancy of 6 weeks was judged to be necessary so metering could be carried out.

Three percent of the DoD housing inventory (10,000 units) use steam, metering of which was a problem because small steam meters designed for family housing consumption levels were not readily available commercially. Meters actually installed for the test were condensate meters which suffered a variety of problems. Actual feasibility of accurately metering domestic steam service was not proven during this test period.

Another major problem encountered in metering installation involved the extremely limited time allowed to install meters at the ten test sites. Public Law 95-82 enacted on 1 August 1977 specified that meters should be in place by 1 January 1978. Installation of meters was performed by construction contract. At most locations, design of metering system was performed by A&E contract. The various steps of contract procurement are rigidly prescribed by law and time required for these operations drastically impacted the total time required for meter

installation. The earliest installation was April 1978, the latest took until November 1978.

Norm Development (Chapter 2)

To be useful, a norm must accurately predict the energy requirements for a given household, including space heating and cooling, domestic hot water, cooking and miscellaneous appliances, and lighting. These energy requirements are heavily dependent on weather conditions, thermostat set points, size and construction of the house, and number and habits of occupants.

The norm calculation as used in the metering test contains almost 300 variables for a 30-day billing period and accounts for a great number of factors which impact upon the energy requirement of the house. However, it still does not quantify or model the complex aspects of the basic quality of American life, nor does it provide of itself a means of comparing military family life with the life in the civilian sector.

The actual test data for the ten locations displayed a very large degree of data scatter, and large deviations were experienced between the norm and the average of unit consumptions. These deviations were not consistent or even in the same direction from month to month. Studies of potential refinement of the norm indicate that while the norm may be refineable to include additional functions or variables previously not modeled, the reliability and dependability of the norm are expected to remain no better than 85 percent. In essence the norm is not considered to be of billing quality and the feasibility of future refinement to an acceptable quality is highly doubtful. A billing system based on such a norm would be grossly unfair to individual housing occupants.

Billing System (Chapter 3)

The computer billing system worked well. Several alternatives for an actual billing system were considered. The use of a number of minicomputers located at activities with more than 500 housing units was found most feasible in terms of providing the best degree of service at the activity level and quick response time for occupant questions and corrections to bills.

Energy Consumption Studies (Chapter 4)

Literature searches and field studies were conducted to determine probable levels of energy savings by metering. These studies included occupant habits and attitudes, energy demand elasticity, population segment comparisons, and facility analyses. The result was a spread of possible energy saving strategies with projected results from near zero to 12 percent or more. These studies quantified potential energy savings and occupant reaction under various conditions. (See Chapter 4, page 5 for further details.)

Adverse Personnel Impact (Chapter 6)

Based on a comprehensive review of morale and compensation factors, it was determined that metering and billing could have considerable adverse personnel impact. Negative retention and morale aspects of metering in terms of perceived employment contract changes could lead to reduced retention and recruiting and ultimately to a reduced force readiness. As a measure of the possible cost impact, an attrition of only one-fourth of 1 percent of career military personnel as a result of a metering program would cost about $118,000,000 for replacement of these experienced midrange management personnel.

Alternative for Energy Consumption Reduction (Chapter 5)

Energy savings from further facility improvement were studied because these savings are much more accurately predicted than energy savings which depend upon occupant attitude and behavioral change. Significant work has been done in improving the energy efficiency of DoD family houses within program constraints; however, there is much that remains to be done, especially as the cost of energy continues to rise. These potential improvements would take the form of either reducing existing energy consumption or creating new energy sources such as solar energy. Based on the approximately 310,000 units covered by the legislation, it has been estimated that a 1 percent annual energy saving (810 billion Btu per year or 139,000 EBO) would cost approximately $27,000,000. While this relationship is not totally linear, it is believed to be so to a saving of 12 percent or more and, therefore, offers the opportunity for considerable energy savings at a predictable and incrementable cost. Further, it is not directly dependent upon the amounts of energy previously saved or being saved by occupants as a result of energy conservation efforts.

Alternatives (Chapter 8)

Several alternatives and options developed during the course of the study. The overall costs and benefits of each are compared in Figure 3. On a more quantitative basis, Table 1 arrays estimated norm and penalty system (alternative I.A) costs, for comparison with costs of other alternatives.

Alternative I.A has the highest first cost because of the requirement not only to install meters on all houses but to develop a norm. Any norm computation must be used in conjunction with a confidence factor which will greatly decrease the incidence of billing and possible savings. This alternative only impacts upon those who are above the norm and does nothing to decrease consumption of those below the norm. It may generate energy savings of 6 percent. The provision for rewards in addition to penalty charges (alternative I.B) would encourage people below the norm also to save and shows potential for savings up to approximately 12 percent. The basic problem with

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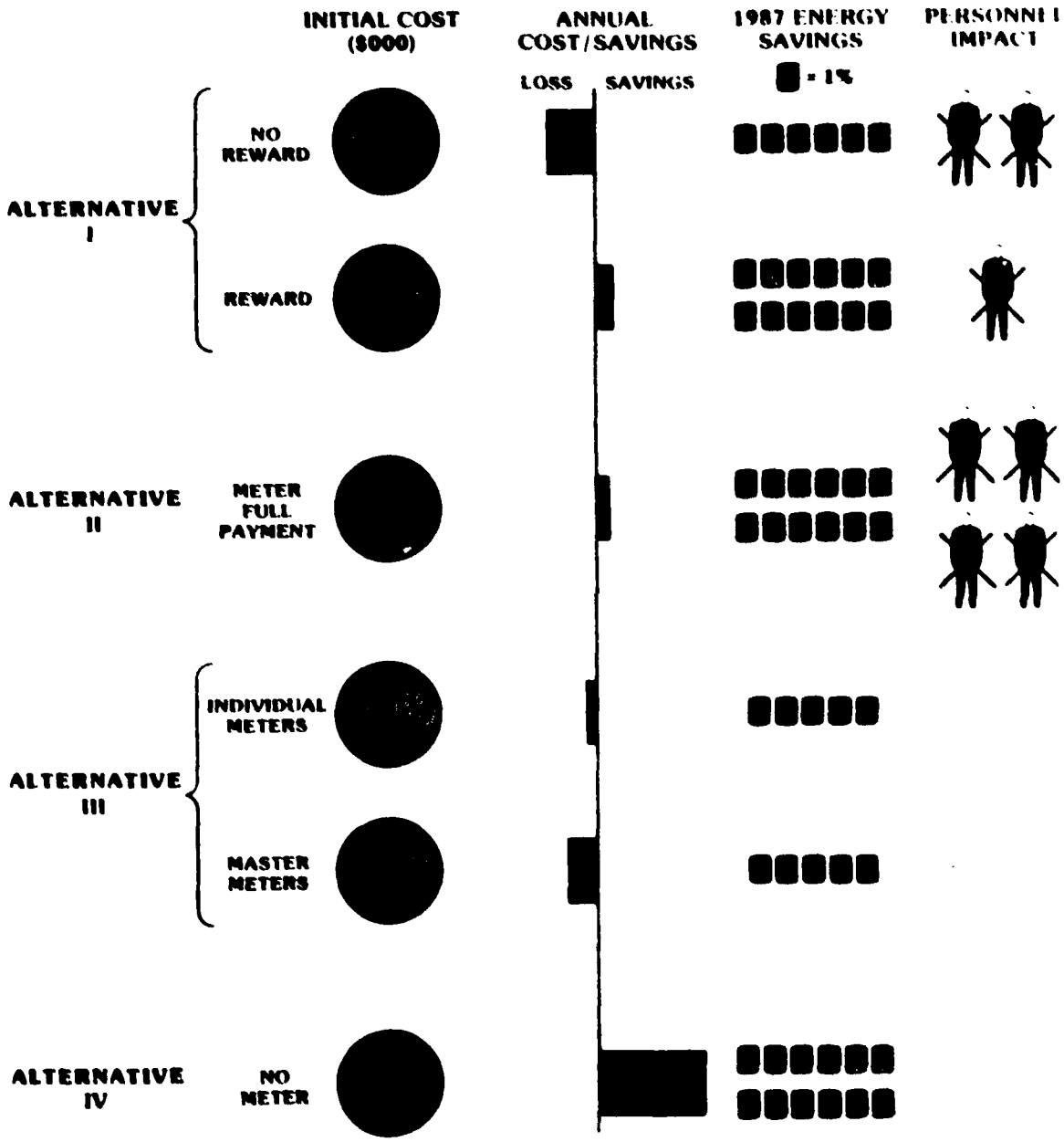

FIGURE 3

alternative I, however, is the fact that the norm itself is and will remain of unsuitable accuracy.

Alternative II, the use of meters without a norm, would impose a requirement for full payment by the house occupant. To impose this requirement without providing some type of monetary energy allowance would amount to a substantial change in take-home pay and in the implied contract of employment with military personnel. It could be expected to have massive personnel and personnel retention impact. Projections for alternative II indicate a possible savings of about 12 percent of all energy now being consumed.

Alternative III, involving metering data feedback in conjunction with occupant education, could produce between 2-1/2 and 5 percent savings depending upon the specific structuring of the program. Installation of individual meters, where economically and technologically feasible, and feedback of individual consumption data could be expected to produce better savings (at higher cost) than the use of group consumption data from master meters, either existing or to be installed. This alternative, however, would involve little or no adverse personnel reaction unless the installation of individual meters, albeit for feedback purposes, was viewed by individual occupants as the first step toward the ultimate charging for all utilities.

Alternative IV involves installation of no new meters but rather concentrates on improving the facility's efficiency and on developing new solar energy. This alternative, although seen as having no adverse personnel impact, has the potential for savings of 12 percent or more depending on the level of investment in facility improvement and solar energy and possible utilization of occupant education also. The investment in facilities improvements may be incremented to suit national policy and budgetary considerations, whereas any type of meter installation cannot be reasonably incremented, thereby becoming an all-or-nothing decision.

Footnotes to Table 1

[1]Includes all startup costs except administrative overhead at the DoD and service levels as well as research.

[2]Meter system design and installation, maintenance program design, meter inventory for maintenance and staffing, and training maintenance personnel.

[3]Includes only those expenditures beyond those expended in a typical year prior to 1981. A goal of 11% savings was used for comparison with other alternatives.

[4]Includes the cost to provide further refinement of the norm, initial collection of norm data for all DoD family housing and training engineering personnel in data collection.

[5]Accounts for system design, purchase of equipment, and the staffing/training of personnel. Includes meter reading bill processing and collection, and the redistribution of receipts where appropriate. Norm processing is included for alternative I only. (Norm data for new housing will be provided as a part of the design and construction.)

[6]Housing occupant education only.

[7]Includes all operating, maintenance and local administration expenses for the first year of full operation, 1987. No cost is included for the value of any energy which may be stolen.

[8]Additional expenses incurred as a result of the increased sensitivity of residents to the effect of the building and GFE condition on energy consumption. The cost varies according to the impact of the program on the residents.

[9]Includes maintenance of new structural improvements and equipment.

[10]Includes meter reading, and data input, computation and issuance of bills, maintenance of the norm data and collection/payment of monthly charges and/or rewards as appropriate.

[11]It was assumed that total energy consumed would not change from 1978 through 1987 without this program. A 10% annual increase in the cost of energy was assumed between 1978 and 1987. 1978 baseline is approximately 81 x 10^6 MBtu per year. Estimated 1978 composite cost per MBtu is $2.701. Estimate 1987 cost as $6.55 for comparison of alternatives.

[12]For conversion to Equivalent Barrels of Oil, (EBO) = 5.8254 MBtu.

[13]Assume initial costs prorated over 25 years with no discount.

[14]Algebraic sum of annual operation and maintenance costs, estimated energy savings.

[15]Personnel attrition as result of negative aspects of metering not precisely determinable. Information shown for attrition of only 1/4% of career personnel. Less impact would be expected for alternative IB but much higher actual experience could be expected for alternative II which would greatly raise costs.Numbers assumed are 496 officers and 857 enlisted personnel in case of 1/4% attrition.

[16]Replacement cost of experienced personnel, not necessarily a one time cost. Attrition could occur over a number of years.

[17]Norm development includes BLAST analysis and data input for each house (6 hrs. x 300,000 units x $12/hr.) plus $500K for refinement studies. Total $22,820K.

[18]Includes following operations: metering reading $13,000K, billing $5,460K, penalty collection and accounting (assuming 15% of occupants are billed) $1,118K, and data base maintenance $9,300K.

[19]Includes all above items plus cost of administering payment of rewards, $1,118K.

[20]No norm is required, but equipment and software for computation of bills for all occupants would be required.

[21]No norm is required but payments would be collected from all occupants. Includes meter reading $13,000K, billing $5,460K and collection and accounting $7,453K.

[22]Retention impact arbitrarily doubled for full billing mode. Actual impact that would result from reducing occupants' take home pay by $100 or more per month is unknown, but could be expected to be severe.

[23]Consumption feedback could take the form of a mock bill, but in any case would require most of the billing system features.

[24]If an extremely intensive program was instituted, the cost could increase to $1,445K and $60,397K for design and annual administration respectively.

[25]Includes following costs: meter reading $5,143K and $2,000K for consumption data feedback to each occupant.

[26]Estimated cost of limited ADP support to provide consumption data to occupants based on master-meter readings.

[27]Intensive initial training of conservation advocates is required.

[28]For data collection and feedback to occupants of average consumption from master-meter readings.

[29]Source of saving: facility improvement 11%, solar energy 1%, total 12%.

Table 1

	ALTERNATIVES			
	I		II	II
	METER/BILL FOR EXCESS		METER/FULL PAYMENT	METER/FEEDI
	A. No Reward	B. Reward		A. Individual Meters Where Feasible
INPUTS ($000) (1981 dollars)				
INITIAL COSTS[1]				
Meter Installation[2]	Inst. - $415,177 Inv. - $2,367	Inst. - $415,177 Inv. - $2,367	Inst. - $415,177 Inv. - $2,367	Inst. - $415,177(~ Inv. - $2,367
Building Improvements[3]	--	--	--	--
Solar Conversions	--	--	--	--
Norm Development[4]	$22,820[17]	$22,820[17]	--	--
Billing System[5]	$24,797	$24,797	$22,797[20]	$22,797[23]
Develop Educational Program[6]	$38	$38	$19	$38[24]
TOTAL	$465,199	$465,199	$440,360	$440,379
1987 MAINTENANCE, OPERATIONS AND ADMINISTRATIVE COSTS[7]				
Meter Maintenance	$3,465	$3,465	$3,465	$3,465
Building and GFE Maintenance[8]	$20,654	$20,654	$25,817	$15,490
Solar Convergion Maintenance[9]	--	--	--	--
Billing Operations[10]	$28,878[18]	$29,996[19]	$25,913[21]	$7,143[25]
Education Program[6]	$2,582	$2,582	$2,582	$2,582[24]
TOTAL	$55,579	$56,697	$57,777	$32,140
RESULTS				
1987 ENERGY SAVINGS[11]				
Estimated % Savings	6%	12%	12%	5%
Amount (MBtu)(x 10^6)[12]	4.86	9.72	9.72	4.05
VALUE ($000)	$31,867	$63,734	$63,734	$26,555
ANNUAL NET COST/SAVINGS				
First Cost Amortization[13]	($18,608)	($18,608)	($17,614)	($17,615)
Annual Cost/Saving[14]	($23,712)	$7,037	$5,597	($5,585)
NET	($42,320)	($11,571)	($11,657)	($23,200)
PERSONNEL LOSSES				
Number (or %)[15]	1/4%	1/8%	1/2% ++[22]	0
COST[16]	$118,000	$59,000	$236,000 ++	0

2

ALTERNATIVES

II METER/FULL PAYMENT	III METER/FEEDBACK ONLY A. Individual Meters Where Feasible	III METER/FEEDBACK ONLY B. Install Master Meters	IV NO METER Facility Improvement
Inst. - $415,177	Inst. - $415,177(-)	Inst. - $25,000	--
Inv. - $2,367	Inv. - $2,367	--	--
--	--	--	$297,000
--	--	--	$100,000
--	--	--	--
$22,797[20]	$22,797[23]	$5,000[26]	--
$19	$38[24]	$236[27]	--
$440,360	$440,379	$30,236	$397,000
$3,465	$3,465	$209	--
$25,817	$15,490	$15,490	$10,327
--	--	--	$2,000
$25,913[21]	$7,143[25]	$2,000[28]	--
$2,582	$2,582[24]	$22,709	--
$57,777	$32,140	$40,408	$12,327
12%	5%	5%	12%[29]
9.72	4.05	4.05	9.72
$63,734	$26,555	$26,555	$63,734
($17,614)	($17,615)	($1,209)	($15,880)
$5,597	($5,585)	($13,853)	$51,407
($11,657)	($23,200)	($15,062)	$35,527
1/2% ++[22]	0	0	0
$236,000 ++	0	0	0

PREFACE

The Congress, noting the continuous and dramatic utility cost increases in military family housing coupled with the energy picture facing the Nation, enacted Public Law 95-82. This law authorized funding and directed the Secretary of Defense to accomplish the installation of energy consumption metering devices on military family housing units, to establish reasonable ceilings for the consumption of energy, and to assess occupants a charge for metered energy consumption above the established ceilings. Such charges, however, were not to be made until (1) the Secretary conducted a test program to determine the feasibility of assessing military family housing occupants a charge for excess energy consumption; (2) the Secretary of Defense provided the written results of such a test program, together with proposed implementing regulations to the Committees on Armed Services and Appropriations of the Senate and House of Representatives; and (3) a period of 90 days expired following the date on which the written results were provided. Public Law 95-101 appropriated $8,500,000 for the specified test.

This report constitutes the written results of the test metering program, with draft implementing regulations, as directed by section 507(d)(2) of Public Law 95-82 for use should DoD-wide metering be directed. The test was conducted in accordance with guidelines provided in the House Armed Services Committee Conference Report No. 95-494, on the FY 1978 Military Construction Authorization Bill. Additional specific guidance was provided to the four services by the Office of the Deputy Assistant Secretary of Defense (Installations and Housing), who conducted the overall test.

Apparently fundamental to the Congressional impetus for conduct of this program was the belief by Congress, as reported in the House Armed Services Committee Report 95-290, that "energy consumption by the occupants of military family housing might exceed consumption by occupants of similar housing in the private sector by greater than 30 percent and in some cases by as much as 50 percent." Further, the report noted that "the only practical program to effect energy consumption reductions involves moving from a nonmetered to a metered environment, coupled with attendant costs to the occupants for excessive usage." Accordingly, the Secretary of Defense was not asked to report or comment on real or potential energy savings resulting from the test of the metering system, nor to explore possible alternatives to metering as a means of saving energy. The test, then, was to demonstrate the feasibility of (1) installing meters in the DoD family housing inventory, (2) developing a method of determining a reasonable energy consumption for each military family housing unit, and (3) developing and operating a system to bill occupants for use over the calculated reasonable consumption.

The DoD fully supports the concept of energy conservation in all of its endeavors, including military family housing, and believes that abuses, if present, should be curtailed. The Secretary of Defense does not, however, believe that military members and their families should be subject to restrictions more severe than those placed on private citizens in the community, nor that they should lose basic entitlements under the guise of energy conservation or that metering is necessarily the optimal alternative for achieving reductions in energy consumption. This report, therefore, goes beyond the basic Congressional requirements and also explores more fully the concepts of energy conservation, the extent of current overconsumption by occupants of military family housing, and the overall fairness, cost, and energy effectiveness of several different options to reduce consumption.

In conducting the metering test, discussing alternatives, preparing implementing plans, and drafting implementing regulations, a considerable amount of detail spanning many disciplines has been reviewed. In many cases, because of the complexity of the material and the time available to complete the report, arbitrary decisions have been made. Logic and rationale, coupled with experience gained in the test, are provided for primary decision points. Wherever possible precise data quantification is provided, but where complex issues (such as the DoD-wide choice of specific ADP equipment) preclude predecision, orders of magnitude have been estimated with recommendations for further study as part of the implementation plan.

The report is organized into three volumes. The first volume is the Executive Summary, which reports the main conclusions resulting from the test and presents several alternatives for achieving energy savings. The second volume is the Report, which contains comprehensive detail on all aspects of the test and related issues. The third volume is the Appendices, which contain directly related reference material.

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DEFENSE FAMILY HOUSING METERING PROGRAM

INTRODUCTION

During 1974 and 1975, the Office of the Secretary of Defense (OSD) joined with the Office of Management and Budget (OMB) in conducting a study of military housing programs. One section of the study considered the feasibility of metering individual units. Subsequent to receiving comments on the study report from the military departments, defense agencies, and its own principal offices, OSD issued "1976 Planning and Program Guidance." This guidance provided for a triservice group chaired by OSD to review the feasibility of metering utilities consumed by occupants of family housing units. Because the objective of the proposed metering program was to stimulate energy conservation by military housing residents, the study was designed to address other alternatives as well as metering to reduce energy consumption.

During the 24 February 1977 hearings on H.R. 5692 (H.R. 6690) to authorize certain construction at military installations and for other purposes before the Military Installation and Facilities Subcommittee of the House of Representatives Committee on Armed Services, discussions about the metering of energy consumed by military families as an energy conservation method were initiated.

On 6 May 1977, the Subcommittee on Military Installations and Facilities of the House Armed Services Committee introduced legislation in the FY 1978 Military Construction Bill (H.R. 6990) which directed the DoD to install individual meters on all family housing units in the United States and possessions as an energy conservation measure. The legislation also provided for the development of norms (or standards) for each type of energy consumed in a housing unit on an installation. Occupants were to be allowed to use utilities up to the norm as part of their normal entitlement but were to pay a charge for any excess energy used.

Consistent with the Secretary of Defense Planning and Program Guidance, an OSD task force of utilities engineers and rate specialists was established on 9 May 1977, with the membership to comprise representation from all three service departments. The Marine Corps became the fourth service organization represented. The members of this Technical Guidance and Norms Task Force were charged with the development of a plan for installing meters and for developing guidelines and criteria to be used in setting norms at each installation. The initial meeting of the group was held on 20 May 1977.

The 12 July 1977 House of Representatives Conference Report No. 95-494 provided guidelines for the conduct of a DoD military family metering test program. These were as follows:

(1) The cost of the test should be limited to $8.5 million;

(2) A representative cross section of at least 10,000 housing units from all regions of the country, including those with meters at the present time, should be included in the test;

(3) A part of the test sample should include the metering of housing units in which storm windows, thicker insulation, and other energy-saving devices had been installed in order to test the comparative effectiveness of the services' ongoing energy conservation program;

(4) Occupants should receive bills for the excess energy consumed, but would not be required to pay for the excess energy consumed during the test period;

(5) The test should be conducted on the following schedule with progress reports submitted to the Armed Services Committees at each milestone:

(a) Complete test design, 1 October 1977

(b) Complete energy retrofit and meter installation on test units, 1 January 1978

(c) Progress report, 1 July 1978

(d) Progress report with preliminary findings, 1 January 1979

(e) Final report, 1 January 1980 (Later changed to 1 March 1980 because of delays in meter installation)

On 1 August 1977, Congress authorized (Public Law 95-82) the installation of energy consumption metering devices on military family housing facilities in any State, the District of Columbia, the Commonwealth of Puerto Rico, and Guam. In addition the Secretary of Defense was directed to:

(1) Establish a reasonable ceiling for the consumption of energy in any military family housing facility equipped with an appropriate consumption metering device;

(2) Assess the member of the Armed Forces who is the occupant of such facility a charge, at rates to be determined by the Secretary of Defense, for any energy consumption metered at such facility in excess of the ceiling established for such facility pursuant to paragraph (1).

Such charges for excess energy consumption were not to be made to any military family housing facility resident in any State, the District of Columbia, the Commonwealth of Puerto Rico, or Guam until:

(1) The Secretary of Defense conducts a test program to determine the feasiblity of assessing occupants of military family housing charges for excess energy consumption;

(2) The Secretary of Defense provides the written results of such a test program, together with proposed regulations implementing this section, to the Committees on Armed Services and Appropriations of the Senate and the House of Representatives;

(3) A period of 90 days expires following the date on which the results referred to in clause (2) have been submitted to such committees.

The Appropriations Committees Conference Report (House of Representatives Report No. 95-650, dated 3 August 1977) limited the expenditure of authorized funds to "a test to determine the feasibility of metering family housing facilities." It was stipulated that "such a test shall follow the specific guidelines established by the military construction authorization conferees." DoD was also enjoined from implementing "a metering program for the current housing inventory without the express prior approval of the House and Senate Committees on Appropriation."

On 4 August 1977, a second OSD task force was established to design and conduct the test of metering utility consumption of military family housing as directed by Congress in the conference report (95-494) of the Armed Services Committees on the Military Construction Bill (Public Law 95-82). The Family Housing Metering Task Force included representatives from all four services and was expected to use inputs from the previously established Technical Guidance and Norm Task Force. The new working group was directed to concern itself with such activities as selection of test installation, billing procedures, reading of meters, test parameters, and administration of the test. The first meeting of this group took place on 18 August 1977. This task force comprised members from OSD and some service groups that overlapped with those in the Technical Guidance and Norm Task Force.

Eleven days later Congress appropriated $8,500,000 for DoD energy consumption metering in family housing (Public Law 95-101, dated 15 August 1977).

Chapter 1. METER INSTALLATION

I. Planning.

A. Site Selection.

In early June 1977, the Technical Guidance and Norms Task Force requested the four services to nominate installations that could be included in a test of the proposed metering program. It was stipulated that nominations be made from conterminous United States (CONUS) within each of five climatic regions, hot and humid, hot and dry, moderate with air conditioning, moderate without air conditioning, and cold. Nearly all of the nominations had been received by the end of July. On 18 August 1977, the newly established Family Housing Metering Task Force met to discuss milestones for the test program, select test sites, and confer on other procedures.

At this time, the committee expanded the criteria for selecting sites to consider not only climatic zones within CONUS but also the following:

1. Congressional requirements (House Conference Report No. 95-494)

    a. A representative cross section of at least 10,000 housing units from all regions of the country

    b. Units with meters at the present time

    c. Some units with energy-saving devices such as storm windows and thicker insulation already installed

2. OSD requirements

    a. A diverse combination of units including some which are difficult, as well as others which are easy, to meter

    b. A variety of construction types and ages

    c. Most types of energy provided to military family housing units

On 1 September 1977, the service departments were informed of the ten sites that had been selected by the committee. The departments were provided with the parameters of the test and the milestone schedule specified by Congress. The installations selected were tasked to determine the best and most expeditious method of installing the required meters. The

services were requested to provide an estimated cost for metering their selected installations and completing the test as directed by Congress.

In a 15 September 1977 meeting, the Family Housing Metering Task Force agreed that Little Rock AFB, Arkansas, could be substituted for Keesler AFB, as requested by the Air Force. Although Keesler AFB had been selected as a test site on 1 September 1977, the Little Rock AFB units provided an opportunity to evaluate the energy consumed by heat pumps used for both heating and cooling. The substitution was approved on 21 September 1977.

As shown in Table 1-1, a cross section of housing from five different climatic zones and several geographical regions of CONUS was identified. The Air Force provided 2,547 units, the Army 2,492, the Marine Corps 3,094, and the Navy 3,472 for a total of 11,605 units.

Table 1-1
Military Family Housing Sites Selected

Climate	Military Service	Location	Number of units
Hot, humid	Air Force	Little Rock AFB, AR	1,535
	Army	Fort Gordon, GA	877
	Marine Corps	MCAS Beaufort, SC	1,276
Hot, dry	Air Force	Cannon AFB, NM	1,012
	Army	Yuma Proving Ground, AZ	290
Moderate with air conditioning	Army	Fort Eustis, VA	1,325
	Marine Corps	MCDEC Quantico, VA	1,818
Moderate, without air conditioning	Navy	PMTC Point Mugu, CA	883
	Navy	CBC Port Hueneme, CA	500
Cold	Navy	NTC Great Lakes, IL	2,089
Total	-	-	11,605

The housing styles ranged from single-family dwellings to apartment complexes of 15 units, and construction materials included wood, steel, stucco, concrete, and brick. Some buildings were built before the turn of the century while others were less than 5 years old.

The sources of consumed energy were electricity, natural gas, fuel oil, propane, and steam. Some units used gas to chill water for cooling while others used steam to heat water for domestic use and heating.

B. Initial Estimates.

By the 15 September 1977 meeting of the Family Housing Metering Task Force, preliminary estimates of the cost and time required to install the meters were available. It should be noted that these estimates were very rough and were not based on actual field conditions in all cases. These preliminary cost estimates for the meter design and installation portion of the test program are summarized in Table 1-2. With the design cost included, the estimates ranged from a low of $362 per unit for the Air Force to a high of $1,011 per unit for the Army. As described in the status reports to Congress on 30 September 1977, the services estimated that a 30-percent premium would have to be paid for meter installation as a consequence of the compressed time frame, i.e., completion of installation by 30 June 1978.

Table 1-2
Estimated Costs for Design and Installation of Test Meter Systems

	Service				
Element	Air Force	Army	Marine Corps	Navy	Total
Units in test	2,547	2,492	2,242 [1]	3,472	10,753
Meters needed	3,559	4,638	5,953	6,445	20,595
PRELIMINARY COST ESTIMATE					
Design & Installation					
Avg. per meter	$ 259	$ 543	$ 139	$ 396	$ 331
Avg. per unit	362	1,011	368	736	635
Subtotal	$ 923,000	$2,520,000	$ 826,000	$2,555,000	$6,824,000
Administrative [2]	972,000	260,000	424,000	206,000	1,862,000
Total	$1,895,000	$2,780,000	$1,250,000	$2,761,000	$8,686,000

[1]Excludes 852 units at MCDEC Quantico; 202 were included.
[2]Excludes cost for computer work in establishing and maintaining norms and for developing a uniform simulated billing system for joint use.

Preliminary estimates of the time required to design and install the metering systems indicated that some installations could be completed by 1 January 1978 as required in the schedule provided in the Conference Report on Public Law 95-82 (House Report No. 95-494, page 36). However, delays in design and other factors required the completion date for installation of all meters to slip to 30 June 1978. This revised meter installation milestone coincided with the progress report milestone provided in the conference report. Such a revised date still provided the opportunity to collect a year's information on the test program and report the results by 1 January 1980 (House Conference Report No. 95-494).

In October 1977, the following funds were allocated to the services for their use in installing the metering systems, developing norms, and designing a billing system:

Military Department	Allocation
Air Force	$1,500,000
Army	2,100,000
Navy (includes Marine Corps)	4,300,000
Subtotal allocated	$7,900,000
Contingency reserve (held in OSD)	600,000
Total appropriated	$8,500,000

All services were requested to keep track of metering costs, including meter installation design, purchase, installation, and maintenance. Costs are identified and summarized in the following section.

C. Design.

It was then necessary to initiate the first of four steps that would result in having meters installed and functioning at all ten sites. The architectural and engineering (A & E) design work was required to provide the specifications and drawings that would be used in contracting for the installations. Table 1-3 summarizes the time frame and costs involved at each test site.

Table 1-3
Designing the Meter Systems

Locations	Units included in Design	Method Used	Work Start	Work End	Total Cost	Cost/ Unit
Cannon AFB	1012	In-house	08-31-77	09-27-77	$24,365	$24.08
Little Rock AFB	1535	In-house	10-01-77	11-16-77	$2,675	$1.74
Ft. Eustis	955	Contract[1]	02-03-78	03-03-78	17,562	18.39
	370	Contract[1]	04-03-78	05-01-78	7,657	20.69
Subtotal	1325				$25,219	$19.03
Ft. Gordon	875[2]	In-house[3]	11-01-77	12-01-77	5,200	5.94
		Contract[3]	12-12-77	01-31-78	15,054	17.20
Subtotal	875				$20,254	$23.15
Yuma P.G.	290	In-house	09-15-77	10-03-77	5,280	18.21
MCAS Beaufort	1276	In-house	08-29-77	09-12-77	2,000	1.57
MCDEC	1168	In-house	08-29-77[4]	01-20-78[4]	11,110	9.51
Quantico	650[5]	Contract	04-01-78	04-30-78	23,460	36.09
Subtotal	1818				$ 34,570	$ 19.02
NTC Great Lakes	189	In-house	09-02-77	09-22-77	2,658	14.06
	500	In-house	09-01-77	09-16-77	9,570	19.14
	1400	Contract[6]	09-23-77	10-24-77	9,950	36.29
		Contract	11-16-77	01-10-78	40,857	
Subtotal	2089				$63,035	$30.17
PMTC	616[7]	Contract	12-27-77	07-07-78[8]	103,848	168.58
Pt. Mugu &	765[9]	In-house	08-23-77	09-09-77	1,430	1.87
CBC Port	1096[10]	In-house	08-23-77	09-09-77	2,511	2.29
Hueneme	1[11]	In-house	04-10-78	04-10-78	13	13.14
Subtotal	1382				$107,802	$78.00
Total	11,602[12]				$285,200	$24.58

[1]370 units were under a renovation contract requiring that the drawings reflect those programed changes. Design work was done under extreme schedule constraints, so that an optimum solution could not be developed.

[2]Two units were already fully metered.

[3]The survey work was done by the Army's Facilities Engineering Support Agency, and the drawings were done on contract. The survey work indicated that extensive structural work was required to meter natural gas in 122 buildings. 112 buildings (278 units) were not metered.

[4]The work was done just prior to developing the contract package, usually within three weeks or less. There was a different start and end date for the design of each installation package.

[5]These units were not metered.

[6]A task order on a present contract was used to establish the scope of the A & E contract effort as well as its feasibility and estimated cost.

[7]Natural gas meters for all units and electric meters for 285. 285 units were not metered.

(Footnotes continued overleaf.)

Both Air Force sites chose to do the designs inhouse. At Cannon AFB, the work on both natural gas and electric meter installations was initiated 31 August and completed 27 September 1977 at a cost of $24,365 ($24.08 per unit). At Little Rock AFB, the design of the electric meter systems started 1 October and was finished on 16 November 1977 at a cost of $2,675 ($1.74 per unit).

Fort Eustis contracted its design effort to an A & E firm for $25,219, a cost of $19.03 per unit. The cost was increased slightly because 370 units were under a renovation contract requiring that the drawings reflect the changes introduced by renovation of the exterior. Fort Gordon requested the assistance of the Army's Facilities Engineering Support Agency (FESA) in designing the meter installation and drafting the specifications for the installation contract. FESA collected the onsite data and contracted the drafting portion of the design. The combined inhouse and contract cost was $20,254 ($23.15 per unit). Yuma Proving Ground accomplished the design with 2 man-months of in-house personnel costing $5,280 ($18.21 per unit).

The design effort at MCAS Beaufort was completed in 2 weeks, using inhouse personnel. This was the lowest design cost ($1.57 per unit), at any test site. At MCDEC Quantico, the design work for the units that were metered was also done inhouse. The electrical metering systems design work took 110 man-hours for 1,099 units; the natural gas metering systems design took 24 man-hours for 935 units, and the steam system designs took 250 man-hours for 57 units. The total cost for the designs installed at Quantico was $11,110 ($9.51 per unit). The cost would have been greater except that 69 electric and 233 propane meters were already on site. However, meters were not installed in an additional 650 Quantico units that would have required very complex, expensive systems. To develop appropriate designs and estimates of the cost to install meters in those units, a contract was awarded to an A&E firm for $23,460 ($36.09 per unit). The complexity of metering steam and its conversion to hot water is reflected not only in a high installation cost but also in a relatively greater expense for the design work. Deficiencies in the design of the 57 steam metering systems installed at Quantico have created major problems with their maintenance and operation. These and other design problems will be described in section II.D.

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[8]Originally completed in March 1978, but there were errors which had to be corrected.

[9]Natural gas meters only. Two units required two meters each.

[10]Electric meters only. One unit was already metered for both gas and electricity.

[11]Fuel oil flow meter only.

[12]Three units were already completely metered

At NTC Great Lakes, several approaches were taken to complete the designs for meter installations. The work for 189 single-family units was done onsite between 2 and 26 September 1977 at a cost of $14.06 per unit. Between 13 and 30 September 1977 engineers at the Naval Facilities Engineering Command's Northern Division completed designs for installing meters on 500 additional units at a cost of $19.14 per unit. The design work for the 1,400 most complex units was contracted to an A & E firm. Because of the complexity, a preliminary contract was used to define the scope and provide a cost estimate for the design acquisition package. Thus the sequential contracts were completed over 3-1/2 months at a cost of $36.29 per unit. As at Quantico, the use of steam for direct heat or for heating water provided a major challenge to the designers. In addition, some drawings which were made when the buildings were acquired or renovated proved inaccurate, and the design work, which depended upon those drawings, incorporated the errors. This resulted in several contract changes and accompanying expensive, time-consuming negotiations. The A & E designs were used in the February 1978 decision to withdraw 13 units from the metering test program because of the high cost.

CBC Port Hueneme and PMTC Point Mugu combined both their design and meter installation efforts. One unit at Port Hueneme was fully metered prior to the program so it required no design work. The least complex installation designs for 1,097 electric and 766 natural gas meters were done inhouse. That work cost $2.29 and $1.87 per unit respectively. Construction drawings were not available for 285 Port Hueneme units that had been renovated to form four- and five-unit buildings from the original six-unit. The electrical and natural gas service surveys and the metering installation designs of these buildings were combined with the most complex natural gas metering design requirements at Point Mugu to form a single A & E contract. When the cost estimates for metering the 285 Port Hueneme units proved to be extremely high, a supplement providing for a design with reduced consideration of esthetics and occupant discomfort was made. The original contract plus the supplement was completed in March 1978 and brought the cost of the design effort for the 616 units up to $168.58 each. The supplemental A&E design for the 285 Port Hueneme units was used in the decision to withdraw those units from the metering test program because of the high cost. When actual installation of the meters in 315 Point Mugu units was initiated, it was found that the A&E firm had worked from inaccurate construction drawings that had been supplied to the Navy when the units were acquired. The A&E firm had not done a field investigation to check the accuracy of the drawings as required by the contract and, therefore, had produced incorrect designs. The A&E firm corrected the drawings at no cost to the government. However, meter installation was delayed by 45 days, and the installation contract had to be modified materially.

The experience of the ten sites in obtaining metering system designs that could be used in deciding to omit units, developing acquisition packages, and installing meters is summarized in Table 1-3. The shortest period of time used by a site to prepare designs for completed installations was 2 weeks while the longest was 44-1/2 weeks. Over all for the ten sites, the design effort was initiated on 23 August 1977 and was completed on 7 July 1978 with an average time of 15 weeks. The average design cost per family housing unit at a site ranged from $1.57 to $78.00 with the average as $24.58. The diversity of the housing, complexity of the meter installations, availability of in-house personnel, and adequacy of construction and renovation drawings had major impacts on the method, cost and time required to design the installations.

D. Revisions.

1. Previously Metered Units. The design work demonstrated that it would not be possible to achieve any significant cost savings or to analyze historical data at the ten test sites using previously metered individual units. Of the 11,605 housing units present on the sites, only three were individually and fully metered. These single-family dwellings had been included in the acquisition of land for those bases. As shown in Table 1-4, more than 1,600 meters were present at the ten test sites, but most of these were master meters used by the local utility company and the base to charge family housing for total military housing utility consumption on the base. Over 500 meters had been installed on individual units, but they typically covered only one type of energy and many were owned by the private supplier of that energy. For example, the propane supplier at MCDEC Quantico had originally installed meters, but these were not in use because bills were based on the weight of fuel metered from the truck at the time of delivery. In fact, only 233 meters remained, because many had been removed as they became inoperable. As part of a special study, 50 electric meters had been installed on heat pumps at the Little Rock AFB, but the lighting, appliances, and cooking usage was not metered. Thus, no significant savings could be realized by using the previously installed meters, because many of them were not the correct size or type for individual units or were in bad repair.

2. Cost Reduction. The results of the A & E work indicated that it would not be possible to stay within the budget and individually meter all 11,605 units at the ten sites using conventional means. Two alternatives were available. One of these alternatives was to measure energy consumption using new designs that provided approximate rather than accurate usage. The other alternative was to omit some of the units from the test program but develop detailed estimates of the possible cost to meter such units. When both the Congressional budget and time constraints were applied, both alternatives were used.

Table 1-4
Meters Installed Before 1978

Location	Number of meters present		
	Onsite	On a unit	Metered
Cannon AFB	0	0	0
Little Rock AFB	50	50	0
Fort Eustis	0	0	0
Fort Gordon	8[1]	8[1]	2
Yuma Proving Grounds	0	0	0
MCAS Beaufort	0	0	0
MCDEC Quantico	302	302	0
NTC Great Lakes	1,313	197	0
PMTC Point Mugu	0	0	0
CBC Port Hueneme	3	3	1
Total	1,676	560	3

[1] Six of these test cases were not meters, but the propane (1 case) or fuel oil (5 cases) usage could be measured at the time of delivery.

a. Indirect Metering. At both Fort Eustis and MCAS Beaufort, elapsed-time meters were used to approximate the amount of fuel oil consumed by the residents of units. Rather than metering the fuel oil usage directly, the timer records the length of time that the unit's burner is running. When the recorded time is multiplied by the manufacturer's specified flow rate of the burner nozzle in gallons per hour, an estimate of the fuel oil consumed is determined. However, the method does not consider the condition of the nozzles nor the accuracy of the manufacturer's specifications.

At both MCAS Beaufort and NTC Great Lakes, estimates of energy consumption were developed from what became known as master/slave metering systems. So that the amount of essential repiping would be minimized and new individual gas-serviced, chilled-water coolers would not need to be installed in 154 duplex units at MCAS Beaufort, elapsed-time meters were installed in each unit to estimate the amount of gas used to heat and cool it. Both units in a duplex were served by a common cooling plant although each had its own furnace for heat. The gas supply line to the building was provided with a master meter to record the total gas used by the duplex. Each unit had two thermostatic controls, one for heating and one for cooling. It was, therefore, necessary to put a separate elapsed time meter on each control as a slave to the master gas meter. To estimate the amount of gas consumed by a single unit, the readings on its heating and cooling elapsed time meters were added together, the sum of the elapsed-time meter readings for the adjacent unit was computed, and the total gas consumed by the duplex allocated on a proportional basis.

At NTC Great Lakes the same type of measure is used in a somewhat different application. For example, a fourplex has a single gas-fired boiler for hot-water heat and a single gas-fired domestic hot-water heater. The flow of hot water for the radiators is metered separately for each unit as is the flow of domestic hot water for sanitary use. To estimate the respective amount of energy consumed by a single unit, percentages are calculated for each unit based on hot-water flow rates rather than elapsed time. The percentages are multiplied by the consumption in therms (for hot-water heat) and cubic feet of gas (for domestic hot water). At NTC Great Lakes, as many as 15 units are on a single master meter. This arrangement requires the meters for all units be specially read every time one tenant moves in or out to determine that occupant's consumption, in addition to the regular routine readings.

The cost to convert master/slave metering systems to traditionally metered individual units will be covered in a later section.

b. Exclusions. A second means used to meet time and budget constraints was to omit the most complex installations from the metering test program. Because the design effort provided much more accurate estimates of installation costs than were available in August and September 1977, it was apparent that many units would have to be omitted. Approval was given to withhold 1,226 units at Fort Gordon, MCDEC Quantico, NTC Great Lakes, and CBC Port Hueneme from the test program as shown in Table 1-5.

The costs are high, because prior to FY 1978 military housing was not built with any intention that individual units would be metered. It was built to save construction costs and to use the sources of energy available onsite at the time of construction. An older apartment house at MCDEC Quantico provides a prime example of the amount of reconstruction that may be required to meter each unit in a building.

The building has six apartments, two on each floor. Each apartment is provided with a study room on the fourth floor and a storage room, a freezer hookup, and laundry space with utilities connections in the basement. The building has a common hallway and a utilities center in the basement.

The primary types of energy for the building are steam, electricity, and natural gas. Steam is supplied to the building from the station's central power plant. Within the building steam presently enters a heat exchanger to heat the hot-water supply (HWS) that circulates through connected radiators to heat all six units, the hallway, and the study rooms. Not only do separate systems for each residential unit need to be installed and metered but also an independent system is required for the common hallway. The complexity of the

Table 1-5
Military Family Housing Units Metered For the Test

Climate	Military Service	Location	Number of Units: Total On-site	Fully Metered	In Test Program
Hot and humid	Air Force	Little Rock AFB, AR	1,535	1,535	1,535
	Army	Fort Gordon, GA	877	599	599
	Marine Corps	MCAS Beaufort, SC	1,276	1,276[1]	1,276
Hot and dry	Air Force	Cannon AFB, NM	1,012	1,012	1,011
	Army	Yuma Proving Ground	290	290	289
Moderate with air conditioning	Army	Fort Eustis, VA	1,325	1,325	1,325
	Marine Corps	MCDEC Quantico, VA	1,818	1,168	1,107
Moderate without air conditioning	Navy	PMTC Point Mugu, CA	883	883	883
	Navy	CBC Port Hueneme, CA	500	215	215
Cold	Navy	NTC Great Lakes, IL	2,089	2,076	2,076
		TOTAL	11,605	10,379[2]	10,316[3]

[1]Six units were not actually fully metered, but the propane (1) and fuel oil (5) usage could be measured at the time of delivery.

[2]1,226 units were not metered because of the high estimated cost per unit.

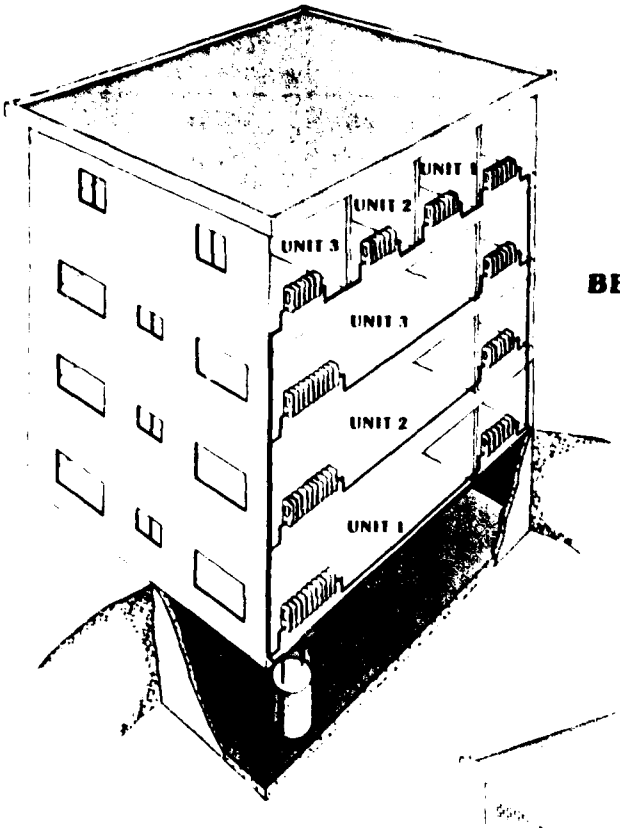
[3]63 metered units were lost due to a tornado, fires, and disposal.

installation is shown in Figure 1-1, which describes the existing and proposed heating systems for one-half the building and the common hallway.

Steam also supplies heat for the domestic hot water used within each apartment and the assigned hookups in the basement laundry space. The diagram for converting the existing system to an individually metered one is very similar to the one described for the hot-water heating except that a return line is not required and the basement laundry facility has to be hooked up rather than the fourth floor study room.

Electricity is used for lighting and appliances. Thus the electrical circuit of each unit must include the fourth floor study room and the basement outlets for the storage area and laundry appliances. A separate circuit is required for the lighting in the common hallway and the central utilities area. See Appendix A for excerpts of the A&E Design Report further describing complexity, problems, and estimated costs.

SIMPLIFIED CUTAWAY DRAWING OF BEFORE-AND-AFTER PIPING FOR HOT WATER HEATING ONLY



BEFORE

AFTER

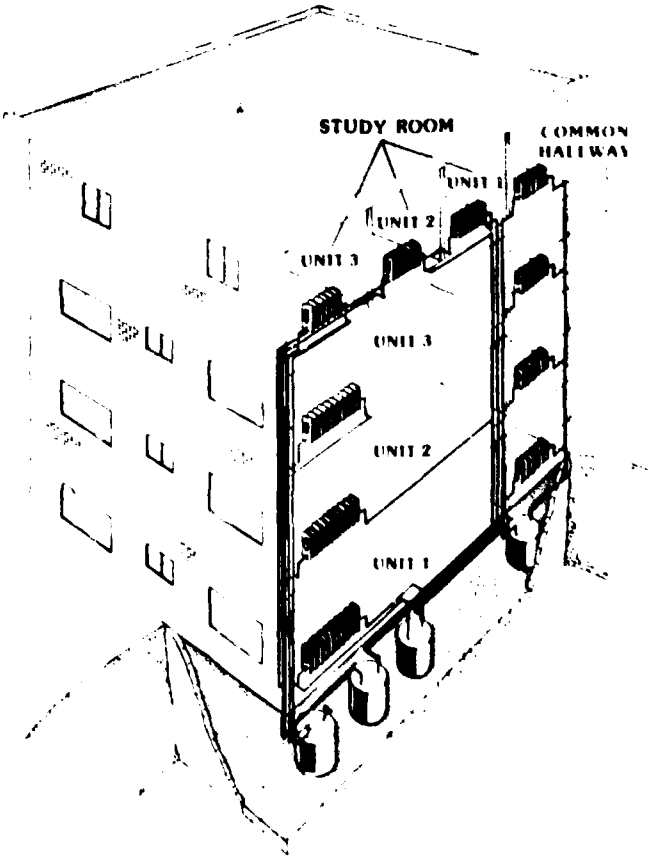


FIGURE 1-1

Natural gas is provided to each unit for cooking.

The design contractor estimated that the average cost of installing individual meters in each of the above units would be $36,495. Because of the disruption involved with tearing apart and rebuilding walls and floors, the need to protect valuable possessions, and the threat to occupant safety, the firm assumed that the units would be vacant at the time of the installation. This may not be practical because of the number of units involved. Therefore, it would probably be necessary to relocate residents for 4 to 6 weeks during the work, thus increasing the cost of installation by more than $1,600 per unit.

The preceding example accounts for seven buildings with 42 of the 650 units that were not individually metered at MCDEC, Quantico. The installation of meters on the 650 units withheld from the test program at that base alone would have cost over $5 million in 1977 dollars.

A different problem was confronted at Fort Gordon. Duplex homes of 1972-1974 vintage have a single gas supply for the two units. The gaslines have a branch tee inside the wall. This arrangement requires breaking the wall and ceiling to expose the pipes for modification to accommodate the meters. The dislocation of all families for a period of 2 to 3 days for the contractor to make the modification to the gas supply was considered impractical. The cost involved in placing the families in temporary housing or motels and the hardship the temporary relocation would have had on the families were too great. However, approval was given to install meters in a representative sample of ten buildings with 28 units to provide an accurate estimate of the cost to meter all 122 of these buildings (306 units). The cost to meter the remaining 278 units was estimated as approximately $150,000 in 1977 dollars.

The metering problem faced at NTC Great Lakes was similar to the MCDEC Quantico example. At NTC Great Lakes, 13 units in three brick buildings were arranged in the shape of a "U." The building forming the bottom of the U has a basement that contains a central utilities center, laundry facilities, and individual storage rooms for each living unit. Garages are provided in two separate buildings, and there is electrical service in each garage. Hot-water heat is provided from a single natural-gas-fired boiler with each building served by a supply and return loop. The design for metering the units indicates that the entire system would have to be repiped to provide for 13 separate loops. A Btu meter would be required for each loop. Domestic hot water is also supplied from a central gas fired water heater. It would be necessary to install individual gas hot-water heaters in each unit with a pipe leading to the clothes washers in the laundry room. Electrical metering would require almost a complete new distribution system and 13 new electrical panels. Rewiring would include service to the

garage and laundry room. Lighting in the common areas such as the basement utility room, hallways, and stairways would be separately metered and charged to general housing operations cost. Cooking and clothes drying are done by natural gas. It would be necessary to repipe the distribution system to provide individual service and a meter for each living unit plus an additional meter for the gas supply to the dryer of each unit. See Appendix A for excerpts of the A&E Design Report showing complexities and strong recommendations that work, although potentially profitable, not be done.

Estimated costs per individual quarters are as follows:

Electrical	$3,975
Natural gas	1,338
Space heating and domestic hot water	3,500
Total	$8,813

Although it appeared to be similar to Fort Gordon, the situation at CBC Port Hueneme was even more difficult to solve than the Fort Gordon example. At Port Hueneme, natural gas lines imbedded in the concrete slab would have had to be capped off outside and new lines installed in the walls and ceilings. This is shown in Figure 1-2.

The projected costs for metering the units omitted at Great Lakes and Port Hueneme would have been approximately $750,000 in 1977 dollars as described in Table 1-6. Thus, excluding any relocation charges or consideration of esthetics, the projected additional cost to install individual meters on the 1,226 units that were not metered at the four test sites would have been over $6.1 million in 1977 dollars.

SIMPLIFIED CUTAWAY DRAWING OF BEFORE-AND-AFTER PIPING FOR NATURAL GAS

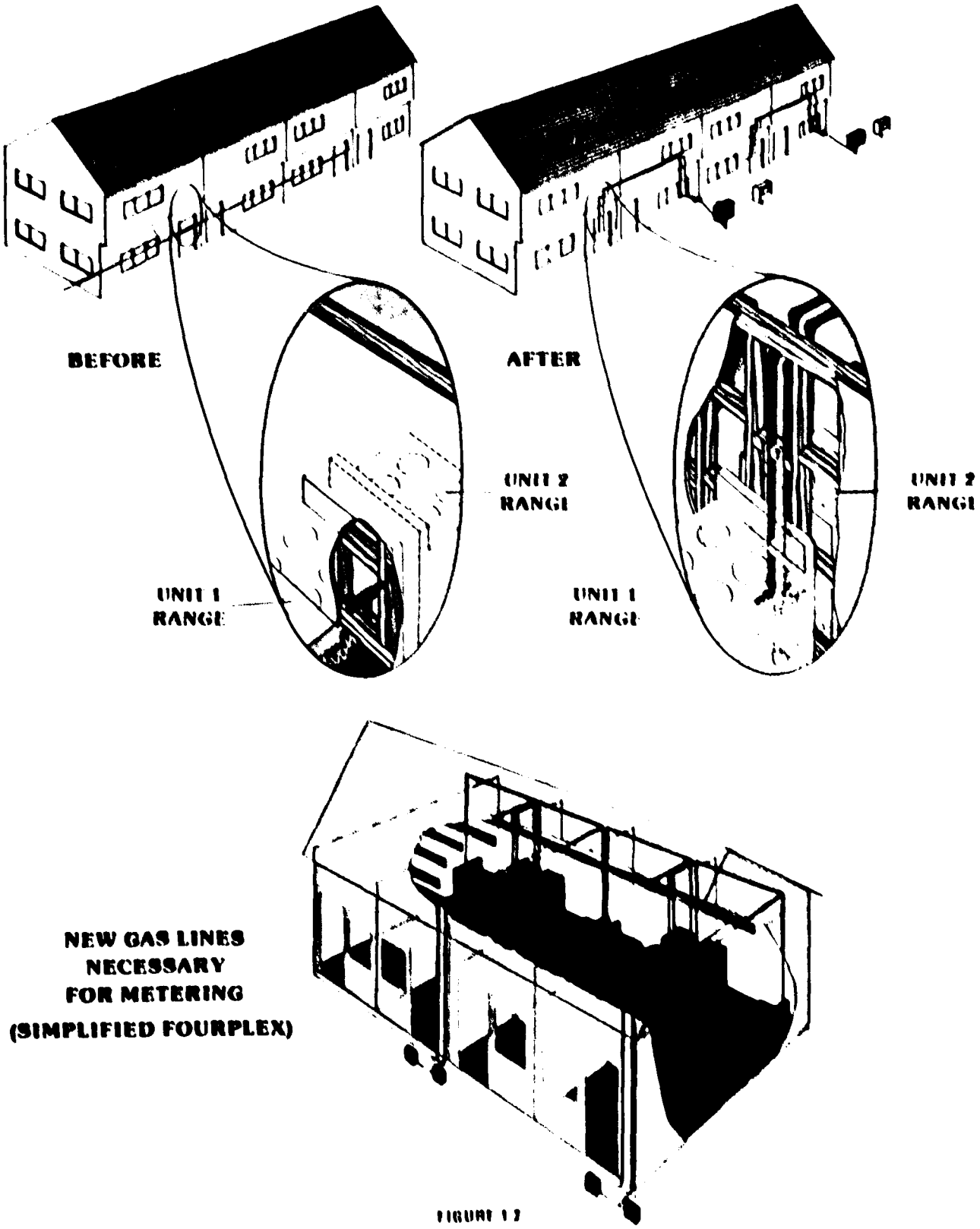


FIGURE 12

Table 1-6
Projected Costs to Meter Unmetered Test Site Units

Location	Utility[1]	Style	Quantity Bldgs	Quantity Units	Cost Per unit	Cost Total
Fort Gordon[2]	G,E	Duplex	94	188	$507	$95,407
	G,E	Fourplex	9	36	503	18,103
	G,E	Sixplex	9	54	576	31,120
Subtotal			112	278	$520	$144,630
MCDEC Quantico	G,E,S[3]	Sixplex	-	42	$36,494[4]	$1,532,755
	G,E,S	Sixplex	12	72	16,088[4]	1,158,312
	G,E,S	Apartments	1	11	11,038[4]	121,414
	G,E,S	Apartments	1	13	6,420[4]	83,454
	G,E,S	Sixplex	16	96	14,448[4]	1,387,008
	G,E,S	Duplex	5	10	1,888	18,880
	G,E	Duplex	10	20	1,857	37,130
	G,E	Fourplex	3	12	2,690	32,277
	G,E	Multiple	25	170	2,621	445,597
	G,E	Multiple	20	77	2,087	160,706
	G,E	Multiple	31	125	2,064	257,940
	G,F	Single	2	2	3,350	6,700
	Subtotal		133	650	$ 8,065	$5,242,173
NTC Great Lakes	G,E	Apartments	3	13	$ 8,813	$ 114,570
CBC Port Hueneme	G,E	Single-family	20	20	$ 2,223	$ 633,555[5]
		Multiple	48	265	-	-
Subtotal	-	-	68	285	$ 2,223	$ 633,555
Total	-	-	316	1226	$ 5,004	$6,134,928

[1]G = Gas; E = Electricity; S = Steam; F = Fuel oil.

[2]These are estimates of the total cost to meter the units although electric meters were installed in the 278 units at a cost of $66,438. The gas meters were not installed, because residents would have had to be relocated as walls were ripped open to install piping. An additional cost to relocate one-half of the families for 3 days was projected to be $20,850 if the work could not be extended over a long period of time as buildings became vacant.

[3]Hot water heat.

[4]Extensive rewiring and repiping is required throughout each building. If present, residents may have to be evacuated at a projected additional cost of $1,600 per unit because the work would take 4 to 6 weeks each.

[5]This estimate is an austere one in which, within reason, esthetic and occupant discomfort considerations were omitted. With those considerations included, the estimated cost was $1,110,820.

II. Installing Meters.

A. Contract Acquisition.

Once the designs for the meter systems had been completed and the decisions made to omit some units, it was possible to prepare for installing the meters. Because only 73 of 19,202 meters were installed by onsite personnel, this meant that acquisition packages had to be developed and contracts[1] awarded at all ten sites for the remaining 19,129 meters.

Cannon AFB took 4 months to issue its single contract. Little Rock AFB required 3-1/2 months between design completion and the notice to proceed.

The two contracts at Fort Eustis were each acquired in 2-1/2 months, while the one at Yuma Proving Ground took 3 months. One contract at Fort Gordon took 4 months because the first acquisition package could not be awarded. The potential contractors were requested to bid on the basis of two completion dates, 30 June 1978 and 31 August 1978. A total of four bids were received ranging in price from $218,128 to $425,445. The low bidder justified his estimate in writing but could not confirm the contract schedule and performance requirements. One bidder objected in writing to the performance schedule, basing the protest on the performance of similar work for the Marine Corps. The other bidders stated at the bid opening meeting that the 30 June 1978 completion date could not be met because of the long lead time required for the procurement of the meters. All four bids were then rejected by the contracting office for the simple reason that alternate completion dates could not be justified in the contract. The contract was readvertised for a completion date of August 1978. In order to eliminate the long lead time for meter procurement, FESA agreed to purchase the electric meters by negotiating special considerations with local distributors. The meters were then delivered to Fort Gordon and furnished to the contractor as Government-furnished equipment (GFE). The other Fort Gordon contract took 3 months to award.

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[1] Typically, construction contracts are awarded in four steps. In the first step, an acquisition package is prepared. In this step the metering system designs are used to prepare the required specifications. In the second step, the package is advertised and a request is made for bids. The normal period allowed for bids to be prepared is 30 days. At the end of this period, the bids are formally opened as the initial phase of Step 3. Investigations of the lowest bidders are made, the lowest responsive bid is chosen, and the award is made. Before issuing the notice to proceed (Step 4), a post-award meeting may be held and a review made of the successful bidder's compliance with acquisition regulations. Finally, the notice to proceed is issued.

MCAS Beaufort awarded three contracts between 12 September 1977 and 1 February 1978. Each took 2-1/2 to 4-1/2 months to award. MCDEC Quantico took 1-1/2 to 3 months each to award seven contracts between 9 September 1977 and 12 April 1978.

Five contracts were awarded at NTC Great Lakes between 16 September 1977 and 31 March 1978. The shortest took 1-1/2 months and the longest 2-1/2 months. CBC Port Hueneme and Point Mugu awarded their three contracts between 9 September 1977 and 2 June 1978. The longest took 3 months because the acquisition package had to be redone after only one unacceptably high bid was received as a result of the initial request for bids.

The time required to complete the process for each of the 25 contracts is shown in Table 1-7. The average time required to go from design completion to the notice to proceed was 79 calendar days. The shortest period of time taken to complete the award of a contract was 42 calendar days at PMTC Point Mugu, and the longest was 141 calendar days at MCAS Beaufort. Principal factors affecting the length of time taken to award a contract were the duration of advertising the acquisition package and the adequacy of the response to the request for bids. The complexity of the meter installation task did not seem to be a critical variable.

B. Execution.

In most circumstances installation of the meters progressed smoothly toward completion by the revised 30 June 1978 milestone. In those instances, either major problems were not present or they had been foreseen and accounted for in the designs. However, in several instances at Fort Eustis, Fort Gordon, NTC Great Lakes, and PMTC Point Mugu, major problems in design, contract award, and meter installation occurred, requiring a change in the schedule, deletion of units from the program, or extension of the time required to install the meters. On 17 January 1978, the Family Housing Metering Task Force was apprised that the cost to meter some individual units at NTC Great Lakes would be extremely high even though previously approved alterations to the program, e.g., using master meters vice individual meters on multiunit garages and storerooms had been taken into account. The task force also was informed that the installation of meters at NTC Great Lakes and PMTC Point Mugu could not be completed until 31 August 1978. In February 1978, both the Army and Navy departments indicated that their costs for metering all units on their eight sites would be in excess of the available funds. On 11 April 1978, the Navy reported that the 13 units at NTC Great Lakes and the 285 at PMTC Point Mugu would be withheld from the metering test program because of excessive costs. Concurrently, the Navy transferred a $500,000 surplus in meter installation funds from the Marine Corps budget to cover unforeseen costs at the NTC Great Lakes and PMTC Point Mugu sites. At the same time

$300,000 in additional funds was requested to cover the high cost of metering units at the latter two sites. Nine days later the Navy provided official confirmation that the meters at Point Mugu could not be operational before 1 August 1978.

On 11 May 1978, the Army reported that all meters would be installed at its three sites by 31 August 1978 except for 370 units at Fort Eustis, which were under a previously awarded renovation contract running through 30 September 1979. The meters were to be installed on those units immediately after each was accepted from the renovation contractor.

To provide a comprehensive perspective of the actual costs, schedule, and problems associated with the installation of meters at each site, a summary of the experience of each service department is provided below. A tabular summary is provided in Table 1-8.

1. Air Force. The Air Force installed 3,559 meters for electricity and natural gas on 2,547 units at two sites. One Cannon AFB unit metered for electricity and natural gas was destroyed by fire, leaving 2,546 Air Force units still in the metering test program. At Cannon AFB, it took slightly more than 7 months for all meters to be installed and considered operational. However, nearly 2 months of that time involved a delay imposed on the contractor by the late delivery of meters caused by a strike at the meter supplier's facility. In addition to that delay, the contractor took 2 weeks to replace bad meters and correct 10 incorrectly installed ones. Because meter installation was accomplished by a lump sum contract, the cost of individual meter installations and units was not available. Averages for all units and meters are shown in Table 1-8.

At Little Rock AFB, installation started a month later than at Cannon AFB and was completed a month after the deadline. However, inaccuracies of construction drawings for 20 duplexes were reflected in the drawings provided the contractor. As a result, crossed wiring in the duplexes caused the meters to be assigned (tagged) to the wrong units. This was corrected by 1 September 1978. With only electric meters required at Little Rock, the average cost of installation per unit was $128, the lowest of any site.

2. Army. The Army has installed 4,298 meters for electricity, fuel oil, and natural gas on 2,212 units at three sites. Two units at Fort Gordon had meters already present, and one unit at Yuma Proving Ground was destroyed by fire. The Army has 2,213 units still in the metering test program. The installation at Yuma Proving Ground included only electric meters in 110 single-family buildings and 90 duplexes. Although the contractor placed the order for meters immediately after the contract was awarded, a 6- to 8-weeks' delivery was allowed because 3-phase service is not a conventional residential utility service. Work was delayed twice for a

Table 1-7
The Contracting Process

Location	Energy[1] Metered	No. of Meters	Design Completion	Advertised	Bid Opening	Award Date	Notice to Proceed
Cannon AFB	E,G	2,024	9-27-77	11-09-78	1-13-78	1-27-78	1-27-78
Little Rock AFB	E	1,535	11-16-77	12-06-77	1-06-78	2-07-78	3-01-78
Ft. Eustis	E,F[2]	1,910	3-03-78	3-29-78	4-26-78	5-04-78	5-15-78
	E,F[2]	632	5-01-78	5-26-78	6-27-78	7-05-78	7-19-78
Ft. Gordon	E	873	1-31-78	2-28-78	3-31-78	NOT[3]	
				4-10-78	5-11-78	6-05-78	6-05-78
	G	593	1-31-78	2-28-78	3-31-78	4-24-78	4-24-78
Yuma P. G.	E	290	10-03-77	11-15-77	12-15-77	1-02-78	1-09-78
MCAS Beaufort	E	1,276	9-12-77	9-28-77	10-31-77	11-08-77	12-06-77
	G[4]	407	9-12-77	9-28-77	10-31-77	11-08-77	2-01-78
	F[2]	1,100	9-12-77	9-28-77	10-31-77	11-08-77	11-21-77
MCDEC Quantico[5]	G	77	9-21-77	10-04-77	10-18-77	11-02-77	12-12-77
	G	629	9-09-77	9-22-77	10-11-77	10-25-77	12-08-77
	G	200	10-14-77	11-07-77	11-29-77	1-03-78	1-12-78
	E	226	9-13-77	9-22-77	10-11-77	10-25-77	10-26-77
	E	630	9-20-77	10-03-77	10-18-77	11-02-77	11-22-77
	E	200	1-20-78	2-07-78	2-21-78	3-29-78	4-12-78

Continued

Table 1-7 (Cont.)

Location	Energy[1] Metered	No. of Meters	Design Completion	Advertised	Bid Opening	Award Date	Notice to Proceed
	S[6]	57	9-19-77	9-27-77	10-11-77	10-25-77	11-16-77
NTC Great Lakes	E	196	9-22-77	9-23-77	10-26-77	11-14-77	11-14-77
	G,S[6]	27	9-22-77	9-23-77	10-25-77	11-11-77	11-11-77
	E	1,554	9-16-77	9-20-77	10-21-77	11-09-77	11-09-77
	G	948	9-16-77	9-20-77	10-21-77	11-18-77	11-18-77
	E,G,S[6]	1,628	1-10-78	1-30-78	3-02-78	3-31-78	3-31-78
CBC Port Hueneme/ PMTC Point Mugu[7]	E	1,096	9-09-77	9-12-77	9-30-77	10-28-77	10-28-77
	G	767	9-09-77	9-12-77	9-30-77	10-21-77	10-21-77
	G	331	3-01-78[8]	3-10-78	4-14-78	NOT[3]	
				4-28-78	5-16-78	6-02-78	6-02-78

1 E = Electricity; G = Natural Gas; F = Fuel Oil; S = Steam

2 Fuel oil usage was estimated using elapsed time meters to measure the cycle time of the burners.

3 Acquisition package was redone and readvertised.

4 Natural gas usage in 154 duplex units estimated using elapsed time meters to measure the heating and cooling cycle times.

5 29 natural gas and 43 electric meters were installed by base personnel.

6 Steam usage measured via a combination of meters, BTU (British Thermal Units), hot water flow, and/or steam condensate.

7 One fuel oil flow meter was installed by base personnel.

8 Design corrections finally completed 7-07-78.

Table 1-8
Meter Installation Cost and Schedule

Location	No. of Units	Energy[1] Metered	No. of Meters	Installation Activity: Start	Installation Activity: Complete	Installation Activity: Operational	Cost[2]	Average Cost: per Meter	Average Cost: per unit	Range in Average Unit Cost: Highest[3]	Range in Average Unit Cost: Lowest[3]
Cannon AFB	1,012	E,G	2,024	01-27-78	08-18-78[4]	09-01-78	$381,000	$188[5]	$377[5]	$377(all)[5]	$377(all)[5]
Little Rock AFB	1,535	E	1,535	03-01-78	07-30-78	09-01-78	196,370	128	128	240(12)	127(1523)
Fort Eustis	955	E,P[6]	1,910	05-15-78	08-30-78	12-15-78	693,873	363			
	370	E,P[6]	632	07-19-78	NOT[7]	NOT[7]	107,735[8]	170[8]			
Subtotal	1,325		2,542				$801,608[8]	$315[8]	605[8]	727(955)	197(100)
Fort Gordon	597[9]	E	873	06-05-78	08-21-78	08-21-78	196,569	225			
		G	593	04-24-78	06-26-78	06-26-78	128,691	217			
Subtotal	597		1,466				$325,260	$222	441[10]	710(8)	345(27)
Yuma P.G.	290	E	290	01-09-78	04-24-78[11]	04-24-78	101,128	349	349	349(all)	349(ALL)
MCAS Beaufort	1,276	E	1,276	12-06-77	06-08-78	06-08-78	157,069	123			
		G[12]	407	02-01-78	05-01-78	05-01-78	33,383	82			
		P[6]	1,100	11-21-77	04-21-78	04-21-78[13]	36,525	33			
Subtotal	1,276		2,783				$226,977	$82	187	302(176)	152(1100)
MCDEC Quantico	1,168[14]	G	77	12-12-77	03-27-78	03-27-78	14,508	188			
		G	629	12-08-77	03-20-78	03-20-78	82,203	131			
		G	200	01-12-78	02-09-78	02-09-78	25,774	129			
		G	29	02-21-78	06-02-78	06-02-78	8,154[15]	281			
		E	226	10-26-77	12-15-77	12-15-77	28,863	128			
		E	630	11-22-77	01-18-78	01-18-78	114,806	182			
		E	200	04-12-78	05-08-78	05-08-78	64,417	332			
		E	43	12-05-77	02-10-78	02-10-78	8,785[15]	204			
		S[16]	57	11-16-77	04-20-78	04-20-78	51,313	900			
Subtotal	1,168		2,091				398,823	191	341[14]	1,235(41)	243(449)
NTC Great Lakes	2,076	E	196[17]	11/14/77	03-20-78	03-20-78	41,266	211			
		G,S[16]	27	11/11/77	01-15-78	01-03-78	9,723	360			
		E	1,554[17]	11/09/77	06-09-78	07-20-78	302,886	195			
		G	948	11/18/77	05-13-78	05-13-78	211,738	223			
		E,G,S[16]	1,628[17]	03/31/78	09-26-78	10-20-78	1,192,871	733[18]			
Subtotal	2,076		4,353				$1,758,484	$404[18]	847[18]	5,500(4)	400(425)
CBC Port Hueneme/	1,097	E	1,096	10/28/77	05-02-78	05-02-78	488,201	445			
PMTC Point Mugu		G	767[19]	10/21/77	06/15/78[20]	06-15-78	72,110	94			
		G	331	06/02/78	11-16-78[21]	11-16-78	395,572	1,195			
		P[22]	1	04/13/78	04-13-78	04-13-78	302[15]	302			
Subtotal	1,097		2,195				$956,185	$436	872	2,099(315)	343(2)
Ten Site Total	10,376		19,279				$5,145,835	$ 282	$496	5,500(4)	127(1523)

Footnotes for Table 1-8

1 E = Electricity; G = Natural Gas; F = Fuel Oil; S = Steam

2 Includes meters (purchased by contractor or government), installation, contract modifications, and supervision, inspection, and overhead (SIOH) costs. Reduced by any penalties for late delivery.

3 The number in parentheses is the number of units metered at that cost.

4 A strike at the meter supplier delayed delivery of meters and installation completion by 53 days.

5 Unit costs were not available because the contract price was submitted as a total package without a unit breakdown.

6 Fuel oil usage estimated using elapsed time meters to measure the cycle time of the burners.

7 Work has been completed on 319 units, but the renovation contractor has not completed work on the remaining 51. The electric meters have been installed in temporary locations on the 51 units, but fuel oil burner timers are not in place. 108 units are all electric; the remaining 262 are heated with oil.

8 An estimate based on projected completion.

9 Two units were already metered. Fuel oil for 5 units and propane for one are not metered, but usage is measured at the time of delivery.

10 Average cost for the 597 units which were fully metered.

11 Completion delayed 3 weeks by late delivery of meters from supplier.

12 Natural gas usage in 154 duplex units estimated using elapsed time meters to measure the heating and cooling cycle times.

13 Fuel oil burner timers were installed too close to the furnaces, and they are melting. They are being replaced.

14 69 electric and 233 propane meters were already installed on individual units reducing the total cost of installation per unit.

15 SIOH costs not applicable since work was done in-house.

16 Steam usage measured via a combination of meters, BTU (British Thermal Units), hot water flow, and/or steam condensate.

17 Many family units required up to four meters to record the total consumption for the residence and related areas.

18 Final costs for the installation contract are not available. Penalty and modification costs are in litigation but are not expected to exceed 2% of the contract.

19 Two units required two natural gas meters apiece.

20 Originally 01-14-78 but extended to 01-23-78 and then 06-15-78 as part of contract modifications.

21 Design errors by the A & E contractor resulted in a 45 day delay as well as major contract modifications.

22 Fuel oil flow meter

total of 6 weeks during the course of the contract because of an initial long delivery time and a later delay in the delivery of meters by the vendor. Thus total installation time at Yuma Proving Ground was 3-1/2 months, i.e., 41 working days at a rate of seven meters per day. No other problems were present.

At Fort Gordon, the electric meters were delivered by the vendor on an emergency basis, so there were no delays because of delivery schedules. The contractor proceeded at a rate of approximately 21 meters per day for 7-1/2 weeks, slowing down during the last 3 weeks for the more difficult installations. Similarly, the gasmeter installations progressed at an accelerated pace of 18 meters per day for the first 5 weeks, slowing down to 15 meters per day as the more difficult cases were done.

Because the facilities engineer at Fort Gordon did not have "as built" drawings of the gas piping layout, the contractor had to determine the pipe run inside the buildings by opening the walls. It was fortunate, however, that the piping was the same in identical style buildings. After the initial cut-and-try procedure, the contractor was able to run the new piping with a minimum of damage to the walls and ceiling. The inconvenience to the individual families was also minimized so that no family relocations took place during the contract period.

The installation of gasmeters at Fort Gordon started on 24 April 1978; the electric meters were operational by 21 August 1978. The installation time was 4 months, not including the lead time for purchasing meters supplied by the government. The electric work primarily involved the replacement of existing breaker boxes with preassembled meter sockets and disconnect switches.

At Fort Eustis, the electric meters were also provided as Government-furnished equipment to compress the time required for installation. Thus the majority of the units had electric and fuel oil burner run time meters installed by 30 August 1978, an elapsed time of 3-1/2 months after the work started. The major problem at Fort Eustis was unique because all units in one subdivision were undergoing remodeling under a separate contract. Consequently, no alteration such as meter installation could be made to the building prior to the release of the units by the contractor and acceptance by the Government. Accordingly, the utility meters were being installed as the buildings became available. The status of the project as of 1 January 1980 was the following: 108 all-electric units as well as 212 of 262 electric and fuel oil combination units were complete.

3. Marine Corps. The Marine Corps installed 4,874 meters for electricity, natural gas, fuel oil, and steam on 2,444 units at two sites. After meters were installed, 58 units were destroyed by a tornado, 2 were destroyed by fire,

and 1 was disposed of, yielding 2,383 Marine Corps units still in the test program. At MCAS Beaufort it took 6-1/2 months for all meters to be installed and considered operational. A modification in the electrical meter installation contract was required when an error was found in the design provided the contractor. Most defiencies noted during inspections were then corrected by the contractor. About 200 elapsed-time meters used to estimate fuel oil consumption had to be replaced by local personnel. The design caused them to be installed too close to the furnace, and they melted. The average cost of metering a unit at Beaufort was $178; the highest cost was $302; and the lowest was $151.

At MCDEC Quantico, it took 8 months, starting 26 October 1977 and ending 2 June 1978, to install all of the meters and make them operational. Problems in the installation of both electric and natural gas meters were minor, including tracing to which unit a meter was recording, defective meters and breakers, and improper and "customized" onsite installation. The major problems developed in the installation of condensate meters to record steam usage in single-family units. Each unit had to be treated as a unique situation because of its age, but the primary design premises were in error. The steam condensate metering system must be redesigned or a substitute found.

4. Navy. The Navy installed 6,548 meters on 3,173 units at three sites. Because 1 unit at Port Hueneme was already metered, the Navy contributed 3,174 units to the metering test program. At NTC Great Lakes, contract installations were started in mid-November 1977 and became operationally available 20 October 1978, 11 months later. Because penalties for late completion and the costs of modification associated with a major contract have been appealed, the final cost of the contract is not known. However, the most likely increase in cost listed in Table 1-8 will be less than 2 percent so those figures are used in the report. The highest overall cost per unit was $5,500 for 4 units within a single apartment building. It was necessary to completely replace all natural gas, hot water, and steam lines to the units. Because the units were occupied during installation, utility shutdowns had to be coordinated with the tenants. Scheduling was critical and coordination of subtrades was a daily administrative matter because only one subtrade could function per unit each day. The lowest overall cost per unit was $400 for 425 units built in 1960. For each unit, a gasmeter was placed within the unit on an existing line. Then a remote reader was connected and placed on an exterior wall. The electrical wiring had to be modified, from the existing type with meters installed in parallel to one with the meters installed in series with the existing electrical line to the individual unit.

Problems during meter installation work at NTC Great Lakes developed from several sources. The primary one was the complexity involved in coordinating tenant activities, utility

Table 1-9
Meters Installed to Assess Energy Consumption

Type of Meter	Manufacturer	Model/Type	Display	Reading
Electric	General Electric	I-55A, Single Phase	Dial	KWH
	General Electric	I-70-S, Single Phase	Digital	KWH
	General Electric	V-66-5, Three Phase	Dial	KWH
	Westinghouse	D4S, Single Phase	Dial	KWH
	Westinghouse	D4S-8, Three Phase	Dial	KWH
	Duncan Electric	MS, Single Phase	Dial	KWH
	Sangamo	J4S, Single Phase	Dial	KWH
Natural Gas	American Meter Co.	AC-175	Dial	Cuft
	American Meter Co.	AL-250	Dial	Cuft
	Rockwell International	S-190	Dial	Cuft
Elapsed Time	Cramer	Series 635	Digital	Hours
	General Electric	Series 200	Digital	Hours
Fuel Oil	American Meter Co.	Lo-Flo 1-A	Digital	Gal
Steam Condensate	Cadillac	Size A	Dial	Gal
	Cadillac	Size D	Dial	Gal
Btu	Hersey (Niagara)	200, mechanical	Dial	BTU
Hot water flow	Hersey (Niagara)	530, Magnetic Drive	Dial	Gal
	Hersey (Niagara)	MHR, Turbine	Dial	Gal
	Hersey (Niagara)	Nutating-Disc-1"	Dial	Gal
	Brooks	666-2"	Dial	Gal
	Aeroquip	V-1, Venturi Flow	Dial	Gal
Remote reader	American Meter Co.		Digital	Cuft

shutdown, multiple trades, and major wall and ceiling renovation on multiple units simultaneously. In addition, some meters, especially steam condensate, did not work properly, inaccurate construction drawings led to modifications, meters were not tagged for the units represented, and a recalcitrant contractor created administrative problems. Because of the age

and condition of existing lines, some hot-water heating system flowmeters became clogged and had to be removed under emergency conditions.

PMTC Point Mugu and CBC Port Hueneme worked together on meter installation as well as design. Installation of the meters initiated in October 1977 was completed on 16 November 1978, 13 months later. Although major rewiring was required, there were no significant problems involved in installing electric meters. The installation of gasmeters on 331 units did not get started until June 1978 because of delays in the contracting process. An additional delay of 45 days occurred because the designs were inaccurate and had to be redone. The meter installation designs reflected construction drawings showing gas going to each unit through overhead lines. However, the lines were actually imbedded in the concrete slab. When the drawings showing the installation of new overhead lines were completed, the revised cost per gasmeter alone had doubled from $567 to $1,131 per unit.

The contract specifications did not require the contractor to tag each meter with a unit identification. Additional time and funds were required to correct this omission.

5. Summary. Among all four services, 19,279 meters were installed between October 1977 and 16 November 1978, a period of 13 months. The average length of time required to complete a meter installation contract was 117 calendar days, but this varied widely according to the type of energy metered, number of meters installed, and complexity of the installation. On the average, a contractor installed 6 meters in a calendar day, but this varied from 1 meter every 3 days to nearly 21 meters per day.

The initial schedule requiring all units to be fully metered by 30 June 1978 was so compressed that it created problems such as the following:

a. Survey work was not done adequately to discover the inaccurate construction drawings.

b. Esthetic considerations could not be included in any contract specifications.

c. Design options could not be evaluated adequately to ensure that the best design was used.

The average cost per family housing unit was $496 with $5,500 being the highest per unit at NTC Great Lakes and the lowest being $127 at Little Rock AFB. A total of $5,145,835 was spent in the installation of the meters.

C. Types of Meters.

The complexity of the installations faced at the various sites made it mandatory that many different models and types of meters be installed (as shown in Table 1-9). In electric meters alone, models from four different manufacturers were used along with the following variations:

1. Type of display (dial versus digital)

2. Number of digits in readout (four versus five)

3. Service metered (1- versus 3-phase)

Five different sizes and models of hot-water flowmeters were used at NTC Great Lakes.

The primary problem that most sites faced with the meters was late delivery because of the supplier's inability to foresee the increase in demand. In addition, digital readout meters and remote readers had a tendency to stick at 999 and not roll over.

Thus far, the use of steam condensate meters to record the amount of steam consumed has not been effective at either NTC Great Lakes or MCDEC Quantico. Several installation and operating problems have interacted so that the general problem of metering steam usage has not been solved. Direct-flow steam meters are very expensive and designed to handle only commercial or industrial applications. Steam condensate meters are cheaper but are sized primarily for commercial and industrial applications. At MCDEC Quantico the systems were not properly designed, while at NTC Great Lakes the meters were not properly installed. Work is continuing to establish effective means to measure the residential consumption of steam, and it appears that steam condensate can be adequately metered. However actual metering has not been proven within this test program.

D. Major Problems.

One major problem leads to the subordinate ones to be described. Before FY 1978 military family housing simply was not built with any idea that there would eventually be units individually metered for energy consumption. For the current inventory that problem cannot be rectified, but is being done for all new construction or major structural renovation.

1. Cost. Except for steam consumption, the metering of detached, single-family units was completed easily, quickly, and at reasonable cost. Many multiplex units, however, required extensive and costly rewiring and replumbing as illustrated in Figure 1-1. In fact, 11 percent of the units in the sample were omitted from the test because of installation

costs projected to exceed budgetary allowances by a large margin. If all 11,602 previously unmetered units at the 10 test sites had been metered, the complete cost, including A & E, would have been $11,763,000 and the average cost per unit would have jumped from $520 to $1,014. Thus the cost would have increased by 95 percent to achieve a 12 percent increase in the number of units metered.

2. Schedule. The statutory requirements for acquiring construction or A & E contracts stipulate specific procedures and times, resulting in a prescribed portion of the total construction schedule. It typically takes several weeks for meters to be delivered, because distributors do not stock meters in the quantity required to meet large contracts. With both design and installation taking up the rest of the schedule, there was no remaining time for site personnel to learn to administer entirely new technologies and equipment. In addition, some problems developed that are not normally present. A small number of meters at a few sites needed some work on them after installation before they could provide valid readings. Although resolution of the problems took some time to work out with the contractors, the following were readily rectified:

a. Extreme fuel oil consumption was recorded, because some elapsed time meters were wired to the furnace fan, which can operate even though oil is not consumed, rather than to the burner.

b. Electric meters were not identified with the correct units.

c. Defective meters never began turning or stuck after being in use for a while.

d. Meters installed backwards recorded in reverse.

Except for the steam condensate meters at MCDEC Quantico and NTC Great Lakes, all installed meters were operational by 1 April 1979. The compression of the schedule was clearly reflected at Fort Gordon where the potential contractors challenged the feasibility of the schedule provided in the initial acquisition package. Therefore, the package had to be redone and readvertised with an August rather than June completion date.

3. Consumption Measurement. The problem of adequately measuring steam as an energy source for residential billing purposes has not been resolved, but appears feasible. By 1 July 1979 the repair work on the steam condensate meters at NTC Great Lakes had been completed. However, over half of the steam condensate meters at MCDEC Quantico were out of service on that same date, and the remainder were in such bad shape that the readings they provided were questionable.

The use of elapsed-time meters to indirectly measure fuel oil or natural gas consumption is questionable. An elapsed-time meter is connected to a burner and records the amount of time the burner operates. Knowing the output of the nozzle in gallons per hour, one can calculate the total consumption by multiplying the output by the number of hours the burner (furnace) is on during the billing period. Inaccuracies in the method enter through manufacturing variations in the size of the nozzles, material deterioration with aging, and deposits of impurities from the oil flow. For the test program, a single constant was used to convert hours to gallons, and no elapsed-time meter was calibrated for its respective burner. The legality of this indirect method of measuring consumption and resultant billing appears questionable. If the method is legal and of billing accuracy, the burner and timer system should be calibrated with an actual oil flowmeter at installation and then recalibrated at 3- to 5-year intervals to minimize any inaccuracies in the computation of oil consumption.

Other methods which could be used to measure fuel oil consumption are:

a. Installation of fuel oil flowmeters as done at Port Hueneme. This is expensive with the meter alone costing $100 vs. $32 for elapsed-time meters with a protective housing for external mounting, or

b. Installation of storage tanks for individual units and billing of residents either for the fuel oil delivered or according to the level of fuel oil in the tanks. This is an impractical method to use if residents pay monthly for fuel oil consumption above a norm or moves are frequent.

The use of master/slave meters as described earlier also provides indirect measure of consumption. These systems incur the following problems in measuring energy consumption:

a. When multiple meters are dependent upon each other, the small amount of error present in each is compounded by that dependency.

b. If one meter goes bad, then all readings in the building are voided.

c. The amount of heat in domestic hot water or hot water heat delivered to the unit most remote from the central heat source is less than that delivered to the one right next to it.

d. Because multiple readings are required for each unit, the chance for human error in reading the meters and recording and processing the information increases dramatically.

The conversion from master/slave meters to direct metering of individual units is very expensive. A master/slave installation at NTC Great Lakes costs $5,500 per unit while a similar situation at MCDEC Quantico was projected to cost $36,495 per unit (1977 dollars). In spite of the extremely high initial installation costs, it will be more practical to meter the individual units directly. Master/slave combinations would be very expensive to administer and produce many errors, because each meter is dependent upon every other one in the system.

Because the meters are used for measuring energy consumption of individual households for purposes of billing, it should be pointed out that the calibration of the instruments is very important from a technical as well as from a legal standpoint. Normally, the meters are calibrated at the factory before shipment. There is no guarantee, however, that the calibration will be the same when the shipment arrives at the destination. At least a sample of meters should be recalibrated by the contractor before installation. Because of the compressed time frame of the Family Housing Metering Test Program, this was not done at any of the installations. Because only fictitious charges were levied against customers during the test, no legal basis existed for refunds resulting from metering inaccuracies. In the future, a sample of meters should be calibrated before installation and periodically thereafter (at least every 5 years).

4. Construction Drawings. Three of ten sites ran into major additional installation cost because the available drawings were incomplete or inaccurate. It is mandatory that the contractor who initially builds a unit provide complete, accurate design drawings. Any changes made thereafter by the facilities engineers or a contractor should be fully documented. In all future meter installation programs, onsite engineers or an A & E contractor should be required to do a thorough field survey before initiating the design work.

5. Contractors. Four contractors have created problems as a result of their management practices. One defaulted and was not able to complete his work. Another used unskilled personnel to install elapsed-time meters resulting in the need to check every installation and rewire most. A third contractor selected couplings that were not suitable for connecting gasmeters to the supply lines, and those couplings had to be removed from the system. The fourth contractor required constant, expensive negotiation and followup to ensure that the contract or modifications were being followed and cost estimates on changes were realistic.

Rigorous inspection and administrative procedures during contract performance would minimize some of these and similar problems; however, variations in contractor performance will continue to require individual attention.

6. Miscellaneous. Elapsed-time meters to record burner running time and steam condensate meters were installed inside the homes or in inaccessible places without remote readers. Meter readers must enter the homes, lift manhole covers, use mirrors, etc., to obtain the readings. These procedures are time consuming, disturbing to residents, and often unsafe. Remote readers should be installed wherever possible under these circumstances.

At some sites minimal consideration of esthetics was present as reflected by large batteries of meters installed beside the main entrance to a building, such as at Port Hueneme. (See pictures in Appendix B.) At one location the meter installation for one style of building interfered with the occupants' ability to open the front door all of the way. The esthetics of military family housing should receive consideration similar to that present in the nonmilitary setting.

Two utility companies, Commonwealth Edison and Arkansas Power and Light, questioned the legality of the purchasing of energy by a military base at commercial rates and reselling.

E. Inspection and Administration.

Three and one-half percent of the cost was set aside for the administration of the meter installation contracts from conception through completion. The Air Force and Navy refer to this as SIOH (supervision, inspection, and overhead), but the Army uses the term SIA (supervision, inspection, and administration).* The amount of effort required to inspect and administer a specific contract is heavily dependent upon the effectiveness and cooperation of the contractor and secondarily on the complexity of the metering systems.

At Cannon AFB, the designs were accurate and no deficiencies were found after acceptance. During installation, inspectors found 3 electric meters which had failed and 10 natural gas meters which were installed backwards. All

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*Approximately 60 percent of the SIOH funds are applied to onsite inspection and contract administration between the notice to proceed and acceptance of the work. The remainder of the funds are applied to headquarters and division expenses such as processing major contract modifications, legal services, technical consultation, preparing and awarding the contract, pre- and post-award conferences, contractor claim litigation, and general administration.

problems were corrected under warranty. At Little Rock AFB, no problems were found prior to acceptance. Thereafter, one meter stopped turning, and the meters on 20 duplexes where the electric service entered a common box were found to be installed on the wrong side. The latter problem was a result of improper wiring during construction which had not been spotted when the units were built. Both the construction and meter installation drawings represented what should have been done, not what had been done.

No problems were found either before or after acceptance of the work at Yuma Proving Ground. At Fort Eustis, the meter readers noted that fuel oil consumption appeared to be excessive. Therefore, all the oil furnance run time meters had to be checked and most of them rewired after the contract had expired. It took facilities personnel 7 months to identify and correct the errors. Typical contractor errors found were: (a) meter had loose or open connections; (b) meter was wired to the AC supply circuit and ran continuously; and (c) meter was wired to the fan blower control unit.

At Fort Gordon, Public Works personnel noticed that the contractor had selected couplings which were not suitable for connecting the gasmeters to the supply lines. This necessitated the removal of these couplings from the system after expiration of the contract.

Because of the age of the buildings at MCDEC Quantico, electric, gas, and steam meter installations had to be tailored for conditions at individual units requiring replumbing, rerouting of conduits, bracket modification, and repiping. Many design deficiencies had to be resolved on the spot. Leaks, defective meters, and three incorrect installations for the natural gas system were found via inspection and corrected by the contractor. The same occurred with the electric metering systems, but they also required contractor corrections of inaccurate tags on meters.

The initial design of the systems for metering steam consumption was faulty. In most instances, steam blows through the traps allowing live steam into the condensate system. The high heat and pressure of the steam hitting the condensate meters blew seals and produced fictitious readings. In addition, many units were found to have condensate running "uphill" rather than flowing to the condensate main. Steam condensate meters are not constructed to operate under these conditions. The contractor met the contractual requirements, but the following problems required modifications to make the system work:

- Due to the weight of the meters and, in some instances, their not being adequately supported, piping failed, making the meters inoperative.

- Several meters faced walls only 10 to 12 inches away. The readers must get on their hands and knees and wedge their heads between walls and meters.

- Some meters were installed in manholes with awkwardly shaped steel covers weighing approximately 100 pounds. In one case the reader must descend a steel ladder and then walk along steampipes to the meter location. In another case, the meter can only be read with head down while the feet are held by another person. Otherwise, the reader would be standing knee-deep in high-temperature water.

- Other than in the two manhole locations, the meters were installed in basements. To read the meters, occupants must be given advance notice of the meter reading date so someone will be at home or will have the basement unlocked. In many locations, personal belongings stored adjacent to meters must be moved for access by the readers. Many occupants resent the inconveniences involved.

Inspection during the contract turned up instances in which meters, malfunctioning or improperly installed, were barely moving, running backwards, or connected with polarity reversed. The contractor corrected these. Six months after acceptance of the work in April 1978, meter readers found that the elapsed-time meters connected to the burners of fuel oil fired furnaces were installed too close to the furnace and were melting. Two hundred had to be replaced and relocated at a cost of $3,856. The problem resulted from an inappropriate system design which did not show up until the fall heating season started and the meters first entered continuous operation.

At PMTC Point Mugu, the contractor found that the natural gas metering system designs were incorrect for 315 units. The systems were redesigned by the A&E contractor at no additional cost, the contract was modified, and the installation progressed smoothly. After all work had been accepted, it was noted that the electric meters on some four- and sixplex buildings were installed so close to the entrance doors that the doors did not open fully. As a result, it was difficult for furniture to be moved in and out. In addition the meters were unsightly.

At NTC Great Lakes, the major contract has not progressed through acceptance because several contractor claims are in litigation. Seven errors in the drawings were identified during installation, and the contract was modified so that the work was done correctly. All but one of the errors reflected inaccuracies present in the original construction drawings provided by the local public works center. The remaining error was the inaccurate design or omission of the tagging system showing to which unit each meter was connected. Three

deviations from the specifications were spotted including improperly sized hot-water flowmeters, the omission of 160 gate valves, and exposed rather than concealed waterlines. The deficiencies were corrected under the contract.

F. Summary.

In most instances contract supervision, inspection, and administration went smoothly. Four factors, outside of local management effectiveness, appeared to influence the adequacy with which the work was done:

- Well-known systems such as electric and natural gas created fewer problems. Unfamiliar ones like steam and elapsed time meters caused more.

- Cooperative contractors worked easily and efficiently to get the work done. Militant ones caused problems on both sides.

- When the buildings were homogeneous, as at Yuma Proving Ground, the contractor was able to work efficiently while at NTC Great Lakes the great variety of structures slowed down the rate with which work was done.

- The age and complexity of a building appeared to cause a geometric increase in the difficulty and amount of time required to complete an installation. The need for constant inspection and administration increased concomitantly.

III. Maintenance Experience.

The special, short-term nature of the Military Family Housing Metering Test Program provided little opportunity to gain experience in the maintenance of the metering systems that had been installed. The common utility meters, electric and gas, are relatively maintenance free over several years so any problems that arise are caused by the installation of a defective meter, improper installation, or vandalism. The two former examples were typically corrected by the contractor and would not be considered normal maintenance. The latter example did not occur often enough to incur significant cost.

At one activity about 20 electric meters had to be replaced because of vandalism, malfunction, or damage from other causes such as being hit by a truck. The cost of a new meter and its installation was $38.50. Vandalism occurred in some instances, because meters on service poles were installed in parallel with the supply lines and not sealed. Therefore, meters could be disconnected or damaged without interrupting service to the occupant.

At another activity one leaking gas meter was repaired at a cost of $10.50. Three defective and five vandalized electric meters were replaced at a total cost of $299.

Twenty-six electric and gas meters at another complex had to be replaced, but only one was due to vandalism. It was difficult to get prompt response from the contractor to a request for repair or replacement of a malfunctioning meter. At this activity fuel oil filters will require annual replacement, but this task was not required during the few months of the test.

At this stage in the introduction of meters at NTC Great Lakes useful maintenance experience and costs were not available. Many meters were still under warranty so they were the responsibility of the contractor. As reported by other bases, the contractor responded slowly because he preferred to wait until a significant backlog of work was available. In addition, any maintenance is time consuming because an adequate, systematic maintenance program has not been developed. A noticeable problem has been the tendency of remote digital-type readers on gasmeters to stick at 999.

Vandalism at NTC Great Lakes, such as disconnecting meter tags that indicate the unit metered, cutting lines between a gasmeter and a remote reader, and removing the hot-water meter in laundry rooms, was a minor problem.

The maintenance experience at the ten test sites has been very limited because of the short time the meters have been in use. It was not feasible for each test site to establish a comprehensive program for meter maintenance and accrue relevant data. Thus, little information is available as a result of the test program for use in forecasting maintenance costs DoD-wide.

IV. Future Implementation.

A. Projected Costs.

1. Design. The military-owned family housing inventory consists of about 310,000 units at more than 375 activities in the United States and its possessions. As was evident during the metering test program, this inventory is a mixture of old, new, single, and multiplex units, most of which were not designed to be individually metered. As shown in Table 1-10, approximately 287,500 of these units are not individually metered at this time. These units are serviced by several different types of utilities and would require a minimum of 538,800 meters of various types to be installed if a full-scale metering program were implemented. Based on the $24.58 per unit design cost experienced during the test, the projected design cost, expressed in FY 1978 dollars, would be $7,067,000. Applying the construction escalation factor from FY 1978 to FY 1981 of 26.4 percent, as published by the Comptroller, increases the design costs to $8,933,000. This figure would probably increase because of the loss of economies of scale due to the large number of activities with fewer than 100 units. Other factors that will impact the design costs are the variety of housing at each activity; the availability and capacity of both in-house and contractor personnel to handle the increased workload; the accuracy of existing blueprints; and the complexity of the work required (rewiring, repiping, and replumbing the utilities for the housing unit as well as the utilities serving the assigned space in detached storage areas, common laundry rooms, and garage areas).

Table 1-10
Unmetered Utilities in Military-Owned Family Housing
(United States and Possessions)

Utility	Army	Air Force	Navy	Marines	Total
Electricity	95,976	114,604	58,959	17,938	287,477
Natural gas	56,875	76,181	36,318	8,384	177,758
Fuel oil	25,326	17,246	7,674	3,701	53,947
Propane gas	4,267	1,290	619	2,072	8,248
Steam	3,888	3,178	1,648	1,538	10,252
Kerosene	-	-	-	1,101	1,101
Total*	186,332	212,499	105,218	34,734	538,783

*Minimum number of meters required.

The exact number and kind of meters required will depend on how the utility is used (e.g., if gas heats forced air, only a normal gasmeter is needed, but if gas heats a central boiler, expensive Btu meters will be required). Each project must be

individually analyzed regarding the life cycle costs to determine the best method for metering.

2. Installation. Once the design work is completed, more accurate meter installation cost estimates will be available. Each project must be individually analyzed regarding the life cycle costs to determine the best method for metering. For now, however, we will again have to project future installation costs from the actual costs and A & E estimates collected during the test. Because costs were not always identified for each individual utility, an aggregate cost per unit must be used.

Table 1-6 shows the A & E estimates to meter individually those units that were excluded from the test. The actual installation costs for the rest of the test units are presented in Table 1-8. Some of these units, 154 at MCAS Beaufort and 399 at NTC Great Lakes, were metered using the master/slave approach (where consumption is determined by calculating percentages for each unit from simple time-elapsed or water-flow meters and applying those percentages to the total consumption from a single master meter). These networks were used to save time, money, and severe inconvenience to the occupants during extensive rework that would have otherwise been required.

As learned during the test, however, this method had four serious drawbacks that make it unfeasible for future consideration. First, although it provided a fair indication of consumption, it was not precise enough for actual billing purposes. Next, even though only one out of two or three different utilities serving a unit may have been metered this way, all utility meters serving all units in the network had to be read to calculate the consumption and norms whenever anyone moved in or out of any unit. At Great Lakes there were 15 units on two master/slave networks, one for hot-water heat and one for domestic hot water. Along with electricity and gas, which were individually metered to each unit, there was a total of 62 meters that had to be read each time there was a change of occupancy. Third, whenever a master or slave meter failed or was read incorrectly, it changed the proportionate consumption of the other units in the network. Finally, it is a programming nightmare to ensure that all meters for all units in the network are rejected when the edit procedures detect a missing or invalid reading (requiring either a new set of readings or, in the case of a change of occupants, an estimate of what the reading should have been several days earlier).

In order to project the true costs of individual metering, we must first include what the additional costs would have been if the units with master/slave networks had been originally metered individually.

a. At MCAS Beaufort, each of 77 duplexes (154 units) has a 5-ton, gas, chilled-water air conditioner. Elapsed-time meters on the thermostats in both units of each duplex record the number of hours of operation, which are then used to prorate the actual gas consumption from a gasmeter. To meter individually would have required the removal of the 5-ton air conditioner, some repiping, and the installation of two 2.5-ton air conditioners in each duplex, at a cost of $340,000. (Btu flowmeters would be a possible alternative.)

b. At NTC Great Lakes, domestic hot water for four units in one building is heated by steam. A steam condensate meter is used to determine the total energy to heat the DHW while flowmeters measure the gallons of DHW used in each unit. Using the flowmeters, percentages of use are calculated to attribute the correct fractions of the total energy to the respective units. Individual electronic Btu meters would have been required for each unit at a total additional cost of $1,120.

c. A situation similar to that described above in paragraph b exists for DHW in 25 more units. However, these units also have steam-heated hot-water heat (HWH) with a similar network of flowmeters designed for proration against a Btu meter. An individual gas hot-water heater would be required for DHW and a Btu meter for HWH for each unit at a total cost of $13,185.

d. There are 160 units, in four- and sixplex configurations, that have a gas-fired HWH boiler and a gas DHW heater serving each building. For HWH there is a Btu meter on the boiler with a flowmeter for each unit. For DHW there is a regular gasmeter on the heater with a flowmeter for each unit to determine its fractional usage of gas. To meter each unit individually would have required installing individual Btu meters for HWH and installing individual gas hot-water heaters in each unit at a cost increase of $58,810.

e. Fifteen buildings, each with 14 units (total of 210 units), have gas-fired central DHW. For each unit there are two DHW lines leading from the central heater, one going to the unit and the other to the laundry room. Readings from the flowmeters on both lines must be added together for each unit before the individual gas usage can be determined. To meter these units separately would have required an individual gas hot-water heater in each unit with a pipe going to the common laundry room for a total additional cost of $55,158.

Elapsed-time meters were installed on 2,312 units at two test locations to measure oil consumption. This method was selected because it was inexpensive and required relatively little time to install compared to oil flow meters. The elapsed-time meters, however, did not prove accurate enough. This was primarily attributable to variations in the condition

and sizes of the burner nozzle orifice which permitted more or less oil through the nozzle to the burner than was indicated by the manufacturers' rated capacity. A test with ten oil flow meters, which were installed along with the elapsed-time meters, showed that consumption varied as much as ±7 percent compared to the oil flow meters. Therefore, the elapsed-time meters should not be used for any future metering program. Had oil flow meters been installed during the test, the cost would have increased an additional $573,376.

If all of the mentioned units had been separately metered as indicated, costs would have increased an additional $1,041,649. As shown in Table 1-11, this would bring the total costs to meter all 11,602 units individually at the ten test sites to $12,322,412 ($1,062 per unit).

Table 1-11
Total Costs to Install Individual Meters at Test Activities
(FY 1978 Dollars)

Source	Test units	Test costs	Cost per unit
Not metered	1,226	$6,134,928	$5,004
Metered	10,376	5,145,835	496
Additional costs		1,041,649	
Replace m/s meters*	(553)	468,273	847
Replace time meters	(2312)	573,376	248
Total	11,602	$12,322,412	$1,062

*Master/slave

It is assumed that the simpler units, about half the inventory, could be metered within 1 year after completion of the design phase. The more difficult units (30 percent), could be done in the second year, while the hardest units to meter (20 percent) could be completed by the end of the third year. The total cost of this effort would be $1,513 per unit, or more than $435 million, as shown in Table 1-12.

Because of the short installation schedule and the limitation of funds during the test, esthetic value could not be a determining factor. In many instances the meter is on the front of the house where the utility enters the unit (see photographs in Appendix B). In one project of multiplex units, an entire bank of meters is between the front doors of two adjoining units. This understandably creates a very negative attitude on the part of the residents. Utility companies and private builders would have incurred the additional expense to mount the meters in more discreet locations. It is not known what the additional costs would be to take esthetics into consideration, but in a full metering program this must be

Table 1-12
Meter Installation Cost Projections

No. of units	Avg cost per unit	Escalation factor[1]	Total cost (000)
143,750 (50%)	$1,062	1.35926 (FY 82)	$207,508
86,250 (30%)	1,062	1.45174 (FY 83)	132,976
57,500 (20%)	1,062	1.54806 (FY 84)	94,532
287,500 (100%)			$435,016

[1] Composite inflation, escalation, and outlay factors for constant budget dollars (base year 1978).

done, as well as correcting eyesores created during the test program.

There are now small-scale pilot programs being conducted by utility companies on state-of-the-art procedures for reading meters electronically (20 meters per second) via telecommunications. Although such a system may increase initial costs, it would save keypunching and meter-reading costs and eliminate associated errors. Some of these use special meters while others use regular meters with slight modifications. The findings of these studies should be evaluated before meters are purchased.

B. Projected Time Frame.

1. Planning. If Congress decides to proceed with the metering program, the first phase will involve planning, orienting, and educating base personnel. The experiences during the test must be compiled, published, and distributed to each installation so they will know what to do and what to avoid in the future. This will prove invaluable when dealing with A&E and metering contractors so that surprises are minimized. This planning phase will take about 6 months.

2. Design. The normal time required to scope a project, notify A & E firms through the Commerce Business Daily, select an A & E, negotiate the price, and finally hire him requires 4 to 5 months. Another 4 to 5 months is then required for the A & E to conduct his onsite investigation and prepare 100 percent design drawings. The construction project must then be advertised for 30 days and, if the bids are reasonable, the installation contract will be awarded 2 weeks later.

Obviously there would be many incidents where, because of uniformity of housing, good utility drawings, small numbers of units, or other factors, the actual design work would be

expedited and the project awarded in less than the 10 to 12 months. But each project, complicated or not, must be reviewed on a case-by-case basis to determine, through life cycle costing, the most energy efficient and cost effective method of metering. It might, for example, be initially cheaper to replace an existing centrally steam-heated DHW system with individual gas hot-water heaters, but would the gas units be as energy efficient? Would it be more practical to keep a central hot-water heating system that has the capability to switch to an alternate energy source when the primary source becomes scarce? Time constraints, therefore, would have to be flexible enough to permit this kind of detailed analysis.

3. Installation. After the contract award, it would be anticipated that all utility meters could be installed within 3 years. With the possible exception of steam-heated units, single-family units would be the easiest to meter; work would be completed during the first year of installation with a minimum of occupant inconvenience. Many of the multiplex units that would not require rewiring or repiping would also be completed within 12 months. But the units which would require extensive renovation could take an additional 1 or 2 years. When the walls and floors must be ripped up to install new pipes and wires, occupants would be subjected to intermittent or sustained loss of utilities, serious physical safety hazard (especially for small children), and reduced security for their possessions. For these reasons, this work would have to be scheduled during a change of occupancy or the residents and their possessions would have to be relocated to another vacant unit. It is certainly hoped that these examples of extensive repiping and rewiring are worst-case situations, but it would undoubtedly occur frequently in the older multiplex buildings. Scheduling the work around the occupants would certainly be one factor that would affect the installation time. Another would be the quality of the design work. Meter installation during the test was delayed at one location because the A & E had not confirmed the accuracy of the gas piping diagrams. This mistake wasted valuable time and caused a change order to the installation contract that was almost the amount of the original contract.

An additional critical factor that would impact on the schedule would be the ability of the various meter manufacturers to meet this unprecedented demand for meters on a timely basis. Manufacturers of electric and natural gas meters usually have standing orders from utility companies on which they base their production capacities. There is little demand, if any, for residentially sized meters for other utilities, and it would not be possible to provide meter companies with accurate estimates of the numbers and types of meters required until the design phase is completed.

After all meters are installed, a full year of intensive monitoring, through continuation of the mock billing procedures, would be required to ensure that meters were functioning properly and the occupants were being billed accordingly. These considerations would contribute greatly to the projected 5- to 6-year full-implementation period, should DoD-wide metering be directed. Additional delays could develop such as the litigation initiated by one of the contractors during the test.

C. Projected Maintenance.

Two different sources produce the requirement for the maintenance of meters. The first of these sources is the meter itself through precipitous malfunction or normal wear and tear over its lifespan. If the meter breaks down, an extreme variance in consumption may be recorded, but typically the meter ceases to record any consumption. Under normal wear and tear, the meter slows down gradually and records less consumption than is actually used.

From within the energy system, steam may enter a condensate meter, impurities in the fuel oil may clog parts, etc. The second source of maintenance requirements is external to the meter. From outside, lightning may damage it, a resident may divert energy around it, etc. As reported earlier in this chapter, the metering test program has provided little useful information to use in projecting the costs of maintaining meters. Discussions were held with public utility and meter manufacturing representatives, public utility industry records were reviewed, and individual company data accumulated to support the projections.

In making the projections, the following guidelines were used:

- Base personnel would do only emergency work involving minor repairs and replacing malfunctioning or damaged meters. With meters located in more than 375 locations across DoD and the number of meters varying from one to 6,600 per site, it would be uneconomical for DoD to have its own meter repair facilities, equipment, and personnel except for the above emergencies. Meter repair or rebuilding, testing, and recalibration would be done by contract personnel at a cost which is 20 percent higher than the average for public utility companies.

- Maintenance costs for work on the energy supply lines are represented in current base budgets. It would also be assumed that no maintenance would be required for energy transmission lines from the meter throughout the housing unit once they had been installed and are operating effectively. The latter have been included in the projection of installation costs.

- From data provided by meter manufacturers and utility companies, the following life cycle times were adopted:

Electric meters	40 years
Natural gas and propane meters and remote readers	20 years
Steam condensate, fuel oil, kerosene, and Btu waterflow combination meters	15 years

- Little information is available on the application of steam condensate and Btu-waterflow combination meters in measuring the consumption of individual housing units.

- The maintenance of a meter would be independent of the unit and any other meters present for that unit.

- The design, installation, and test of meters would start in 1981 and be completed over a 5-year period. Electric and natural gas meters would be installed at a rate of 50 percent in 1982, 30 percent in 1983, and 20 percent in 1984. All propane, fuel oil, and kerosene meters would be installed in 1982. Steam meters would be installed during the fourth year, 1984. Thirty-four percent of the remote readers and 37 percent of the Btu-waterflow combination meters would be installed in 1982 and the remainder in 1984. Therefore, the maintenance of 309,401 meters and remote readers would start in 1983, 139,570 meters in 1984, and 147,616 meters and remote readers in 1985.

- In the first year that the meters were in use, an inventory of meters which can be used to replace those being repaired would be established. The inventory would be set up and kept at a proportion of the meters installed at that site. The proportions would be as follows:

Electric meters	2:100
Natural gas, propane, and remote readers	4:100
Fuel oil, kerosene, steam, Btu-waterflow	6:100

Table 1-13 shows the forecast of funds that would be required to maintain the meters projected for design, installation, and test in 1981 through 1985. The annual rates used in projecting the cost of repairing or replacing meters for different reasons are shown in Table 1-14. It would be expected that the cost of recalibrating meters would start to enter the

projections in 1987 with the greatest initial cost incurred with the steam meters and the least with electric meters. No figures are shown for replacing or reconditioning meters at the end of their life cycle because none should have reached that life stage. The requirement for such action would occur first for steam meters, probably about the year 2000.

A labor cost of $13.53 per hour in 1979 dollars was used to project meter repairs for all meters. The 1979 base cost of new meters and supplementary parts applied in the projection was the following:

Electric	$ 26.08
Natural gas (includes regulator (50%), insulated connectors, and filter)	$ 73.50
Propane (includes insulated connectors and filter)	$ 46.10
Fuel oil (includes filter)	$120.00
Kerosene (includes filter)	$120.00
Steam	$718.35
Waterflow (includes Btu meter and sensors)	$223.00
Remote readouts	$ 19.25

Tests may show that the cost of steam condensate meters can be reduced dramatically if water treatment is upgraded to improve water quality and adequate steam traps are installed. It is assumed that propane would be measured in the vapor rather than liquid state to allow the use of lower cost meters. The projection assumes that kerosene and fuel oil meters would be installed on the supply (suction) side of the burner pump, eliminating the requirement for expensive meters which must provide for the recycling of unburned fuel.

Table 1-13
Five-Year Projected Maintenance Costs[1] for Unmetered Utilities

	Number of Meters	1983	1984	1985	1986	1987
Electricity	287,477	$257,426 2/	$527,633 2/	$748,171 2/	$1,143,167	$1,197,618
Natural Gas 3/	177,758	700,479 2/	882,428 2/	891,231 2/	1,136,875	915,618
Propane Gas	8,248	391,224 2/	24,094	25,456	26,334	10,718
Fuel Oil 4/	40,460	489,-018 2/	419,329	435,734	463,157	448,455
Kerosene	1,101	13,835 2/	11,413	11,910	12,572	13,260
Steam 5/	5,026	-	-	273,712 2/	111,419	117,499
Water Flow	36,389	268,927 2/	194,008 2/	759,927 2/	603,559	636,577
Remote Reader 6/	40,028	23,576 2/	20,598 2/	72,458 2/	66,775	68,114
Total		$2,144,485	$2,079,503	$3,218,599	$3,564,386	$3,465,337

1 The following rates of inflation were provided by the Navy Comptroller to adjust 1978 dollars: 1979 - 8.6%; 1980/1981 - 8.0%; 1982 - 7.3%; 1983 - 6.7%; 1984 - 6.0%; 1985/1986/1987 - 5.5%. It is felt that such rates are a gross underestimate considering the 1979 experience of more than 12% actual inflation. Utility company maintenance costs used in the projections were increased by 20% to reflect the inefficiency present in maintaining a small number of meters in many locations.

2 These figures include purchasing an inventory of meters for maintenance (e.g. steam condensate meters in 1985 cost $220,936 while maintenance that year is only $52,776.)

3 In 10% of the installation these will be check meters. Where central natural gas fired boilers are used to produce hot water for space heat or domestic use, Btu and flow meter combinations will be used. This also applies to central chilled water systems.

4 25% of the installations are central systems. Energy consumption will be metered by water flow meters as for natural gas.

5 An additional 5,026 steam systems are central ones. Energy consumption will be metered by water flow meters. These figures assume that traps and drains are appropriate and the water quality is good. If the assumptions are not appropriate, maintenance costs will increase four times.

6 These meters are attached to natural gas (10%), fuel oil (25%), steam condensate (all) and water flow/Btu (10%) meters which are not accessible without entering a unit.

Table 1-14
Annual Rates Used to Project Maintenance Costs

Type of Meter	Annual Sample of Meters tested[1]	1979 Rate of Failure for Meters		
		Natural Causes & Malfunction[2]	Vandalism[3]	Theft[4]
Electricity	3%	0.05%	0.2%	1.0%
Natural gas[5]	4%	2.00%	0.1%	0.9%
Propane	4%	2.00%	0.3%	0.7%
Fuel oil[5,6]	6%	4.00%	0.3%	0.7%
Kerosene[5,6]	6%	4.00%	0.3%	0.7%
Steam[6]	6%	3.00%	0.0%	1.0%
Hot water[6]	6%	3.00%	0.0%	2.0%
Remote readers	4%	2.80%	0.2%	N/A[7]

[1]The 1979 cost of testing a meter was $15.00 for all meters except natural gas regulators ($1.00), steam ($25.00), hot water ($10.00), and remote readers ($5.00).

[2]Fire, lightning, wind, etc.

[3]Vandalism is not a significant factor in public utilities maintenance requirements. It is projected at a double normal rate for the first 1-1/2 years meters are present.

[4]Theft is an increasing problem. The present annual increase of 10 percent is projected to continue through 1985. It will then stabilize as the means to identify perpetrators improve, and they are charged accordingly.

[5]Filters are cleaned or replaced biannually (natural gas) or annually.

[6]Meters must be flushed when contaminants are present. In steam and hot water systems, water quality is critical to meter life and accuracy.

[7]Included under other meters.

V. Summary and Conclusions.

The time and cost to progress from the receipt of metering funds to an operational metering system includes A & E design, contract preparation and award, system and installation test. This would vary widely according to the size of the installation contract, the complexity of the metering systems, and the type of energy metered. Design and installation was $5,431,035, with an average cost of $523 per unit. The most expensive installation cost $5,536 per unit, and the least expensive was $129 per unit.

The schedules for installing meters also varied widely. The average installation project took 235 calendar days, but the range was 110 days for 226 electric meters at MCDEC Quantico and 394 days for 1,628 electric, natural gas, and steam meters at NTC Great Lakes. In all, the meter installation portion of the test was initiated on 23 August 1977 at PMTC Point Mugu and completed at the same site on 16 November 1978 (nearly 15 months later).

However, 1,226 units were omitted from the test program because of the problem of the high cost. The estimated average cost for these units was $5,004 for a total of $6,134,928, excluding design. If all 11,602 units had been metered, the total cost for designing and installing meters would have been $12,607,612, an average of $1,087 per unit. Because these units were not only the most costly to meter but also the most complex, it is anticipated that the omitted metering systems would take longer to install than the meters that were put in place. For example, it was forecast that one building with 6 units at MCDEC Quantico would need to be vacant for 4 to 6 weeks. Although these problems were skirted for purposes of the test, they would have to be addressed in a DoD-wide metering scenario.

Outside of cost, a very critical second problem faced in the test program meter installation phase was the compressed schedule. Although Congress' initial schedule stipulated that all meters should be designed and installed in 4-1/2 months, the shortest period of time taken to complete work at a site was 7-1/4 months. In that instance, only one source of energy was metered for detached, single-family, and duplex units. The largest, most complex group of structures with three different sources of energy required 13 months to proceed through feasibility study, design, and installation.

A third important problem, adequacy of measurement, was related to cost and time. The metering of electricity is straightforward, but the cost increases significantly for a building with more than two units because of the extensive rewiring required. For other sources of energy, the complexity of metering individual units was very great. To minimize the complexity and cost in some instances, indirect methods of metering were used which would not be feasible in an actual

billing system. The application of elapsed-time meters and master/slave systems to meter oil, natural gas, and steam at Fort Eustis, MCAS Beaufort, and NTC Great Lakes has demonstrated that they are cheaper to install. The indirect measures provide approximations that can be used to monitor natural gas and fuel oil usage although the applicability to steam consumption has not been demonstrated. However, the approximations are not sufficiently accurate for billing purposes. In addition, the master/slave systems create increased costs for operating and maintaining them, so they may not be cost effective in the long term. Although several different systems for recording residential steam consumption were designed and installed, none has worked effectively for any period of time. Development of accurate, though expensive, methods of metering steam appears feasible. If full metering is to be used, this development must be pursued vigorously.

A large number of different meters were used in the test program. Many of these served the same purpose but were supplied by different distributors and manufacturers. A limited number of expensive fuel oil flow, water flow, and steam condensate meters were available to meter the small quantities of energy utilized in individual residential units, but they have not been used extensively in residential application in the past. Therefore, the results produced by these meters cannot be considered as accurate as those provided by conventional residential meters. The digital readout on a remote reader did not appear to operate as error free as did the display on the meter itself.

In several instances the attractiveness of the housing was reduced materially and the occupants were significantly inconvenienced by the location of the meters. In others the poor location made it difficult for the meter readers to gain access or read the information. Additional planning and expenditures would be required to avoid these problems in the event of DoD-wide meter installation.

The projected cost of designing and installing individual energy consumption meters in the remaining DoD-owned family housing inventory in the U.S. and possessions during 1981 through 1986 is estimated to be $415,177,000 or $1,384 per unit (FY 1981 dollars). The work should be phased so that the simplest installations would be done first and the most complex ones, especially involving steam or hot-water heat, would be completed last (preferably during change of occupancy.) Additional funds would be necessary for analyses that would contribute to optimal decisions about maximum energy conservation at reasonable cost. It is apparent that some reductions in the 1981 through 1986 installation costs could be made by converting from steam to natural gas as a source of energy for producing heat and domestic hot water. It is not, however, apparent that such conversions would be effective in conserving energy over the lifespan of the housing units.

The projected annual cost of maintaining the meters to be installed in 1981 through 1986 would be approximately $3,500,000 in 1986 dollars after the initial inventory of replacement meters has been purchased. Except for inflation, the annual cost should not change materially until the meters approach the end of their normal lifespan.

The annual cost of maintaining meters for steam condensate, hot water, fuel oil, propane, and kerosene would be much higher than for electric and natural gas meters. Although the number of such meters is only 16 percent of the requirements for unmetered units, the cost of maintenance is very high, because the meters are expensive, and filters need to be changed annually for fuel oil and kerosene meters. Therefore, 16 percent of the meters require 38 percent of the 1987 meter maintenance budget. If the theft was omitted from the comparison, the 16 percent would account for more than 50 percent of the 1987 budget.

If DoD-wide metering is to be implemented, a period of 5 to 6 years must be allowed for proper planning and installation, including a full year for system testing. (Although discussed in greater detail in Chapter 3, procurement of ADP equipment to support the billing aspect of the program would require slightly over 4 years prior to the 1-year system test.) From the occupants' point of view, billing should not be started for any unit before the entire system is complete, althouth some uses could be made of the isolated consumption data once available.

VI. Recommendations.

Because of disruptions in livability of some units requiring intensive internal modifications, installation of meters on these units, if directed, should be done during vacancy periods and where possible in conjunction with other required repairs and improvement projects.

Where utility meter installation costs are extremely high, consideration should be given to determining an upper limit, beyond which the unit will be excluded from metering.

From the time of installation, meters should be monitored to detect faulty meters. Feedback to occupants should be accomplished, wherever possible, in advance of any actual billing to build credibility of the metering system and to assist occupant conservation efforts.

Experience gained from the metering test program should be widely disseminated to reduce problems in future meter installations.

Chapter 2. NORM DEVELOPMENT

I. Establishing Norms.

In Public Law 95-82 (1 August 1977), Congress directed the Secretary of Defense to "establish a reasonable ceiling for the consumption of energy in any military family housing facility equipped with an appropriate consumption metering device." However, such a ceiling[1] was not to be implemented until its feasibility had been determined in a test program.

A. Planning.

On 9 May 1977, as part of the DoD plans and programs, the Technical Guidance and Norm Task Force, consisting of utilities engineers and rate specialists from all four service organizations, was established. One of the tasks of this task force was to develop guidelines and criteria for setting norms at each installation. The initial meeting of the task force took place on 20 May 1979. During the next 4 months, this group made reviews of energy sources and usage, identified criteria for the norm development tasks in the program, and decided to develop preliminary norms and norm calculation procedures[2] which could be applied as part of the computerized billing system. After meters had been installed and the billing system was operating, the initial norms were to be evaluated and revisions made using information produced during the test period.

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[1]The term "norm" is used throughout this chapter as a synonym for the consumption ceiling referred to by Congress. The norm is used to describe the energy which should be used by a normal or typical family of a given size residing in a specific military family housing unit. The normal family is considered to use reasonable energy conservation practices such as keeping the thermostat for space heating at 68° F. Because energy conserving practices reflect the life style of building occupants and how they operate their housing units, the definition of good energy conservation practice is more one of policy than technology.

[2]Some norms cover stable energy consumption which does not vary from one time period to another, such as for cooking. These norms remain fixed throughout the year. Other norms cover energy usage which varies in a repetitive pattern from one time period to another throughout the year, such as for lighting and appliances. Simple tables are included in the computer program so that such norms can be adjusted for a specific time period or other salient factor. The most complex norms cover energy usage which varies in a nonrepetitive pattern from day to day, such as for heating. These norms can be calculated by mathematical formulae using data supplied on a daily basis.

Both the Army and the Navy have had experience with a commercially available computer program, Trane Company's TRACE II, which can be used to calculate the heating and air conditioning loads for each housing unit. Initially, it was felt that the TRACE II program was the only one which could be made available soon enough to meet the 1 January 1978 deadline for initiating field data collection within the metering test. However, the cost of the TRACE II program was very high. Later discussions indicated that the Building Loads Analysis System Thermodynamic (BLAST) energy analysis program formulated by the Construction Engineering Research Laboratory (CERL) was fully operational and capable of providing the energy consumption data for the test program at 1/10 the cost of TRACE II. On 21 September 1977, the decision to use the BLAST program was made.

B. Technical Guidance and Norm Task Force Norms.

On 21 September 1977, the task force provided preliminary sets of norms for stable energy consumption (pilot lights and range use for cooking) and for systematically varying energy consumption (domestic hot water, electrical appliances, and lighting).* Criteria were also provided to CERL for use in developing procedures for establishing heating and air conditioning norms.

To simplify the application of criteria, the loads for determining cooking, appliance, and lighting norms were divided into two groups. One for one- and two-bedroom housing and the second for three- to five-bedroom housing. It was expected that such subgrouping would not have any appreciable effect on the total load of any individual house because of the diversity factor; however, one element of the demonstration was to verify or correct this assumption. Each bedroom in a home was assumed to have two occupants, except for the last bedroom, which was assumed to have a single occupant.

1. Appliances and Lighting Norms. For each house size, the task force used its experience to decide upon the number and size of the appliances which would be found in a typical military family residence and the amount of time appliances would be operated each day. Primarily using Edison Electric Institute (EEI) and General Electric (GE) data, the task force calculated the average monthly consumption for lighting in kilowatt-hours (kWh). The energy consumption figures for appliances and lighting were added together and monthly kWh allotments calculated by adjusting the average monthly usage for the number of daylight hours in the month. The results are shown in Table 2-1.

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*Exclusive of electrical loads attributable to heating and air conditioning equipment such as radiant heaters, fans, pumps, and condensing units.

Table 2-1
Monthly Electrical Energy Consumption Norms
for Appliances and Lighting

Month	kWh per Unit 1-2*	3-5*
January	489	698
February	477	681
March	464	664
April	466	667
May	469	671
June	472	674
July	475	678
August	477	681
September	479	684
October	482	688
November	484	691
December	487	695
Average	477	681

*Number of bedrooms per unit.

2. Cooking Norms. The DoD criteria for normal family housing consumption of energy for cooking were based on data for the number of bedrooms in the units and the fuel used. A combination of EEI data, personal experience, and data gathered from an Air Force study of 16 families in the Virginia area provided guidance for task force use in establishing electric range usage at 12,200 watts and 1,175 kWh/year for a four-bedroom unit and 90 percent of that for a two-bedroom unit as norms. The gas range and oven norms became 100 and 90 therms/year for the same units. The results are shown in Table 2-2.

Table 2-2
Daily Energy Consumption Norms for Cooking

Number of bedrooms per unit	Natural and LP gas Btu	Electricity kWh
1-2	24,600	2.88
3-5	27,400	3.22

3. Domestic Hot Water Norms. It was assumed by the task force that domestic hot water consumption for personal hygiene, dish washing, clothes washing, etc., would vary primarily according to the number of occupants in the housing

unit. The acceptable amount of water to be used each day was set at 25 gallons per person, and the temperature of such water was placed at 140° F. Therefore, the daily energy consumption would be that required to heat 25 gallons of water per person per day up to 140° F from the temperature of the cold water supply entering the unit.

4. Pilot Light Norms. The DoD task force used the results of a survey of family housing to specify the representative number of pilot lights which would be present on equipment in housing units. CERL provided the average values of energy consumed by such equipment, and the combination became the norms expressed in Table 2-3.

Table 2-3
Daily Energy Consumption Norms for Pilot Lights

Equipment Type	Btu
Range	4,100
Hot water heater	9,600
Clothes dryer	9,600
Furnace	20,500
Space heater	9,600
Air Conditioner	20,500

5. Heating and Air Conditioning Norms. The task force set the following criteria for CERL to use in its calculations of the daily heating and air conditioning norms. The highest allowable temperature for heating the home would be 68° F and the lowest allowable temperature for cooling the unit would be 78° F. In both instances CERL was requested to consider the increase in heat which would take place within the unit from pilot lights, radiation from a domestic hot water heater, cooking, and fan motors. All electrical loads for air handling units, pumps, oil burner motors, and supplementary resistance heating were to be included in the air conditioning and heating loads.

6. Miscellaneous Energy Consumption Norms. It was specified that a category for miscellaneous energy consumption should be provided to include exterior lighting or other extra energy consumption devices attached to the housing unit metering system.

C. The Energy Use Norm Development.

The energy use norm (EUN) for the family housing unit was to reflect the actual construction of the housing unit, its operation and occupancy, and the weather conditions during the billing period. The DoD task force required that the EUN be developed using state-of-the-art energy analysis computer programs. The Department of Army, through CERL, was assigned the

task of developing the procedure for calculating energy use norms for family housing units.

The objectives of this task were to develop the procedure for establishing energy consumption norms for family housing units, to devise a procedure for collecting family housing unit data so that an energy use norm could be calculated, to apply this procedure during the demonstration program, and to determine how the procedure could be applied should Congress require full-scale implementation of the metering program.

- To meet the objectives of this task, the following steps were executed:

- A procedure was developed for calculating energy use norms which implement DoD guidance for good energy conservation practices for family housing units.

- The data required to be able to calculate an energy use norm for family housing units were defined.

- A survey form was developed from which the required data could be obtained from family housing units and survey teams were trained from each of the military services to collect the data.

- Based on the data from the buildings surveyed and the use of the BLAST energy analysis program, algorithms for use in the billing routine to calculate the monthly energy use norms were developed.

- The procedure for calculating energy use norms was expanded to include all other housing units should full implementation of this program be directed by Congress.

II. Development of a Procedure for Calculating Energy Use Norm.

The first step in establishing an EUN is to break down the energy consumption of a housing unit into its various components, such as heating, cooling, cooking, and hot water, and to establish the DoD criteria for good energy conservation practice in each of these areas. The energy use categories and the criteria for good energy conservation practice were established by DoD prior to the initiation of CERL's efforts.

A. Energy Use Categories.

These categories are as follows:

1. Electrical energy to run all electrical loads except for heating and cooling. This category includes energy consumption for lights, wall outlets, and any other electrical loads. The DoD criteria for good energy conservation practice are based on the month and number of bedrooms in the housing unit. The criteria for one- and two-bedroom units, given as monthly kilowatt-hour allotments, are shown in Table 2-1. The kilowatt-hour allotments are also shown in Table 2-1 for three-, four-, and five-bedroom units.

2. Energy for cooking. The DoD criteria are based on the number of bedrooms in the housing units and the fuel type used. For one- and two-bedroom units, the allotment is 0.246 therms/day for gas or 2.88 kWh/day for electricity. For three-, four-, and five-bedroom units, the allotment is 0.274 therms/day for gas or 3.22 kWh/day for electricity (Table 2-2).

3. Energy to run pilot lights used for heating, cooking, and hot water appliances. The DoD-specified criterion was an allotment based on the number of pilot lights for each type of appliance, as determined during a survey of the family housing unit. Average values of energy consumptions of the various appliances were determined by CERL.

4. Energy for heating domestic hot water. The DoD criterion was the energy required to heat 25 gallons of hot water per person per day to 140° F from the cold water supply temperature for the installation.

5. Energy for space heating. CERL was assigned the responsibility of developing a procedure establishing an allotment for space heating which would take into account the actual weather conditions during the billing period and the construction of the housing unit. The heating energy norm was to take into account the internal loads generated by all items in the preceding paragraphs and reflect an internal housing unit temperature of 68° F.

6. Energy consumption for space cooling. As with space heating, CERL was to develop a procedure for establishing a space cooling energy consumption norm which would reflect actual weather conditions during the billing period, take into account all standard internal loads, and reflect an internal housing unit temperature of 78° F.

7. Miscellaneous energy consumption. DoD specified that a category for miscellaneous energy consumption should be provided to cover such items as fans and pumps for heating and cooling systems and any exterior lighting or energy consumption devices attached to the metering system of the housing unit.

DoD directed CERL to develop algorithms for calculating space heating and cooling norms based on the use of the BLAST computer program. Because of the great similarity of family housing units on military installations and the great cost of surveying and analyzing all 10,379 units in the demonstration program, DoD did not require a computer analysis of each individual family housing unit. Instead, after typical buildings were analyzed using the BLAST program, a procedure was developed to generalize these results to all buildings so that the calculated heating and cooling loads accounted for most of the housing unit variations which would impact energy consumption.

B. Procedure for Calculating Energy Use Norms.

Energy consumption (E) for a family housing unit as specified previously is given by the following equation:

$$E = Elec + Pilot + Cook + DHW + Heat + Cool + Other \qquad \text{(Eq. 2-1)}$$

where:

Elec = Energy to run all electrical loads except for heating and cooling for the specified billing period

Pilot = Energy to run pilot lights for heating and cooling for the specified billing period

Cook = Energy used for cooking

DHW = Energy used for heating domestic hot water

Heat = Energy used for space heating

Cool = Energy used for space cooling

Other = Miscellaneous energy consumers such as fans and pumps for heating and cooling distribution, exterior lighting,

and other electrical loads not part of the residence but connected to the meter.

The EUN is the value of energy consumption as in Equation 2-1 when the factors on the right-hand side represent energy-conservative operation. Thus,

$$EUN = E + P + DHW + CK + EH + EC + EO \qquad \text{(Eq. 2-2)}$$

where the variables E, P, CK, DHW, EH, EC, and EO are equal to the energy-conservative values of Elec, Pilot, Cook, DHW, Heat, Cool, and Other, respectively. Because energy-conservative operation reflects the life style of the building occupants and the way in which they operate their housing units, the definition of good energy conservation practice is one of policy rather than technology. Some energy-usage values corresponding to good energy conservation practices as defined by DoD have been tabulated (see Tables 2-1, 2-2, and 2-3).

Based on this tabulated information and a description of the housing unit, the computer analysis of the building's energy consumption leads to a procedure for calculating a housing unit's energy use norm using Equation 2-2. The step-by-step procedure for calculating EUN described in the next section will be the basis for developing the billing algorithm.

C. Step-by-Step Procedure for Calculating Energy Use Norm.

Based on Equation 2-2, the steps used in calculating an EUN are as follows:

STEP 1. Calculation of nonheating and noncooling electrical consumption for the billing period. The energy norm for electrical consumption can be expressed as,

$$E = \sum_{i=1}^{12} N_i E_i \qquad \text{(Eq. 2-3)}$$

where:

N_i = Number of days in billing period which fall in the ith month (i = 1, January; i = 2, February; etc.)

E_i = Daily DoD-specified electrical energy consumption (in kWh) for other than heating or cooling in the ith month. The values for E_i are given in Table 2-1 and depend on the number of bedrooms in the housing unit.

STEP 2. Calculation of energy (P) to run gas and oil pilot lights for the billing period.

$$P = N \cdot P_d \qquad \text{(Eq. 2-4)}$$

$$N = \sum_{i=1}^{12} N_i \qquad \text{(Eq. 2-5)}$$

where:

N_i = Number of days in the ith billing period

P_d = Total daily consumption for all pilot lights

Consumption of pilot lights for individual pieces of equipment is given in Table 2-3.

STEP 3. Calculated energy consumption for domestic hot water (DHW).

$$DHW = \frac{(140^{\circ} - T_{sw}) \cdot (8.34) \cdot (25) \cdot (Occ) \cdot (N)}{Eff_{hw}} \qquad \text{(Eq. 2-6)}$$

where:

N = Number of days in billing period

T_{sw} = Average temperature of supply water for billing period (^{o}F)

Occ = Number of occupants in housing unit

Eff_{hw} = Efficiency of hot water heater including losses from storage tank

STEP 4. Calculation of energy consumption for cooking (CK).

$$CK = N \cdot C_d \qquad \text{(Eq. 2-7)}$$

where:

C_d = DoD-specified allowable energy consumption for cooking as given in Table 2-2. C_d depends on number of bedrooms and types of appliances.

STEP 5. Calculation of energy consumption for heating (EH).

The algorithm for calculating the heating energy based on the BLAST analysis of 69 typical family housing units is,

$$EH = \frac{(N)(A)(B3)}{Eff_H} \cdot (HDD_d + B1) \cdot (1 - e^{-B2\ HDD_d}) \qquad \text{(Eq. 2-8)}$$

$$HDD_d = HDD/N \qquad \text{(Eq. 2-9)}$$

where:

A = U-factor-infiltration constant

B_2 = Building mass factor for heating calculation

B_3 = Housing unit construction constant

HDD_d = Average number of heating degree-days per day in the billing period

HDD = Number of heating degree-days in billing period

Eff_H = Efficiency of heating supply system

STEP 6. Calculation of energy consumption for cooling (EC).

The algorithm for calculating the cooling energy based on the BLAST analysis of 69 typical family housing units is,

$$EC = \frac{(HR)(C1)}{COP}(10{,}650 + .275(A) + .158(VOL)(ACR) + 13.2(WA)) \qquad \text{(Eq. 2-10)}$$

where:

HR = Number of hours in the billing period during which the dry-bulb temperature exceeds 78°

C_1 = COP adjustment factor

COP = Seasonal coefficient of performance for the cooling system

A = Conduction-infiltration constant

VOL = Volume of housing unit

ACR = Air change rate

WA = Window area

STEP 7. Calculation of other energy consumption (EO).

$$EO = PH + E_{out} \qquad \text{(Eq. 2-11)}$$

where:

PH = Electrical energy for heating and cooling fan system

E_{out} = All energy loads outside the dwelling which are billed the occupant

STEP 8. Calculation of energy use norm.

Using Equation 2-2, the results of steps 1 to 7 are summed by energy type (gas, oil, electricity) and converted to the appropriate billing units (therms, kilowatt-hours, gallons of oil, etc.).

The flow chart for this step-by-step procedure is shown in Figure 2-1. To implement this calculation procedure, a data base is required for each housing unit. Table 2-4 shows this data base and the corresponding variables used in the flow chart. Table 2-5 defines the input variables required to calculate a norm for each billing period. Table 2-6 lists constant and output variables calculated in the norm procedure.

The values for the arrays in Table 2-6 come from Table 2-1 ((E(I,BED)) or are calculated from the input data (N(I)). The values for the input data variables specified in Table 2-4 come from measurements made by the installation during each billing period. The housing data base values listed in Table 2-6 come from the family housing surveys and the data generated from BLAST analysis of selected family housing units. The survey procedure is described in section II.E of this chapter.

The CERL and task force work indicates that to compute an aggregate norm for all of the energy consumed within a family housing unit, information must be obtained about the weather, temperature of the water supply, occupants, building characteristics, and the amount of energy used by cooking, pilot light, and heating and cooling equipment present. Weather and ground water temperature information must be collected daily. Occupant data are collected initially and whenever occupancy changes. Building construction and equipment descriptions are required initially and whenever a change is made.

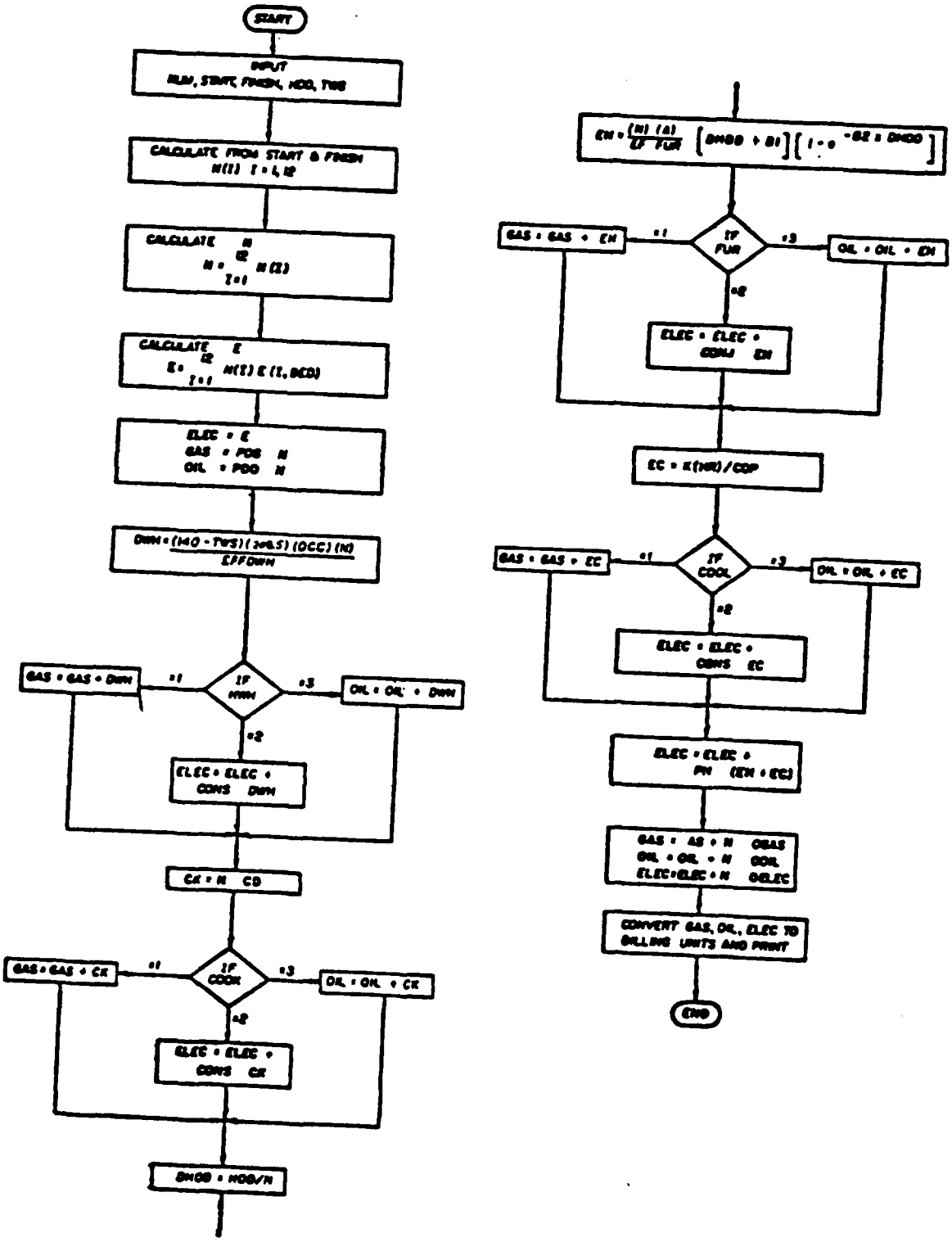

FIGURE 2-1
Norm Calculation Procedure

D. Variables and Parameters.

The heating and cooling loads in family housing units are dependent upon the interrelationship of many variables. Among these variables are outdoor air temperature; indoor set-point temperature; insulation levels of the walls, roof, and floor; amount of window area; rate of outdoor air leakage; amount and usage of lights and appliances; number of occupants; orientation; shading; and system efficiencies. The first step in the development of a family housing heating and cooling norm was to determine how the energy consumption in a family housing unit reacted to changes in the climatic, construction, and operational variables. A parametric analysis using the BLAST program was performed by varying each parameter over wide ranges to determine its effects on the consumption of heating or cooling energy.

To determine climatic effects on energy consumption, one-year hourly weather tapes from eight cities were chosen to represent a variety of climatic conditions. The weather sites chosen were Amarillo, Texas; Atlanta, Georgia; Chicago, Illinois; Los Angeles, California; Madison, Wisconsin; New Orleans, Louisiana; Norfolk, Virginia; and Washington, D.C. The number of HDD and number of hours that the dry-bulb temperature exceeded 78° F were determined from the weather tapes for each month. These tapes are used to provide hourly weather data to the BLAST computer program during 1-year simulations of the family housing unit.

Effects of different construction parameters on energy consumption were determined by describing typical housing units (single- and multistory) and coding their geometries for input to the BLAST program. A variety of wall, roof, and floor constructions were selected that ranged from very low to very high insulation levels and with various construction densities. The coded housing units were then simulated with the BLAST program for each weather tape and each type of construction, holding all other variables constant. The monthly heating and cooling requirements for each type of construction, as provided by the BLAST program at each climatic site, were determined. In the same manner, other variables such as infiltration rate, solar gain, and internal gains were studied to determine their effects on heating and cooling requirements.

The data obtained from the BLAST program simulations were then plotted so the various effects could be observed. Equations that best modeled the curves for heating and cooling were developed. The heating and cooling equations obtained were stated in Equations 2-8 and 2-10, respectively, in the step-by-step procedures for calculating energy use norms. These equations can be used to determine the energy requirement of any family housing unit provided the input data for the unit is available. The coefficients B_1, B_2, and B_3 in the heating

Table 2-4
Norm Data Base for Each Housing Unit

SITE	=	Location
NUM	=	Building number
BED	=	Number of bedrooms (= 1 for 1 and 2 bedrooms; = 2 for 3 to 5 bedrooms)
OCC	=	Occupants
HWH	=	Type domestic hot-water heat (gas = 1, electricity = 2, oil = 3)
EFFDHW	=	Efficiency of domestic hot water heater
COOK	=	Type of cooking appliance (gas = 1, electricity = 2, oil = 3)
CD	=	Daily allowable cooking energy (Btu)
A	=	U-factor-infiltration constant
B1	=	Building occupancy/internal load for heating calculation factor
B2	=	Building mass factor for heating calculation
PDG	=	Daily gas consumption for all gas pilots
PDO	=	Daily oil consumption for all gas pilots
EFFUR	=	Efficiency of heating system
FUR	=	Type of furnace (gas = 1, electricity = 2, oil = 3)
K	=	Building cooling consumption factor
COP	=	Coefficient of performance of cooling system
COOL	=	Type of cooling system (gas = 1, electricity = 2, oil = 3)
PH	=	Electrical power consumed by heating or cooling system fan per Btu of heating or cooling
OGAS	=	Daily gas consumption billed to occupant but external to dwelling
OOIL	=	Daily oil consumption billed to occupant but external to dwelling
OELEC	=	Daily electrical consumption billed to occupant but external to dwelling

Table 2-5
Input for Each Billing Period

NUM	=	Building number
START	=	First day of billing period
FINISH	=	Last day of billing period
HDD	=	Heating degree-days in billing period
TWS	=	Average temperature of water supply during billing period (^{o}F)
HR	=	Number of hours in billing period dry-bulb temperature exceeds 78° F

Table 2-6
Arrays and Variables Used in EUN Flow Chart

Arrays:

N(I)	=	Number of days in billing period which fall in the Ith month (I = 1, January; I = 2, February; etc.)
E(I,BED)	=	Daily electrical energy use norm (Btu) for lights and appliances for Ith month as function of number of bedrooms. Values are obtained from Table 2-4 and stored in program.

Calculated Variables:

N	=	Number of days in billing period
E	=	Electrical consumption for lights and appliances (kWh)
ELEC	=	Total electrical consumption for billing period (kWh)
GAS	=	Total gas consumption for billing period (Btu)
OIL	=	Total oil consumption for billing period (Btu)
CONS	=	Conversion factor from Btu to kWh (= 3.41297 x 10^3)
DHW	=	Energy used during billing period to heat domestic hot water (Btu)
CK	=	Energy used during billing period for cooking (Btu)
DHDD	=	Average daily heating degree-days for billing period
EH	=	Energy used for heating during billing period (Btu)
EC	=	Energy used for cooling during billing period (Btu)

algorithm (Equation 2-8) are obtained from fitting the BLAST-simulated consumption and weather data for a particular group 3 building to the equation by means of regression analyses. These coefficients then establish the heating energy use curve for a particular group 3 building (see categories of group 3 buildings described on page 2-17). The energy use for a particular building within that group can then be adjusted using the conduction-infiltration constant A for a housing unit, which takes into account variations in the thermal conductivity of the unit, window area, and infiltration rates.

The coefficients listed for the cooling algorithm are similar for all the housing units. As can be observed from study of Equation 2-10, adjustments between housing unit energy use are dependent upon the conduction-infiltration constant A, the infiltration into the unit, and the window area. The constant 10,650 represents an internal gain.

The heating consumption of a family housing unit is primarily a function of the overall U value of the building envelope, the rate of infiltration of outside air (combined in the norm calculation as the conduction-infiltration constant A), and the indoor set-point temperature. Each of these parameters has a direct correlation with heating degree-days, and therefore is a function of the average outdoor temperature. The equation accuracy tends to degrade at low heating requirements (less than 100 heating degree-days), and has an error rate of 5 percent (based on the simulations) even for months that exhibit significant heating requirements (greater than 100 heating degree-days). While modeling the house envelope to this extent, the norm does not necessarily properly account for the life style of the occupants and so is not considered sufficiently accurate for billing of occupants.

The cooling consumption of a family housing unit depends on the internal load (lights, equipment, and people), the solar gain through the windows, the heat gain through the walls, and the infiltration rate. The cooling load per hour when the outdoor temperature is above 78° F can be determined for these building parameters. It is assumed that a family housing occupant will use natural ventilation in the house when the outdoor temperatures are below 78° F during the cooling season.

E. Family Housing Survey Procedure for Demonstration Program.

To determine an energy consumption norm for a family housing unit, it was necessary to obtain information about the heat transfer properties, heating and cooling systems, occupancy and operation, and any other energy consuming devices associated with the dwelling. Therefore, it was necessary to survey the dwellings which are part of the family housing metering demonstration program.

The basis for the establishment of the energy consumption norms was computer analysis of the housing unit using the BLAST energy analysis program. Because it was impractical from time, manpower, and economic standpoints to make a BLAST analysis of all 10,000 family housing units, only selected housing units were analyzed using BLAST. The results of the BLAST analysis of the selected housing units, with the use of appropriate correction factors, were then applied to all housing units. This simplifying use of BLAST was justified for two reasons. First, many of the family housing units are essentially identical from an energy consumption standpoint because DoD makes great use of standard designs and usually builds multiple versions of the same unit at each location. Second, for many of the variations in the housing units such as size, insulation

level, and geometry, the effect on energy consumptions can be accounted for by easily calculated correction factors. The survey procedure has been developed with this in mind.

1. Survey Procedure. The first step in the survey procedure was to group the buildings to minimize the amount of survey data required. Three different groupings were used. Group 1 consisted of all family housing units included in the metering demonstration program. After the group 1 buildings were identified, they were divided into subgroups of thermodynamically identical buildings (i.e., those instances where the same unit has been built several times on one installation). More specifically, thermodynamically identical buildings are identical with respect to their external structure (i.e., that portion of the building which is above ground level, including the roof) and cross section of the external structure (i.e., the insulation levels and external wall construction). From a thermodynamic standpoint, units are identical if the overall building U-factors are identical. Two units were also considered identical if the only differences between them were the following:

a. Orientation.

b. The units were mirror images (e.g., right and left halves of otherwise identical duplex units).

c. The units had a different arrangement of interior partitions.

Group 2 then consisted of one building from each of the subgroups of identical group 1 buildings.

Group 3 buildings were representatives of group 2 buildings from each type of construction (frame, masonry, brick) and type of dwelling (single-family, duplex, one- and two-story, townhouse) found on the installations. Because BLAST runs were made for the group 3 buildings, the number of buildings in this group greatly affected the length of the survey. Within the following guidelines, the number of units in group 3 was left to the judgment of the survey team.

If any of the units in group 2 fall into the following categories, there must be one representative sample from that category in group 3:

a. One-story single family

b. Multistory single family

c. Duplex

d. Townhouse end unit

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e. Townhouse center unit

f. Townhouse top floor

g. Townhouse lowest floor

h. Precast concrete construction

i. Frame construction

j. Brick and concrete block construction

k. Masonry or stone construction

A dwelling type (categories a through g) did not have to be represented by every construction type (categories h through k) for purposes of the test.

The survey team could add additional units to group 3 if it felt (after training in use of this survey form by a BLAST representative) that some feature of the building required that the building have a BLAST analysis. CERL determined, based on the survey sheets, how many of the group 3 buildings actually required BLAST analysis. The group 3 buildings were chosen from group 2 so as to maximize the total number of dwellings covered.

2. Survey Form. The survey form shown in Appendix C consists of the Basic Building Survey Data form plus supplemental sheets for floor, ceiling and roof, and exterior wall descriptions.

For group 3 buildings, the entire form (except for question 18) plus the required supplemental sheets were completed. The entire form provided the data required to make the BLAST analysis.

For group 2 buildings, questions 1 through 18 of the basic form were completed. Because BLAST runs were not made on these buildings, detailed building descriptions were not required. In place of the detailed building description was the simpler U-factor calculation of question 18. From the results of this question, correction factors were developed from which the results of the BLAST analysis for the buildings were extended to these group 2 buildings.

For group 1 buildings, only questions 1 through 17 of the basic form needed to be filled out. The answer to question 18 was not required because it was the same as the group 2 building which was identified on the cover sheet.

This sampling technique was required because of time, personnel, and funding constraints; however, it was recognized that it is not as accurate as a more detailed survey. Results of the test and analysis of the resulting data as well as independent norm refinement efforts indicated that the accuracy by sampling was not as good as desired. Additional factors not considered as variables, such as building orientation and shading, were found to have significant impact.

III. Norm Change Procedures.

Changes to the norm data collected on pages 2, 3, and 4 of the Basic Building Survey Data form were necessary because of original survey errors, keypunching mistakes, and reporting errors. Transactions were also required to incorporate changes to the physical properties of a unit (e.g., adding insulation or storm windows) or the type of appliances in the house (e.g., replacing an oil furnace with an electric heat pump). Detailed procedures for making these changes were incorporated in the user manual section 5.3 of Appendix D. Generally the changes could be classified as major and minor changes.

A. Major Changes

Because a major change affected the data on page 4 of The Basic Building Survey Data, it could not be done by metering personnel alone. Correcting the building volume, window area, weather stripping, or stormproofing data on pages 2 and 3 required the services of a mechanical engineer to reevaluate the air change rate on page 4. Alterations to the heating or cooling systems which changed the fuel used or type of system (radiant to forced air) had to be sent to CERL to determine the correct efficiencies for page 4. Revising the amount of insulation or other survey errors which changed the thermodynamic properties of the unit could have involved recalculations by both a local mechanical engineer as well as CERL. Only CERL or the mechanical engineer were authorized to make a change to the original page 4 data.

B. Minor Changes.

Any of the other data elements on pages 2 and 3 (pilot lights, number of bedrooms, cooking fuel, etc.) could be changed by the metering personnel whenever necessary. These minor changes were made by entering the correct information on a special form, having it keypunched, and feeding it into the computer. The norm files were automatically updated for future use.

C. Additional Considerations.

During the test, changes to the data on page 4 could only be processed at the central control site. This procedure was adopted to ensure the quality of the norm data as well as to prevent its unauthorized manipulation.

It is suggested that the responsibility for processing all future norm data be at the activity level to permit faster changes and maximum flexibility. Programs could be written to accept the data only after entering a code word known only by authorized personnel. It would remain the responsibility of the activity to obtain the assistance of engineers or other agencies when major changes are required.

D. Problems.

During the surveys to determine the building characteristics, it was necessary to rely almost blindly on the as-built drawings to know the thickness and kinds of materials used and the amount and type of insulation in the walls. Sample verification could only be made in attics or, if present, in units undergoing repair or improvement.

The problem lies in identifying those units where the materials shown are incorrect because of bad or outdated drawings or construction deficiencies. Such cases would probably tend to show the occupants' overconsuming compared to the norm. Unless the difference was of sufficient magnitude to warrant further investigation, however, the tenant would continue to be unjustly billed.

Further, there is inherent in any norm data collecting effort of this type a possible ripple effect. An error detected in the norm survey of a group 3 unit will affect all related group 2 and group 1 buildings on the base. Similarly, an error in a group 2 calculation will affect every identical group 1 unit. To make these sweeping changes would cause considerable delay in subsequent billing and create untold havoc with occupants' trying to get their money back (or the base trying to collect more money) for as far back as they have lived in the unit. Trying to track down former occupants, some of whom may no longer even be in the service, would be even more futile. Once all units were metered and all norm data entered into the computers, a 1-year test would be required to try to detect and correct as many of these errors as possible. It was inevitable that many errors would still get through, however, and that other modifications which should have been entered would not be caught until later.

IV. Analyzing Test Data.

The purpose of this section is to analyze the adequacy of the 1-year test norms as described in chapter 2, section I, and to determine areas where the norm could be refined to produce an accurate and defendable system that could be used to charge military occupants for excessive energy use. CERL checked the consistency of the norm against actual consumption for various sizes, construction types, occupancies, and locations of military family housing units.

A large amount of data is available for each family housing unit included in the test metering program. Even so, analysis of the data to determine the exact variables causing variations between actual data and norm projections was difficult. Numerous variables are involved in the heating, cooling, and hot water requirements of a family housing unit as in any other structure. Among the most important are weather conditions; thermal adequacy of the units, including insulation levels and infiltration rates; size; construction materials; indoor temperature set points; number and age of occupants; and occupant lifestyle. The field survey of the family housing units in the test metering program included a determination of the insulation levels and infiltration rates and numerous other building parameters, but because occupant lifestyle or appropriate lifestyle could not be defined as a survey item, only the number of occupants was included in the survey.

A. Approach.

During the actual running of each military family housing billing cycle, historical data tapes were produced by NAVFAC. The data included the survey information for each family housing unit, the weather conditions, the actual consumption and the calculated norm for each billing cycle. The NAVFAC tapes also included a monthly proration of the actual and norm to produce monthly reports. It is the proration data that were used in the analysis. The proration of actual and norm consumption are not exact for complete comparison with weather data purposes; however, it provides a good basis for comparing actual consumption and norms over a continuous period of time and will show accurate trends in consumption by the units.

CERL proceeded to recode the NAVFAC data so it could be handled easily by the Statistical Package for the Social Sciences (SPSS), an integrated system of computer programs designed for the analyses of scientific data. This program allows the user to select and compare subgroups of data for extensive analyses. CERL selected units for analyses by examining the data to determine the mean of the actual consumption and norm for several groups of family housing units that were thermodynamically equivalent. These groups were then subjected to mean, variance, and standard deviation computations to produce the curves and graphs presented herein.

B. Scope.

The study included actual and norm data comparisons (electrical and heating fuel) for 15 types of units at Port Hueneme, California; Cannon AFB, New Mexico; Fort Gordon, Georgia; Quantico, Virginia; and Little Rock AFB, Arkansas.

C. Data Analyses.

1. Port Hueneme, California. At Port Hueneme a total of 515 family housing units are provided natural gas for cooking, space heating and domestic hot water, as well as electricity. The units have no air conditioning. Appendix E contains additional information regarding the construction characteristics and consumption data of these units as well as those at other locations analyzed in this effort. Figure 2-2 shows the mean electrical consumption, mean norm, maximum, and minimum values of actual consumption in the sample, and the values associated with one standard deviation from the mean actual consumption. (Sixty-eight percent of the actual data fall between the one-standard-deviation lines.) The data show that for this type of three-bedroom unit, the actual consumption averages 15 percent below the norm.

Figure 2-3 shows the natural gas consumption against heating degree-days for this same sample of housing units. Again, it is seen, the norm is higher than the mean actual consumption. The norm baseline consumption for pilot lights and cooling is shown on this figure to provide an indication of contributors to the norm. The dashed line shows the calculated norm, including the heating prediction as calculated by the heating algorithm. Weather parameters for Port Hueneme are shown on Table 2-7. The norm is then increased by an additional 470 cubic feet for each occupant of the unit for domestic hot water heating. The dotted line shows what this consumption would be with four occupants in each building.

Table 2-7
Weather Parameters for Port Hueneme Activity

Month	Daily heating degree-days	Total heating degree-days	Hours above 78°F	Temperature of water supply °F
January	13.77	427		65
February	14.67	411		65
March	10.58	328	7	65
April	9.20	276		65
May	6.12	190	11	65
June	2.76	83	25	65
July	2.32	72		65
August				65

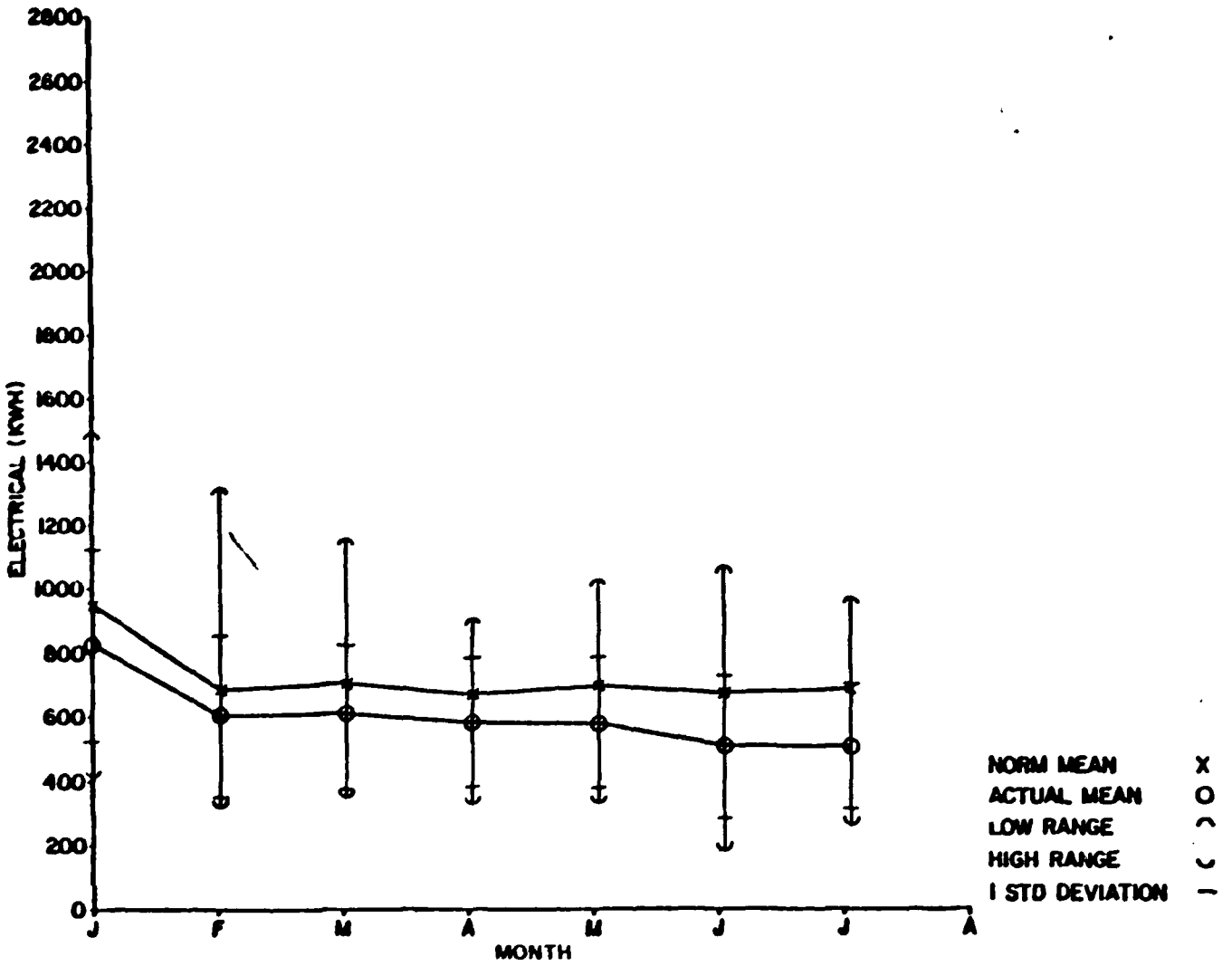


Figure 2-2
Electrical Consumption and Norm Versus Months (Port Hueneme)

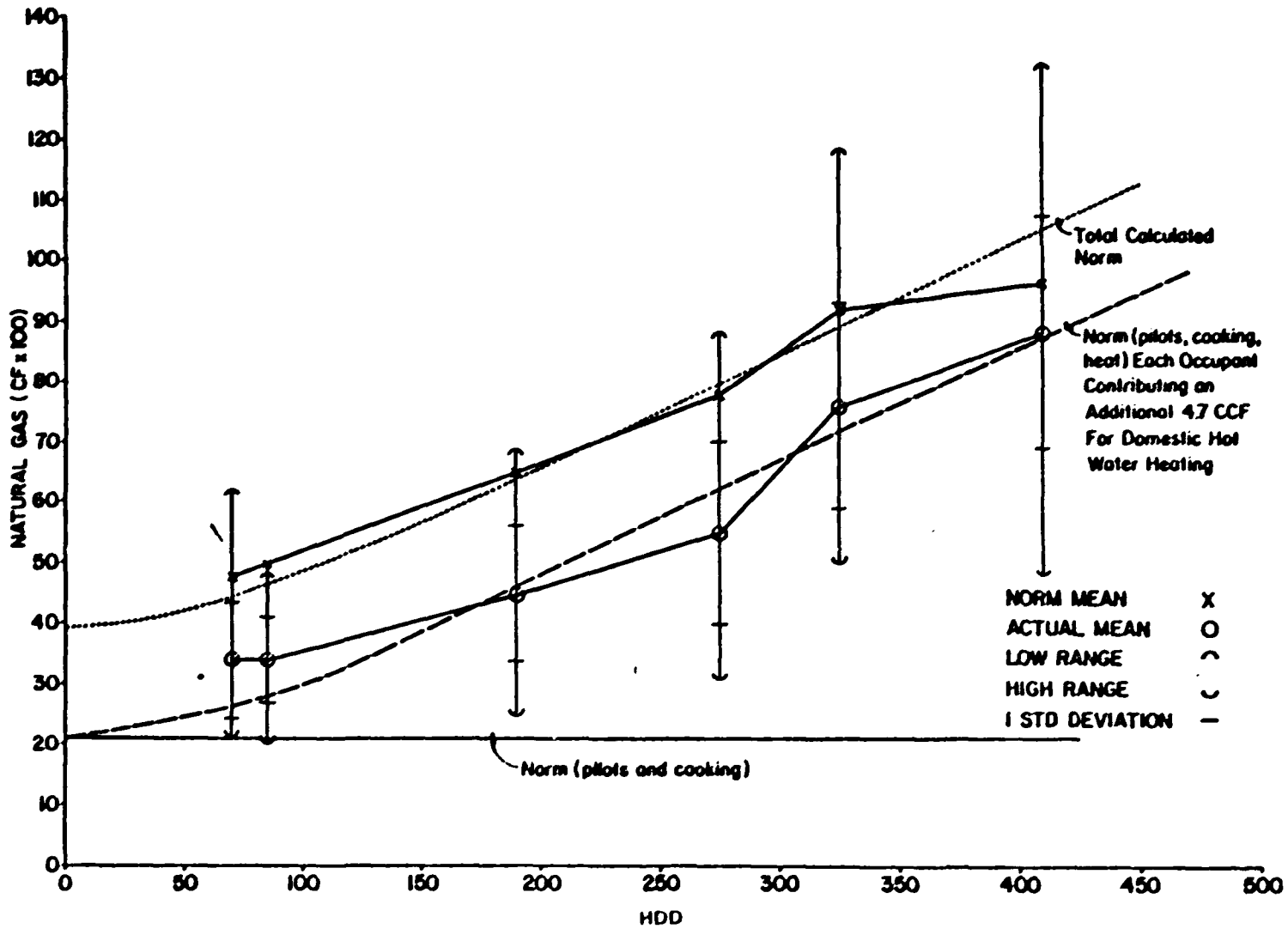


Figure 2-3
Gas Consumption and Norms Versus HDD (Port Hueneme)

The reason for the discrepancies between the norm and the actual consumption cannot be accounted for exactly. The norm and the actual consumption track each other quite well through the variable heating degree days indicating the heating algorithm contains the correct variables. We can surmise that any of the following problems could exist: Pilot or cooking norm consumption are too high; the heating algorithm is predicting too high because of an incorrect thermal conductance-infiltration factor, furnace efficiency factor, or improper regression coefficents from the BLAST program; the hot-water heating norm algorithm overpredicts actual requirements; or the occupants may be utilizing energy at a rate below prediction. A single cause for a discrepancy cannot be determined. Analysis of additional buildings at Port Hueneme may provide clarity for the trends indicated by this building group. Other types of units at Port Hueneme were similarly analyzed with generally similar results, though the degree of alleviation varied. The differences noted at Port Hueneme in the electrical consumption between duplexes and single-family units cannot be accurately determined. The four-bedroom units use 100 kWh/month more than the duplex units which are three- bedrooms units. The number of occupants in each sample group is equivalent. The gas consumption for all three units track quite well indicating the heating algorithm correctly predicts consumption based on heating degree-days. Adjustments to heating system efficiency or corrections to the conduction-infiltration factor for the buildings could bring the actual consumption mean and the norm mean very close together, although the appropriate direction of movement is not fully clear. The large differences between the minimum and maximum consumption in these thermodynamically equivalent units, however, support a determination that wide variances in actual consumption are primarily due to occupant demography and life style differences.

2. Cannon AFB. Cannon AFB, the next activity chosen for analysis, has a total of 1,012 family housing accounts. The units are heated by natural gas, have gas hot water heaters, and gas ranges. The units are equipped with electrical central air conditioners. Here the norm was consistently higher than the actual electrical consumption. However, as the norm goes up the actual consumption also increases. The norm and actual consumption difference becomes less in the summer months indicating that the cooling algorithm underpredicts the actual cooling load. Again, it can be seen from Figure 2-4 that the baseline electrical norm tends to be high for this type of unit.

For this sample of buildings, for very low heating degree-days the norm is only slightly higher than actual consumption. As the number of heating degree-days increases, the actual consumption becomes higher than the predicted norm. This variation could be due to norm use of a high furnace efficiency, incorrect determination of the conduction-infiltration factor, thermostat set points higher than 68°F within the family housing units,

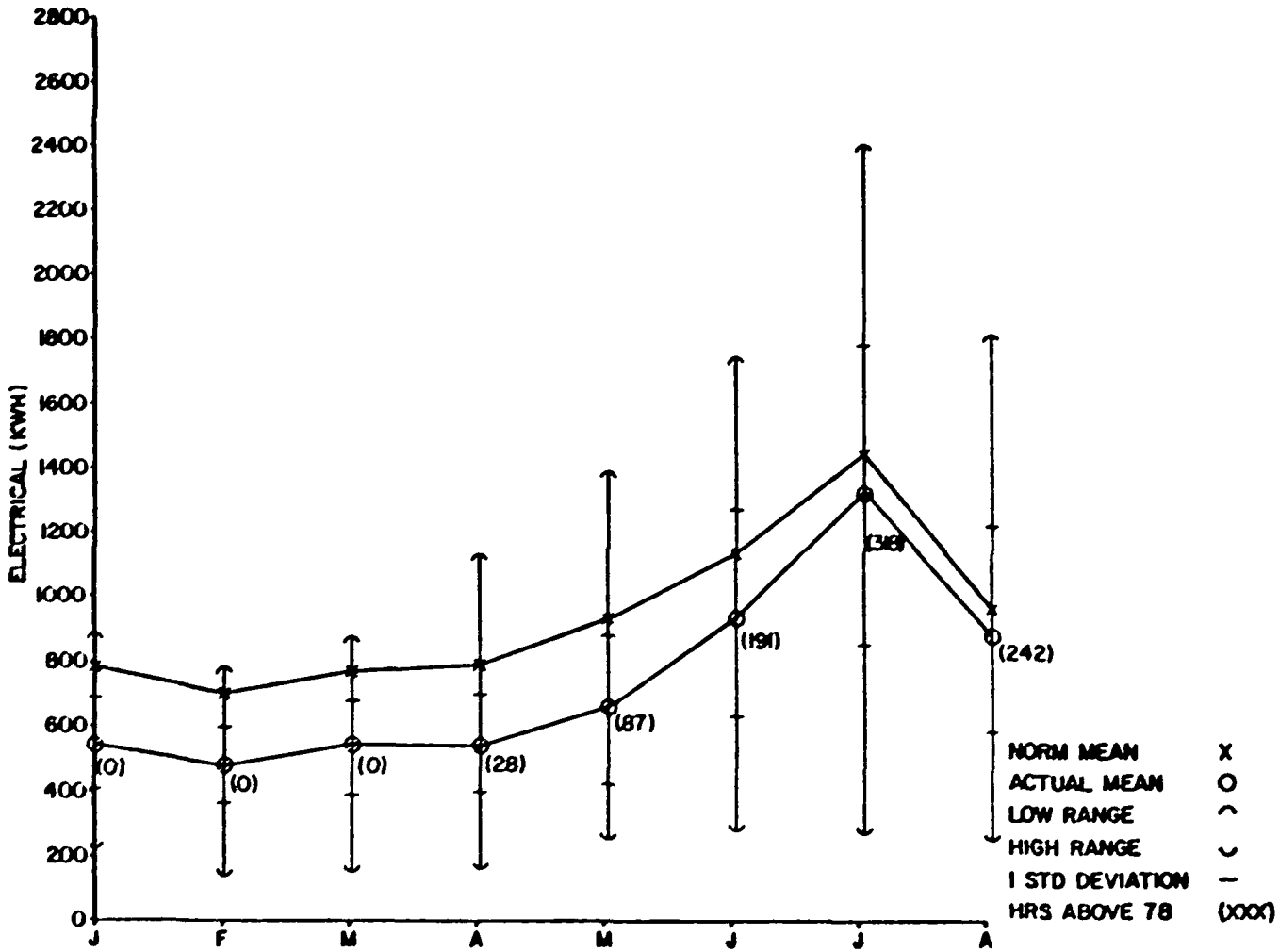


Figure 2-4
Electrical Consumption and Norms Versus Months (Cannon AFB)

demographic differences or other variations. The fact that the norm mean and actual mean track accurately indicates that the norm heating algorithm accurately predicts the trends in gas energy consumption, though the spread of data is of concern.

Figure 2-5 shows a frequency distribution of the gas usage for this unit in the month of January. This figure indicates the extreme variances in usage between the minimum users and the maximum users. This sample includes 46 thermodynamically equivalent family housing units. Figures 2-6 and 2-7 show the frequency distribution of gas usage for the months of February and March, respectively. Again, the large variance between the low user and the high user is evident. The larger group of cases within the midportion of the figures indicate the validity of the data as a statistical sample, though correlation for individual unit consumption versus norm is lacking.

Figure 2-8 shows electrical actual consumption and norm data from a sample of 140 1,560-square-foot single-story duplexes. This unit also has a gas-fired furnace, a gas range, and a gas hot-water heater. The building was built in 1974 and has 193 square feet of window area. As was evident from the Port Hueneme data, this four-bedroom unit agains uses roughly 100 kWh/month more than the smaller three-bedroom units. The trends of the actual and the norm track each other well. Also evident from this curve--the cooling algorithm tends to underpredict the cooling requirements in the building or the occupants are cooling their facilities to temperatures below 78° F, causing higher usage. The norm always falls within one standard deviation from the actual consumption, showing that a large percentage of the units use less energy than the norm allows.

Figure 2-9 shows the gas consumption and norms versus daily heating days for this unit. The norm is consistently lower than the actual mean data. However, comparable data for other units show that these units with a conduction-infiltration factor of 15,621 (approximately 50 percent higher than the other units) use 50 percent more heating energy than the other units. This shows that the conduction-infiltration factor is a valid parameter for describing the thermodynamic operation of a housing unit. Tracking of the norm and actual consumption shows the accuracy of the algorithm in predicting the heating requirements based on heating degree-days. However, the difference between the norm and the actual consumption is fairly large (30 percent) indicating some major problem may exist with the survey definition of this building type.

To summarize the Cannon AFB data, it has been shown that the electrical norm has been consistently higher than the actual mean data for identical building groups, which difference indicates that the DoD-projected electrical energy consumption per unit, though containing proper diurnal adjustments, may be higher than it should be if actual consumption is considered as representing proper level of consumption. (Because

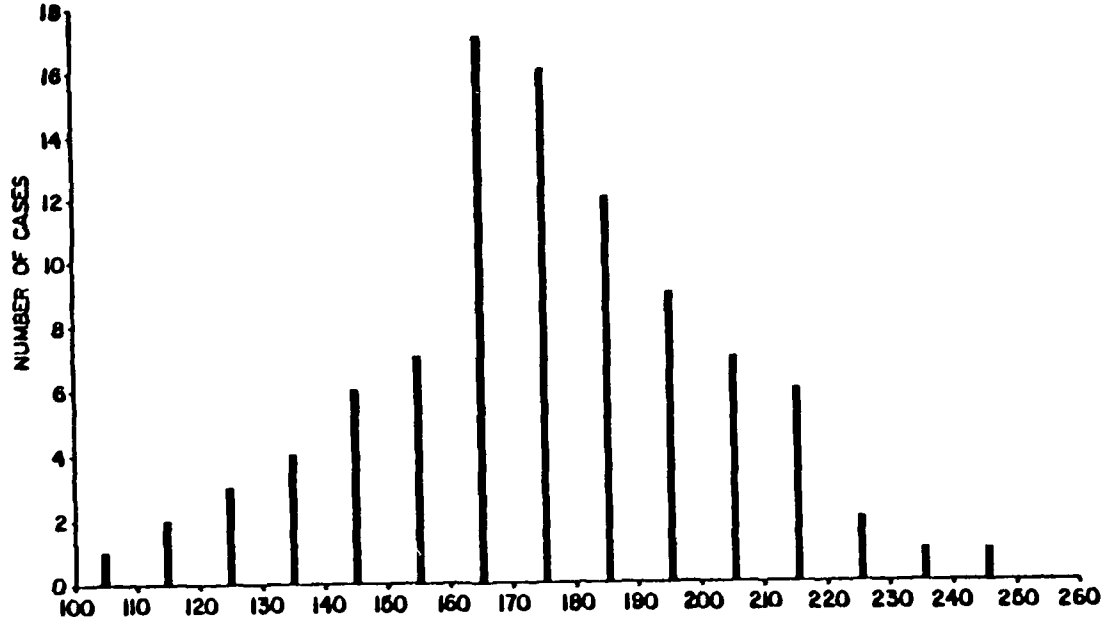


Figure 2-5
Frequency Distribution of Gas Usage - January

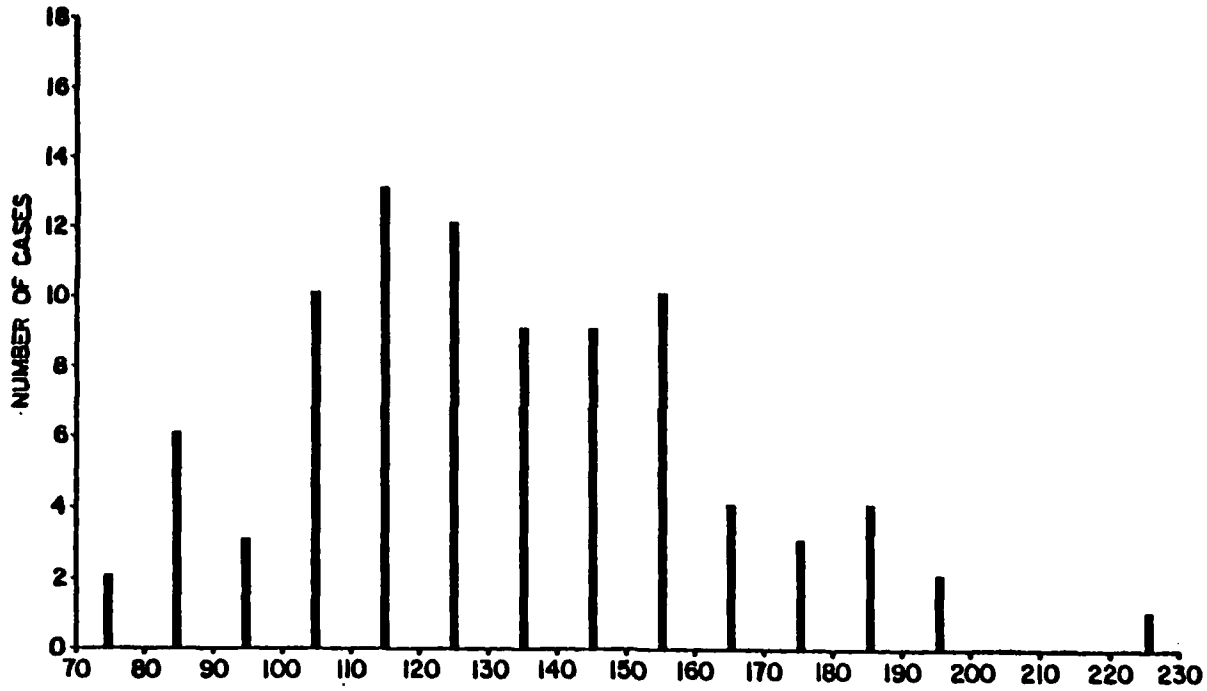


Figure 2-6
Frequency Distribution of Gas Usage - February

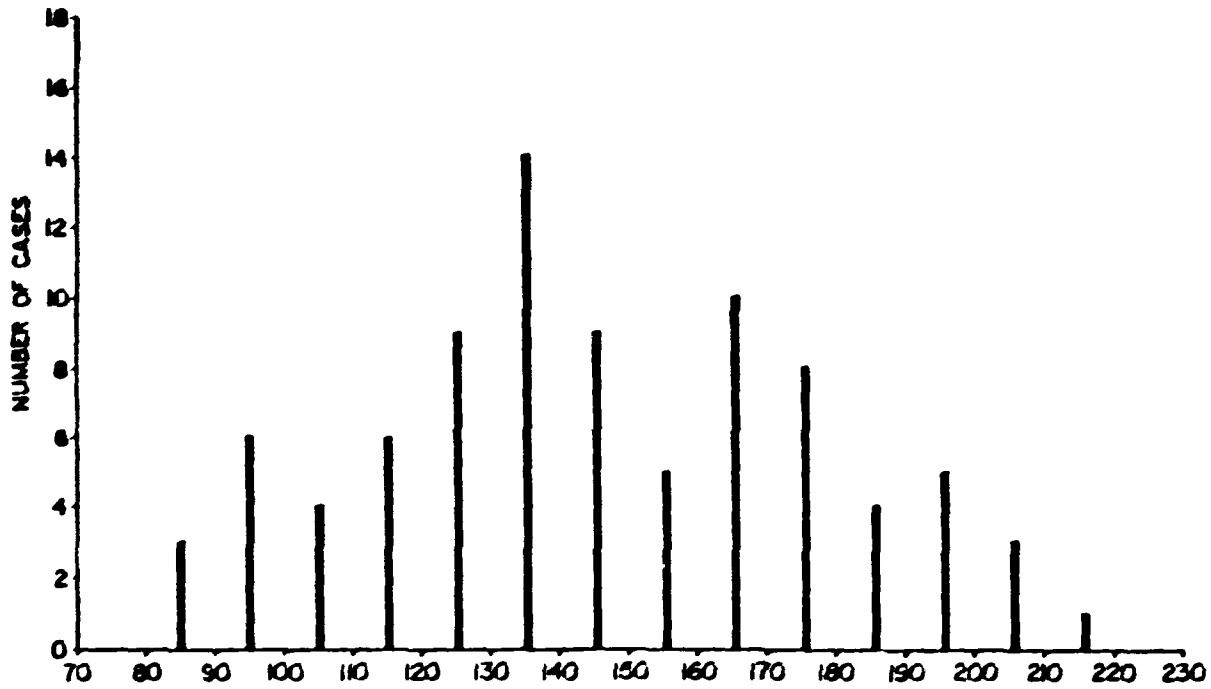


Figure 2-7
Frequency Distribution of Gas Usage - March

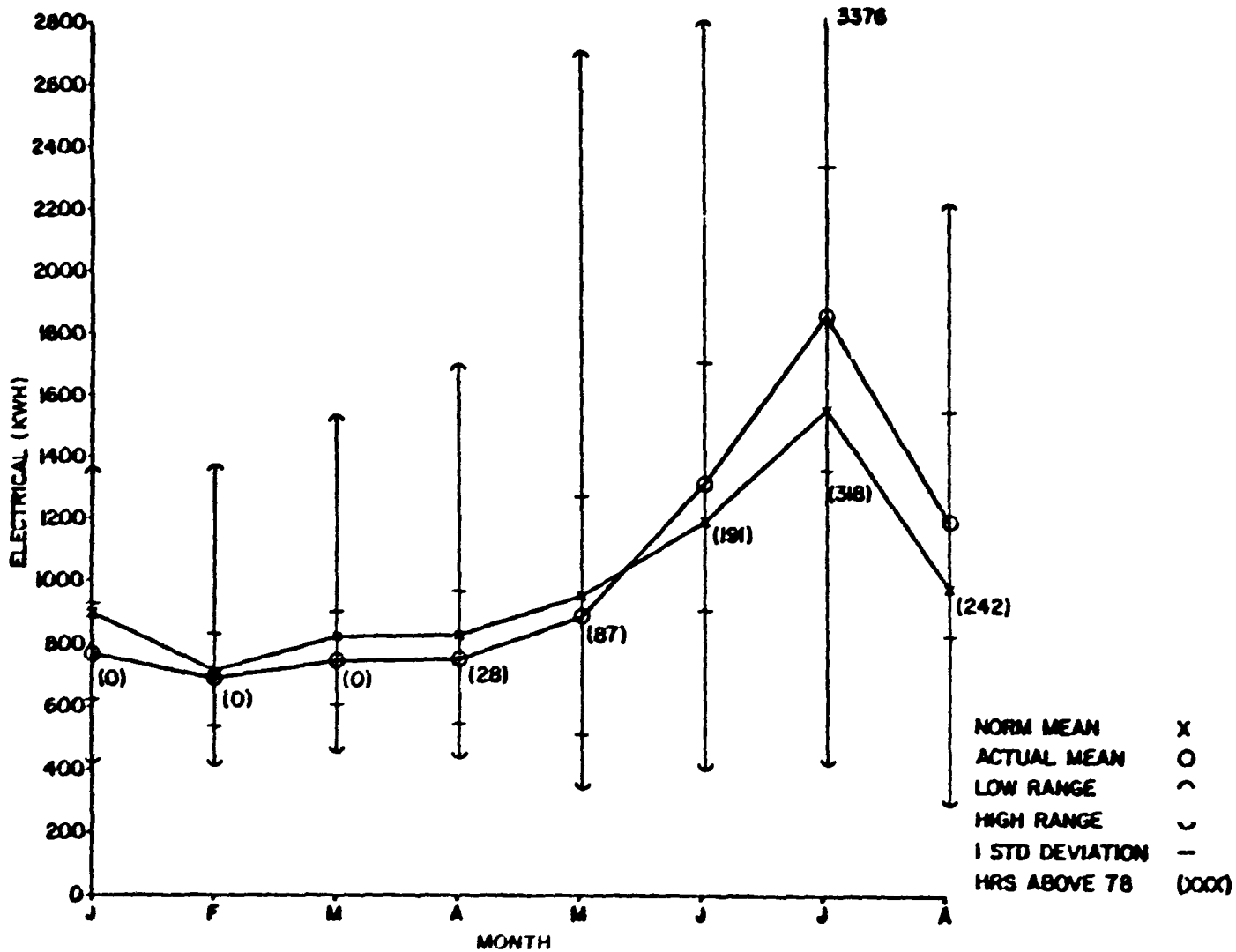


Figure 2-8
Electrical Consumption and Norms Versus Months (Cannon AFB)

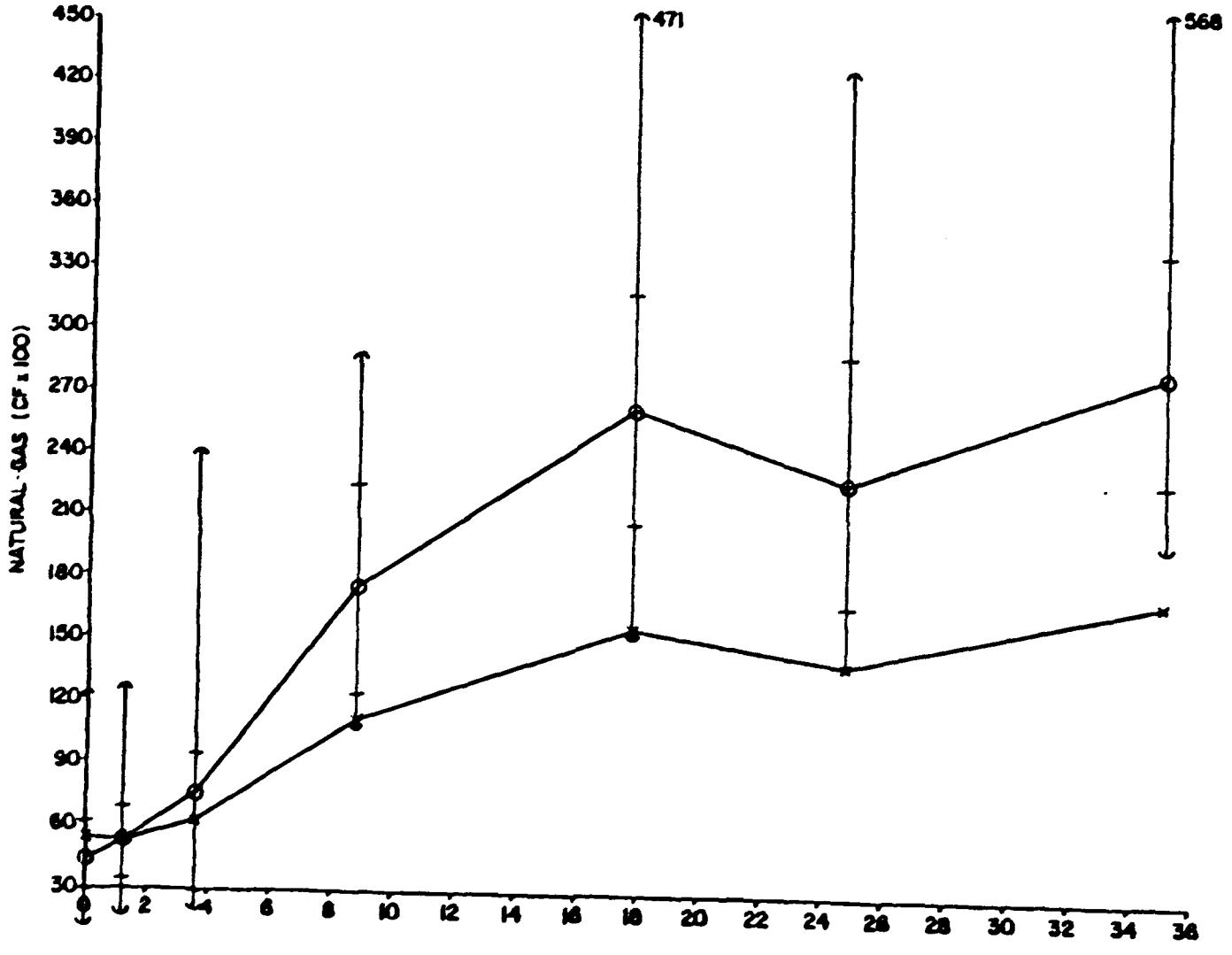


Figure 2-9
Gas Consumption and Norms Versus Daily HDD (Cannon AFB)

of pressure from prior administrations as well as the entire defense establishment to reduce energy consumption in family housing, actual consumption may already be below reasonable norm levels for American quality of life.) Data tend to indicate a more significant difference between three- and four-bedroom units than between two- and three-bedroom units as was used in calculation of the electrical norm. Data indicate either the cooling in the units may be accomplished at lower setpoints than 78° F or the algorithm utilized in the calculation of the norm needs to be adjusted so that it will more closely predict the cooling requirements of the buildings. The gas consumption at Cannon AFB is consistently higher than the calculated norm. Furnace efficiencies should be refined, indoor setpoints sampled, and the calculated conduction-infiltration factor rechecked to determine and reduce the cause of the variance.

3. Quantico, Virginia. The next installation studied was Quantico, Virginia, with a total of 1,110 family housing units. Heating is done primarily by natural gas, but propane is also used in some of the units.

A frame duplex building studied is a 693-square-foot two-bedroom unit with 81 square feet of window area built in 1942. This building utilizes propane for heating, cooking, and domestic hot water heating and has a conduction-infiltration factor of 11,937. Figure 2-10 shows the electrical consumption for this unit. The actual electrical consumption is less than one-half of the norm but does track the norm consumption closely. Initial analyses of this data indicate the meters or the meter conversion factor may be in error as the actual consumption is much too low for this type of unit. This is the widest variation that was found between actual and norm data in the family housing units. As in previous electrical consumption and norm figures, the differences in the summer months when cooling is required are less than that in the winter months, indicating greater use of the cooling system than predicted by the cooling algorithm.

Figure 2-11 shows the propane consumption and norms versus heating degree-days for this unit. Although the norm and the actual consumption are very close together in the low heating degree-day months, a larger difference is noted during the heating season. Although the two curves track each other well, the wide difference in norm and actual consumption for electricity cannot be explained without an onsite evaluation. Again, a conversion factor of Btu to pounds of propane or meter readings may be in error.

In observing all the Quantico data, it can be seen that the electrical norm is lower than the actual consumption for the two-bedroom unit and higher than the actual consumption for the three-bedroom units, again suggesting the "number-of-bedroom" electrical norm may be incorrectly separated at the two- and three-bedroom levels. The second data case indicated on Figure 2-11 is assumed to be in error from the actual consumption data

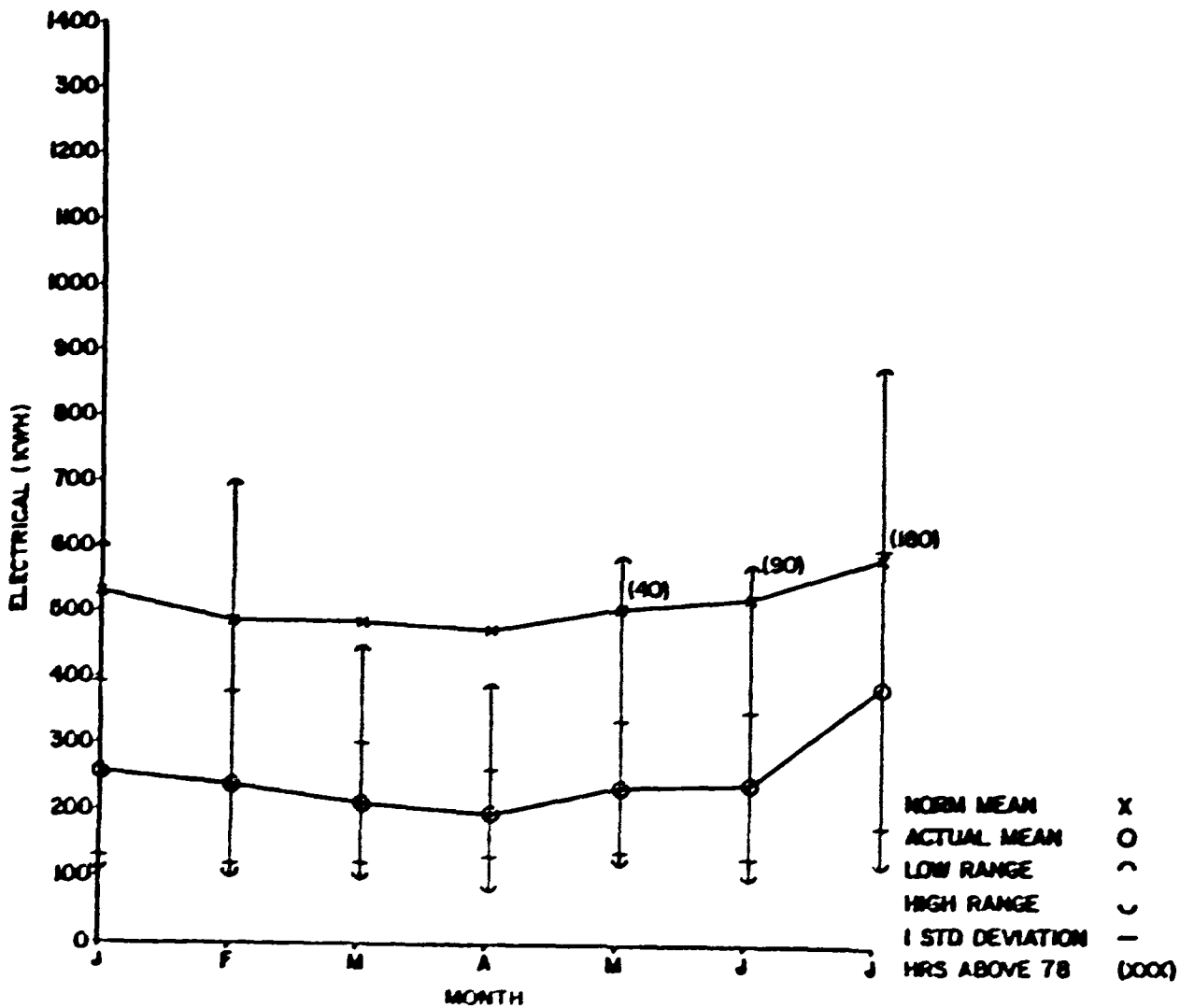


Figure 2-10
Electric Consumption and Norms Versus Months (Quantico)

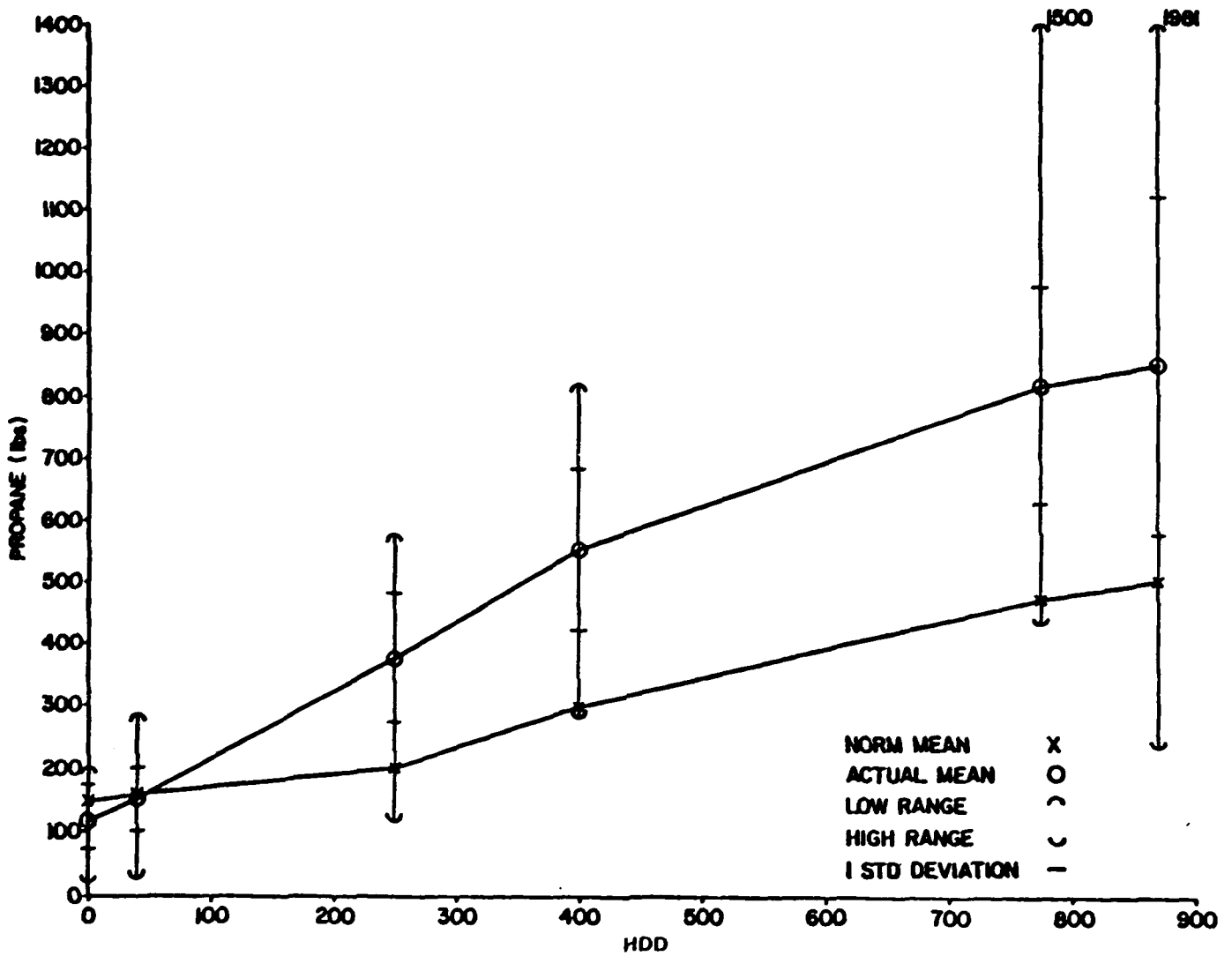


Figure 2-11
Gas Consumption and Norms Versus HDD (Quantico)

standpoint. In all cases, the gas consumption is higher than the norm-predicted value. As mentioned previously, this could be due to any number of factors including higher indoor set point temperatures used by the occupants during the heating months, improper field calculation of conduction-infiltration factors or higher than actual furnace efficiency factors in the norm algorithm. The excellent tracking of norm and actual curves provides confidence that the heating algorithm equation form is correct, on a statistical basis, even if not useful for accurately predicting individual unit requirements.

4. Fort Gordon, Georgia. The next activity studied was Fort Gordon, Georgia, with a total of 593 family housing accounts. The family housing units, served by natural gas for heating, cooking, and hot water, have central electrical air conditioning. The results were generally as previously described, although some inconsistencies appeared during season transitions.

5. Little Rock AFB, Arkansas. The last activity studied was Little Rock AFB, Arkansas, with a total of 1,538 family housing units. The family housing on this activity is totally electric, using electricity for heating, cooking, cooling, and domestic hot water heating.

The first building studied is a 940-square-foot frame duplex built in 1958. The two-bedroom, one-story structure contains 115 square feet of window area and has a conduction-infiltration factor of 0.504. Figure 2-12 shows the electrical consumption and norms by month for the sample of 323 thermodynamically equivalent buildings. In addition to the number of hours above 78° F during the monitoring period, the bracketed number indicates the total number of heating degree-days during the month. The curves shown in Figure 2-12 are slightly more complex to analyze than those previously shown. It can be seen during the heating months that the actual consumption is higher than the norm consumption but tends to merge together and become lower than the norm when heating is no longer required and cooling becomes a significant portion of the electrical load. During the cooling months, the norm consumption is higher than the actual mean consumption by about 10 percent. The two curves track very well for the heating periods and cooling periods, individually. The wider variance between the norm and actual consumption in January versus that in March and April results from the action of the heating system coefficient of performance (reciprocal of efficiency) for the heat pumps in the facilities. A constant heat pump coefficient of performance was used in the calculations of the norm. Because heat pumps are more efficient in warmer months, a variable coefficient of performance based on the number of heating degree-days must be developed and added to the norm calculation procedure to more accurately calculate the consumption in the building.

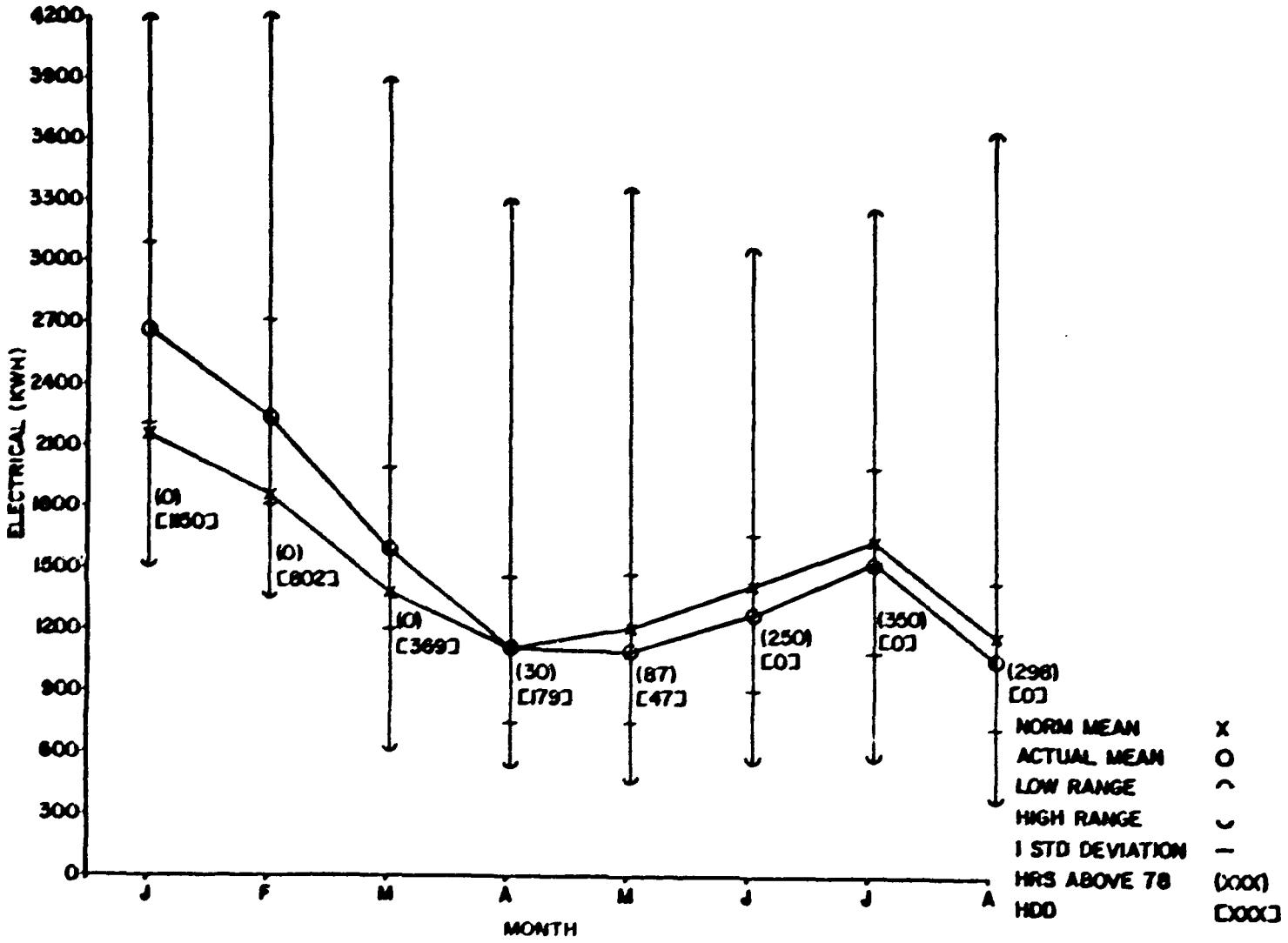


Figure 2-12
Electrical Consumption and Norms Versus Months (Little Rock AFB)

The second building studied at Little Rock AFB is a 1,052-square-foot, single-story, three bedroom frame duplex with 142 square feet of window area and a conduction-infiltration factor of 7,561. Figure 2-13 shows the total electrical energy consumption and norms versus heating degree-days and hours above 78° F. This curve is very similar to that shown in Figure 2-12 where the actual consumption is higher than the norm during the heating months and lower than the norm during the cooling months. This again indicates that the total norm algorithm predicts too high for heating and too low for cooling at this installation. The fact that the two curves track each other well indicates that the norm algorithm can be adjusted slightly to decrease the variance between norm and actual consumption; however, the great range of actual consumption reported is of considerable concern.

6. Domestic Hot Water. An analysis of actual consumption data for family housing during nonheating and noncooling months was accomplished to determine the effects of the number of occupants in a unit on DHW usage. The norm algorithm for the hot water heating energy requirements predicts a constant 145-kWh increase per occupant for the average supply water temperature of 74° F during this period. This indicates either that the DHW norm which allows 25 gallons of 140°F hot water per person will be consistently overgenerous in its energy allowance or that occupants for one reason or another, including conscious energy conserving efforts, choose to use less than the allowed 25 gallons.

During the minimal heating months of May, June, and July, the gas hot water data reflect the actual energy consumption for pilot lights, minimal heating, cooking, and domestic hot water. Data show an increase in energy requirements of 260 cubic feet (CF) of natural gas for an increase of two occupants to three. Larger amounts of energy are used when occupancy changes from three to four occupants (460 CF) and from four to five occupants (620 CF). The average calculated norm increase per occupant for Cannon AFB during this time period is 620 CF. The domestic hot water norm again will tend to be generous in its allowance for domestic hot water heating energy.

Fort Gordon data does not show any significant variance in energy use for family housing units for occupancies ranging from two to four occupants. However, as occupancy increases from four to five occupants, an increase of 450 CF of natural gas is observed. Likewise, as occupancy increases from five to six occupants, an average increase in natural gas consumption of 390 CF is shown. The calculated average hot water norm for this activity and time period is 540 CF per occupant in the units. This will cause the norm to be inaccurate as the number of occupants in a unit increases.

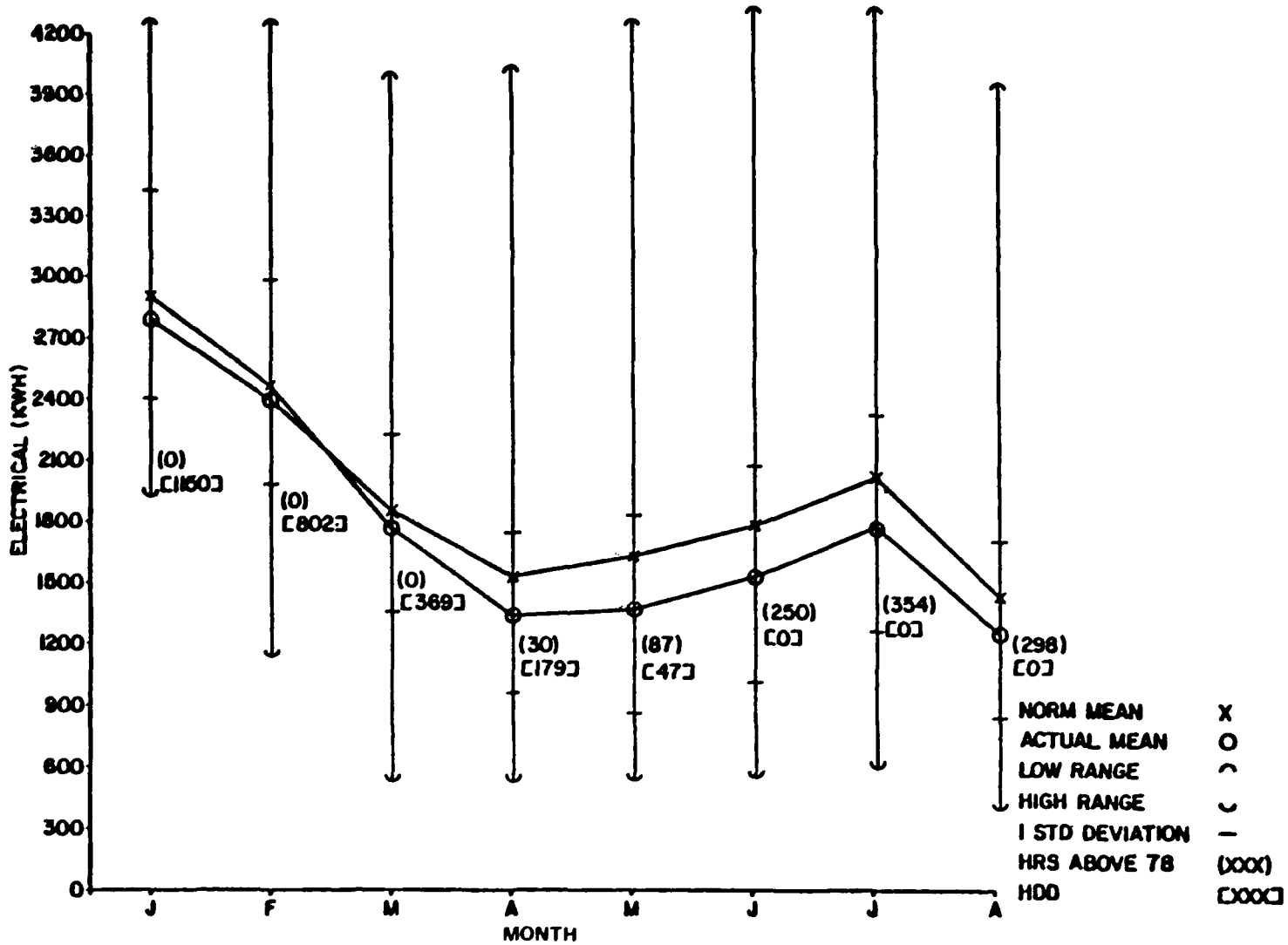


Figure 2-13
Electrical Consumption and Norms Versus Months (Little Rock AFB)

The analysis of energy usage versus occupancy indicates the hot water norm will tend to be high only for family housing units with a large number of occupants. Energy usage for domestic hot water by two and three occupants remains substantially the same. An even smaller increase in energy usage for domestic hot water is evident for occupancies greater than five. These tendencies would indicate that an additional variable (such as occupant age) may be necessary to accurately predict domestic hot water energy consumption.

7. Summary. The heating and cooling loads in family housing depend on the interrelationship of many variables, including outdoor temperature and relative humidity; indoor set point temperature; insulation levels of the walls, roof, and floor; amount of fenestration; amount of outdoor infiltration; amount and usage of lights and appliances; heating and cooling system efficiencies; and number and life style of occupants.

Outdoor air temperature is used in the norm algorithm in the form of heating degree-days for heating, and number of hours the outdoor temperature exceeds 78° F for cooling. The overall tracking of the norm and actual consumption for the buildings analyzed indicate that the weather parameters used in the norm algorithm properly predict trends in heating and cooling requirements.

The indoor set point temperature or the actual thermostat setting within the military family housing unit is a noncontrollable item from the norm algorithm standpoint. The norms were developed by using a constant 68° F indoor set point for heating and 78° F for cooling, as directed by OSD. Variations from these set points in the actual units would increase or decrease the energy used for heating and cooling. Other studies have shown that a 1° F change in the heating set point, can cause up to a 5 percent change in energy usage. Some of the family housing units may be setting temperatures other than 68° F in the heating season and 78° F in the cooling season as prescribed for this test, although other factors could account for variations noted.

The insulation levels of the walls, roof, and floor, as believed to exist, and estimated amount of air leakage in the building are taken into account by the infiltration-conduction factor that was calculated for each family housing unit in the test metering program. Training and instructions were provided to the survey teams for calculating this important parameter. In the early stages of the program several of the activities were found to have made errors in their calculations. The gross errors were easily detected, but a method must be developed to insure that accurate calculations of this parameter are accomplished. It should be noted that accurate determination of existing field conditions is difficult because most insulation is concealed, and may have holidays, or have settled. At best

a detailed look at each house is required. The conduction-infiltration factor is directly related to the energy consumption and calculated norm of the family housing unit. A 5 percent error in its calculation would produce a corresponding 5 percent variation in the norm calculation.

The heating and cooling system efficiencies for the test metering program were selected from data available in reports published by the National Bureau of Standards and appear to be rather stringent. (A higher-than-actual efficiency will cause the calculated norm to be low.) For the test program, a constant annual efficiency was selected for heating systems and cooling systems. It has been shown on the curves developed that the efficiencies do change based on the amount of usage of the system, on heating degree-days, or on hours above 78° F. This is evident from curves such as Figure 2-3 where the variance between the norm and actual consumption is wider in the lower heating degree-months than in the higher heating degree-months. This indicates a higher efficiency during cold months and a lower efficiency during warm months. Further analyses of the actual data and more research into family housing system efficiencies are required to completely define the seasonal variations of family housing system efficiencies which can be utilized in the programs to produce a more accurate norm. Because the occupant does not have direct control of this variable, the norm should be designed to provide the most reasonable estimate of heating and cooling system efficiencies, and the efficiencies may need to be adjusted on an activity-by-activity basis.

The number and life style of occupants remain the most unpredictable influence in norm development. It was determined that even the increase among thermodynamically equivalent units with different occupancy does not follow consistent patterns. The curves shown previously indicate wide variations in the minimum and maximum consumption in units that are supposedly thermodynamically equivalent. Refinements can be made to the norm algorithm to allow a better prediction of electrical domestic hot water heating and cooling energy requirements; however, the correctness of the resulting norm relative to the appropriate level of consumption still remains uncertain. Wide fluctuations in actual usage will still exist due to the occupants' demographic profile and individual life styles and corresponding usage of energy; and a "standard" American lifestyle has not been defined.

The test metering program and analysis of actual data have uncovered areas that would require considerable further study prior to a full implementation of a family housing metering and excess billing system throughout DoD. Further analysis of actual energy use data and testing of heating and cooling systems to determine actual operating efficiencies and efficiency variation at different operating hours would be required. A detailed training program would be required to insure family housing survey teams are sufficiently trained to perform the

surveys, select and group thermodynamically equivalent buildings, and calculate infiltration-conduction factors consistently for all activities. Any time schedule for implementation should include a 1-year testing period to allow for validation and refinement of the norm and to achieve total fairness to all participants.

The greatest problem with the use of the norm algorithm, even in a relatively refined form, however, is the confidence in the accuracy of modeling of requirements of the individual facility and human occupants to an accuracy necessary for billing and collection of penalties. Statistical curve modeling is at present somewhat rough, but even if refined so that the means for norm and consumption are coincident, significant unexplained individual deviations are expected. To fairly handle these, a significant range of nonbilling, possibly approximately 15 percent would be expected to be necessary, although it would significantly reduce the number of occupants who would receive an overconsumption bill on the raw data.

8. Civilian Norm Comparisons. At Port Hueneme, a norm algorithm was used to compare average energy consumption in a group of civilian homes with a group of roughly comparable military family housing units. The norm was useful in providing an overall comparison of average energy consumption between the two groups. Results of this study are discussed in greater detail in Chapter 4, "Occupant Response"; however, in view of the foregoing observations, application to individual units appears to be of limited usefulness.

V. Refining the Norm.

Although a calculation technique for determining the energy consumption norm of a DoD family housing unit was already available, it was thought to be more pertinent to initially define the requirements of a norm. Once the requirements were identified they would define the kind of calculational techniques required. The complete report of this study is contained in Appendix F and summarized below.

A. Approach.

The review of the norm concept resulted in four basic principles that guided the development of appropriate algorithms. They are as follows:

1. The norm should be fair to all DoD personnel.

2. The norm should use a readily available calculation process.

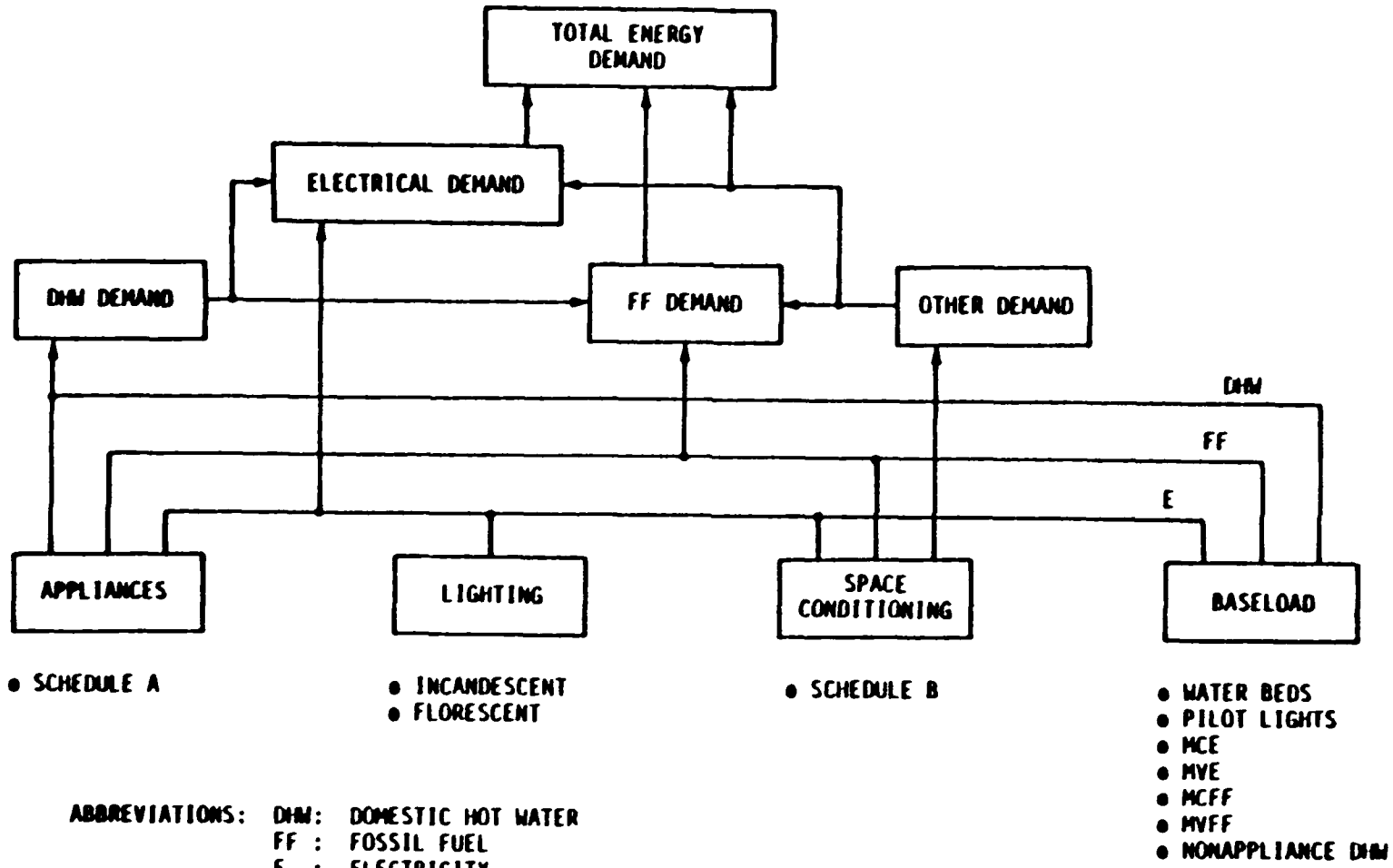
3. The norm should be a relatively simple calculation process.

4. The norm should be flexible to accommodate anomalies and housing improvements.

In order to meet this guideline it was necessary to address all major components in the consumption of energy in a residence. The building block approach to the energy consumption calculations is illustrated in Figure 2-14. The energy consuming equipment is disaggregated into four major categories of subsystems:

- Appliances
- Lighting
- Space conditioning
- Baseload

Several currently available calculation techniques to assess space conditioning energy consumption were reviewed to determine if they met the requirements of the norm concept.



ABBREVIATIONS:
- DHW: DOMESTIC HOT WATER
- FF : FOSSIL FUEL
- E : ELECTRICITY
- MCE, MCFF: MISCELLANEOUS CONSTANT ELECTRIC, FOSSIL FUEL
- MVE, MVFF: MISCELLANEOUS VARIABLE ELECTRIC, FOSSIL FUEL

Figure 2-14
Energy Demand Flow Chart

Generically, there are six types of energy calculation methods:

- Degree-day methods
- Equivalent full-load-hour methods
- Bin methods
- Computer simulations
- Hybrid methods
- Lifeline billings

From the evaluation of available techniques, it was apparent that all methods considered were not without practical, as well as theoretical, problems. However, for the norm process visualized, it appeared that some kind of simulation method would be the most appropriate choice. From the simulation methods review, the Home Energy Audit Program (HEAP) was chosen as the basis for the norm space conditioning energy consumption methodology because of its ease of use, low cost per residential analysis, and flexibility.

The use of the modified HEAP program as the norm procedure for calculating energy consumption of the residential building was validated against a more detailed methodology and against field test data. The detailed model chosen for validation of HEAP is the BLAST computer program. The BLAST program is a comprehensive set of subprograms for predicting energy consumption in buildings. The assumption was thus made that BLAST would provide accurate results that can be used to validate HEAP. Therefore, comparing results of BLAST and HEAP against each other would not show which code is more accurate. However, being able to obtain reasonable agreement between the two is important for the purposes of demonstrating that a less detailed and significantly faster running program can be used to simulate the building loads and therefore can be used as the norm procedure.

BLAST runs and modified HEAP runs were made for a typical townhouse in the Washington, D.C., area with approximately 1,200 square feet of living area built on a slab-on-grade. The results of the analysis show two general trends. First, modified HEAP always predicted heating requirements that were less than those predicted by BLAST. Secondly, HEAP always predicted cooling requirements that were greater than those predicted by BLAST. Figure 2-15 shows a typical plot of the results for the townhouse in Washington, D.C.

To gain further confidence and feeling for the performance of the modified HEAP model, sensitivity analyses and comparisons of predictions against analyses with BLAST were performed. The

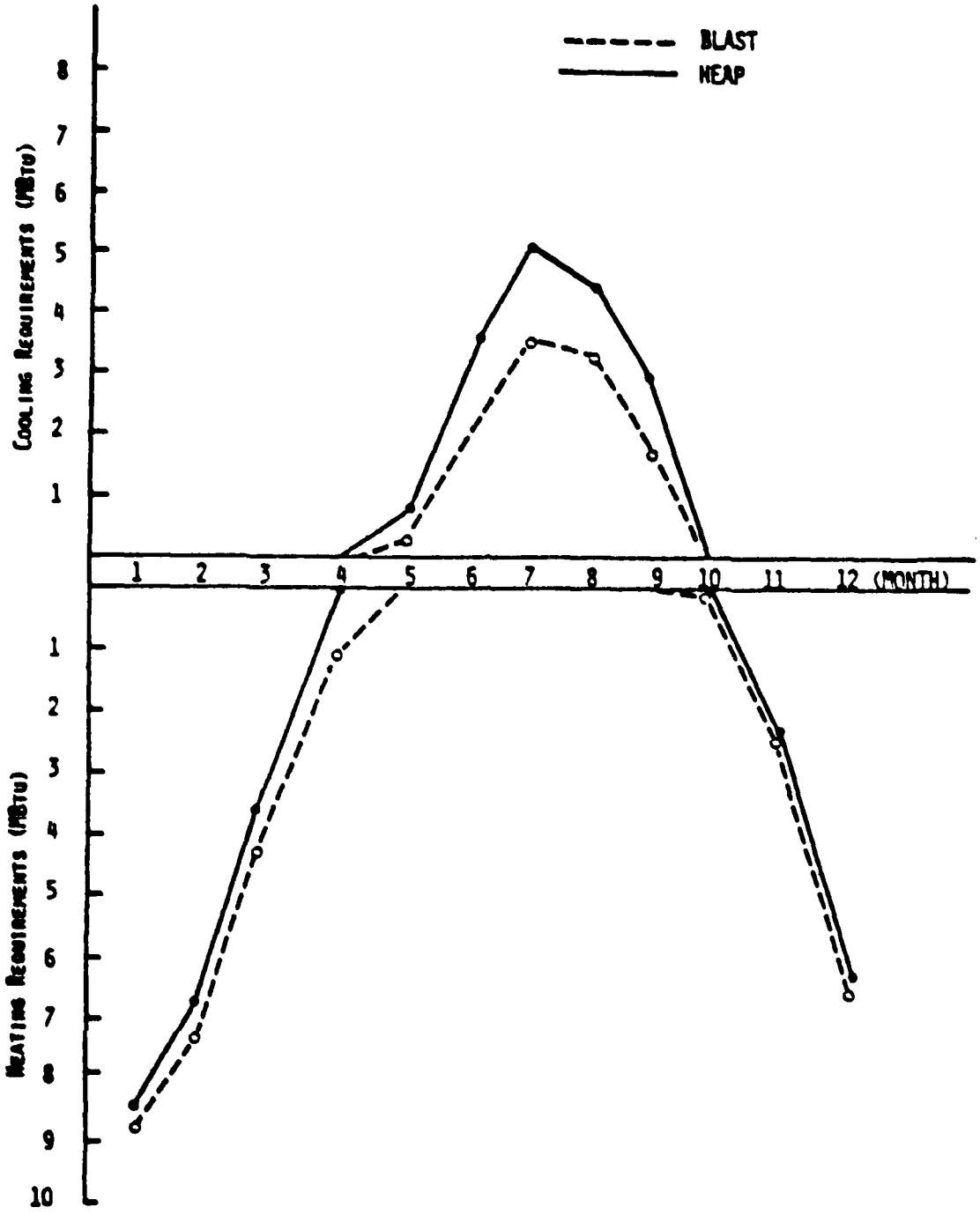


Figure 2-15
Comparison of HEAP and BLAST Monthly Heating and Cooling Requirements for a Washington, D.C., Townhouse

first set of analyses were performed using the reference townhouse located in the Washington, D.C., area, and the results are shown in Table 2-8. The table shows the effect on the heating and cooling requirements when the respective parameter being examined is changed from some reference value while all other parameters remain at reference conditions. The results show which parameters have the greatest impact on the heating and cooling requirements. Those parameters which most affect the heating and cooling requirements need to be determined as accurately as possible, so that the modified HEAP does not over- or underpredict actual requirements.

B. Human Factors.

The evaluation of existing residential energy consumption techniques did not reveal any procedure that adequately addressed the energy consumption calculation criteria of the norm concept. Therefore the norm appliance energy consumption calculations required a completely new development. The procedures used to determine nonspace heating energy consumption were based on an extensive evaluation of human factor considerations and usage patterns. Tables 2-9 and 2-10 summarize the data that became the basis of the norm appliance utilization procedure. The HEAP procedure as developed by the National Bureau of Standards (NBS) was modified to incorporate the ability to use random billing periods. The combination of the modified HEAP program and the appliance utilization procedure became the norm calculational procedure.

C. Field Test.

For the field test, the criteria for selection centered mainly on the climatic factors. It was desirable to achieve a diversity in climate among the sites chosen in order to fully test the space conditioning components of the norm calculation procedures. The chosen sites exhibit the following diverse climatic characteristics:

Fort Eustis, Virginia	Significant space conditioning requirements in an environment near the Atlantic Ocean
Great Lakes, Illinois	Significant space conditioning requirements with weather strongly affected by Lake Michigan
Fort Hood, Texas	Very significant space cooling requirements in the summer, and it is in an inland environment
Point Mugu, California	Virtually no space conditioning requirements, and no air conditioning units permitted on base

Table 2-8
HEAP Sensitivity Analysis Results

Parameter (reference value)	Values	Percent change-heating-req't	Percent change-cooling req't
Wall U value (0.1 Btu/hr-ft^2-^{o}F)	0.05	-9.0	-7.0
	0.15	9.0	7.0
	0.20	18.0	14.0
Wall surface absorptivity (0.90)	0.4	2.0	-7.0
	0.7	0.8	-2.8
	1.0	-0.4	1.4
Roof absorptivity (0.90)	0.4	1.0	-6.5
	0.7	0.4	-2.6
	1.0	-0.2	1.3
Shadow factor (0.0) (wall, door, window, roof)	0.5	7.5	-12.0
	1.0	15.0	-24.0
Wall shadow factor (0.0)	0.5	1.0	-2.4
	1.0	2.0	-4.8
Roof shadow factor (0.0)	0.5	0.6	-3.7
	1.0	1.2	-7.4
Window shading coefficient (0.8)	0.0	21.0	-47.5
	0.55	6.0	-15.0
Building air changes/hour (0.5)	1.0	11.5	0.5
	1.5	23.0	1.0
	2.0	34.5	1.5
Attic air changes/hour (3.0)	0	-0.5	1.5
	6	0.5	-1.0
	20	1.2	-4.0
Air leakage through ducts (10%)	0	-5	-9.0
	40	15	27.0
	80	35	63
	100	45	81
Ground reflectance (0.2)	0.4	2.75	16.0
	0.6	5.50	32.0
Thermal time constant (20)	10	0.51	-
	40	0.35	-

Table 2-9
Appliance Consumption (kWh/day)
Versus Number of Residents

Electrical Appliance	Number of residents 1 to 2	3	4	5	6+	Correlation Factor
Range						0.848
Average consumption	1.994	1.672	2.061	2.324	2.870	
Standard error	0.974	0.728	0.630	0.843	1.681	
Number metered	14	8	16	13	8	
Dishwasher						0.737
Average consumption	0.299	0.160	0.510	0.386	0.630	
Standard error	0.146	0.105	0.284	0.190	0.256	
Number metered	7	2	7	10	5	
Clothes Washer						0.981
Average consumption	0.119	0.220	0.263	0.338	0.396	
Standard error	0.071	0.107	0.100	0.172	0.136	
Number metered	32	23	28	26	15	
Clothes Dryer						0.916
Average consumption	1.601	2.712	2.399	3.957	4.005	
Standard error	1.030	1.457	0.999	2.519	2.369	
Number metered	19	10	20	14	10	
Water Heater						0.963
Average consumption	9.193	10.003	11.481	15.327	15.551	
Standard error	2.657	0.057	3.093	5.670	9.897	
Number metered	5	2	5	2	3	
Central Air						0.734
Average consumption	7.527	9.880	10.937	12.474	10.055	
Standard error	4.297	7.322	4.098	17.333	6.234	
Number metered	8	8	8	12	6	
Room Air Conditioner						0.714
Average consumption	2.623	1.656	2.442	5.806	5.813	
Standard error	2.934	1.650	2.152	7.731	3.948	
Number metered	15	9	11	2	2	

Table 2-10
Monthly Energy Consumption Indices for
Major Appliances (From MRI Data)

Appliance	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Refrigerator	1.09	1.05	1.05	1.00	0.945	0.91	0.90	0.91	0.98	1.04	1.04	1.07
Freezer	1.04	1.12	1.12	1.05	.98	.93	.88	.90	.92	.99	1.03	1.05
Range	.82	.86	.91	1.03	1.11	1.18	1.24	1.20	1.05	.94	.87	.81
Clothes washer	.87	1.00	1.04	1.08	1.00	1.00	1.00	1.00	1.04	1.04	1.04	.96
Clothes dryer	.84	.95	.96	1.00	1.02	1.07	1.08	1.08	1.04	1.01	.97	.95
Water heater	.85	1.05	.94	.95	1.00	1.04	1.10	1.12	1.10	1.03	.94	.85
Central air conditioning	3.21	2.26	1.49	.45	.12	.11	.11	.09	.12	.29	1.15	2.59
Room air conditioning	3.37	2.45	1.74	.53	.14	.14	.11	.07	.15	.23	.83	2.24
Cook top	.69	.91	.96	1.07	1.15	1.08	1.16	1.16	.97	.89	1.24	.71
Separate oven	.73	.75	.92	1.17	1.17	1.23	1.22	1.08	1.00	.98	.88	.84
Dishwasher	.88	.88	.90	.95	.97	1.05	1.02	1.10	1.07	1.12	1.02	.95

The choice of Point Mugu provided one site at which there would be no space conditioning component for the norm through the summer months of the field test program. This provided a site where the appliance portion of the norm could be validated without introducing the additional complicating factors having to do with space conditioning. Also, about half of the residences selected at Great Lakes did not have space cooling capabilities, making it possible to examine closely the effects of having or not having air conditioning among houses at the same site. A summary of participant data is presented in Tables 2-11 and 2-12.

Evaluation of the field test data indicated a fairly good agreement between the actual energy consumption and the norm. The norm generally tended to underpredict. Comparison of 1- and 4-week data samples shows the following mean variances and the corresponding standard deviations between the norm and actual consumption.

	Fort Eustis	Great Lakes	Point Mugu
Four-week period	-10.6% (16.7)	-11.0% (15.1)	-11.9% (16.8)
One-week period	-13.1% (22.7)	-5.5% (18.4)	-10.1% (19.0)

The mean magnitudes of the percent variations were the following:

	Fort Eustis	Great Lakes	Point Mugu
Four-week period	16.1% (11.5)	15.8% (10.0)	14.8% (14.4)
One-week period	22.9% (12.6)	15.3% (10.1)	16.0% (16.5)

The norm procedure generally tended to underpredict energy demand with respect to the actual energy consumption recorded in the field test and the military versus private comparison. The standard deviations are reasonably small indicating that the procedure developed is feasible for groups of houses or for periods of time such as 3 to 6 months; however, there is a ± 15 percent confidence factor. Modeling for individual houses or for shorter periods will pose more severe problems.

D. Implementation.

The norm is not in the final form but rather is a procedure that still requires improvement. The presently identified raw data base for implementation of this norm procedure does not differ significantly from the current norm procedure except in the area of appliance data. The building characteristics are derived from the same data requirement of an onsite evaluation of orientation and shading and shadow coefficients. Weather data requires the additional determination of solar and wind data and deletion of hours above 78° F. Appliance data is required on the major energy-consuming appliances and the amount of lighting in specific rooms. The approximate time

Table 2-11
Summary of Field Test Military Housing
Characteristics, Occupancy, and Ages for All Four Sites

Characteristic		
Number of units (all sites)		40[1]
Percent of units with:	2 bedrooms	30%
	3 bedrooms	63%
	4 bedrooms	7%
Total number of occupants in field test		176
Average number of occupants per unit		4.4
Average number of occupants per bedroom		1.36
Percent of occupants in the following age brackets:		
Less than 18 years		56%
18 to 25 years		9%
26 to 30 years		13%
31 to 40 years		20%
41 to 50 years		2%
Average age of occupants under 18 years		6.4

1 Fort Eustis - 11 units
Great Lakes - 11 units
Fort Hood - 7 units
Point Mugu - 11 units

required to tabulate these data, based on field test experience, was approximately 6 man-hours per unit. This assumes that as-built drawings are available which are required to complete data acquisition.

Additional work is required to take the norm procedure and develop it fully for application to the billing program application even with a confidence factor or the bill generated. The procedure must be expanded to allow determination of energy with steam and hot-water fuel types. Actual energy consumption data is required to verify these additional portions of the procedure. Additional field data is also required for all fuel types with both heating and cooling to provide an overall assessment and identification of changes to be made to improve accuracy. Because the HEAP norm generally underpredicts actual consumption, it is expected that modifications could be made or weighting factors added to shift the predicted mean to be coincident with the mean of the measured energy consumption and allow determination of level of accuracy. This activity would take approximately a year to accomplish.

Table 2-12
Summary of Field Test Appliances for
Military Field Test Units

Appliance type and number of appliances in living unit, where applicable		Percent of living units having appliance (40 units total)
Refrigerators:	1	82
	2	18
Freezer		36
Clothes washer		90
Clothes dryer:	gas	0
	electric	90
TV sets:	0	2
	1	67
	2	24
	3	7
Dishwasher		67
Microwave oven		13
Central air conditioner		60
Window air conditioner		0

Final implementation procedures would require another year run-in time to allow assessment of building specific determination of estimated shadow factors and assumptions in the air changeover rate calculations. A run-in period would be required for all buildings that enter a billing program. With these adjustments made, the norm procedure would be ready for application in the operational billing program. The introduction of the norm procedure into the billing program, including specific identification procedures for acquiring the raw residence data, development of the preprocessed data file, and processing of weather data to produce the final billing norm, remains to be done. These activities could be accomplished in parallel with the final run-in assessment of the norm procedure. Unless field validation supports a smaller value, there should be at least ±15 percent allowance applied to the energy requirement computed for any individual housing unit for purposes of determining excess utilization for billing purposes.

E. Military Versus Private.

In a test of the HEAP norm as well as to compare military with the private sector, an evaluation was made of the

differences in energy consumption between a segment of housing at Port Hueneme and a nearby private housing segment of housing in Oxnard, California. The HEAP norm algorithm was used, so the results are slightly different for the military units than in the main metering test which used the BLAST formula. The relative consumption of civilian versus military household is what is most significant. In a comparison of relative performance against the norm, natural gas consumption by military residences occupants was 22 percent less than for civilian residences over the 6-month period studied. Relative comparison of electric consumption with respect to the norm indicated a 44 percent greater actual consumption by military residences than civilian residences for the 6-month period with total energy consumption of the civilian units 14 percent higher than the military units on the basis of variation of the norm. Total energy consumption compared against the norm indicated that military occupants consumed 12 percent less on a per capita basis than the civilians for the 6-month period even though the relationship on a per unit basis was reversed.

It was found that civilian occupants in the survey were generally younger and had fewer and younger children than the military personnel as is indicated in the summary of occupancy and building data presented in Tables 2-13 and 2-14. As a consequence the civilian segment used less total energy, especially electricity, than the military segment on a residence basis. However, in comparison to the norm which leveled occupant and facility variables the military sector had less consumption as a percent of the norm and less variance in total energy than the civilian sector, as is summarized in Table 2-15.

Table 2-13
Comparison of Dwelling and Occupancy
Data for Civilian and Military Dwellings

Category	Overall Averages	
	Civilian	Military
Average dwelling floor area square feet per dwelling	1065	1239
Average number of occupants per dwelling	3.9	4.4
Average number of occupants per square foot	.036	.036
Average number of bedrooms per dwelling	2.7	3.2
Average number of occupants per bedroom	1.4	1.4

Table 2-14
Comparison of Detailed Occupancy Data
for Civilian and Military Dwellings

Category	Overall Averages	
	Civilian	Military
Percentages of		
Adults	55	51
Children	45	49
Percentages in age brackets		
18 to 25	19	8
23 to 30	21	3
31 to 40	7	36
41 to 50	6	5
Over 50	3	0
Average age of children, years	6	10

Table 2-15
Actual Consumptions as a Percent of NORM at Oxnard
and Port Hueneme, California

	Actual Consumptions as Percent of NORM		
	Natural Gas	Electricity	Total
Civilian			
Late winter	112	109	112
Spring	158	108	147
Early summer	107	99	105
Total	141	106	134
Military			
Late winter	85	164	94
Spring	125	148	130
Early summer	118	140	124
Total	110	151	117

F. Energy Conservation Modifications.

An evaluation was also made of the effectiveness in reducing energy consumption in typical residential buildings at Great Lakes Naval Training Center, Fort Hood Army Base and Port Hueneme Naval Base. Energy consumption analysis on three different housing units each located in a different climatic region indicate the following important conclusions:

1. Ceiling insulation was already present to varying degrees in all units, and therefore did not figure prominently in potential for further improvement in these specific units, although if not present at all or if inadequate in a given unit, would be a candidate for early improvement.

2. Replacing the single glass windows with double glass windows will result in significant reduction of heating loads.

3. Improvements in thermal characteristics of floors and attic roofs does not contribute a great deal to reduction of heating loads.

4. Improvements in air leakage will have a large effect on energy consumption and could be considered as a good portion of total energy saving.

5. Addition of R-11 or R-19 blanket insulation to exterior walls will significantly reduce the building loads but replacing R-11 with R-19 will not result in major reduction in heating loads.

VI. Future Norm Implementation.

The implementation of a DoD wide utility consumption norm for family housing units will be a major undertaking for many reasons, not the least of which is the tremendous scope of over 310,000 individual housing units. However, before beginning to specify requirements and to collect data on each house and its occupants, a more basic consideration must be addressed--how to assure its proper provision of fairness in the use of the norm.

Data from the field tests have displayed considerable scatter in both individual units and even between the means of the norm and actual consumption. Before proceeding with further development to make these means coincide, the question of which represents appropriate consumption levels must be resolved. The norm algorithm used for the test was constructed based on best technology available, without any purpose of erecting an artificially high (or low) target to be later used to modify occupant behavior. On the other hand many physical variables have been recognized that impact on a unit by unit basis. The feasibility of developing a norm calculation to accurately and fairly compute an exact energy requirement for a given housing unit is extremely questionable, and if developed, would be far more complex than the present formula which itself uses almost 300 data elements for the monthly calculation for a single unit.

The net result is the need for a non-pay allowance factor to be applied to the calculated energy requirement. A reasonable value of this factor is now seen as ± 15 percent. This factor will reduce significantly the number of occupants who will receive a penalty bill because many units will be clustered close to the norm, although the exact distribution is not predictable. As will be discussed further in Chapter 4, this factor could reduce the potential billing and potential energy saving from metering to such a point that the whole concept may become less attractive than other energy saving alternatives.

For purposes of the following paragraphs it will be <u>assumed that the foregoing problems are overcome</u> and implementation of the norm is undertaken. The steps in implementation are data element determination, training of data collectors, data collection, and entry into ADP storage. The cost of this effort must be estimated and a procedure established for maintaining the data current.

Data element delineation is dependent upon completion of refinement of the norm calculation to eliminate present divergences. It is probable that additional data elements will be necessary, as well as adjustment of coefficients. Actual specification of data elements and forms must await this effort, but once completed satisfactorily, formats for data

will be designed to cover all cases and variations. A format must be designed which will facilitate ease of accurate field collection as well as input into the computer data bank. Although this test has identified most variations, some flexibility must be built into the data base to allow for unforeseen items.

The specific qualifications and necessary training for data collectors will depend on final data requirements, but two basic types of data required, facility and occupant, suggest the skills required. Facility data must be collected for each unit in the field to assess properly actual conditions regarding the house, orientation, and shading. Engineers or engineering technicians are considered essential to insure proper evaluation and application of criteria. Gathering of occupant data including appliance loading, while under the supervision of an engineer, should be within the capability of less technically oriented persons. Due to the size of this one-time effort, collection of field data by A&E contract appears most feasible. Data input will be by usual ADP techniques, followed by checking and validation.

This entire initial data input will be very critical to the whole program and must be done as accurately as possible. It is estimated that good collection, input, and checking may take approximately 6 man-hours per unit.

After initial data base creation, any of the following changes would require reconsideration and revision for each specific unit:

- Change of occupant
- Change of appliances owned
- Facility improvement
- Facility degradation
- Change in shading factors
- Temporary changes by maintenance personnel

It is anticipated that maintenance of the data base would be done by activity maintenance and housing management personnel or design agent in the case of improvement projects, but the effort required will obviously be significant, amounting to at least several man-hours per unit per year.

The cost of the norm implementation is thus in three segments, the first two of which are initial costs:

- Norm algorithm refinement
- Data collection and data base loading
- Data base maintenance

The cost of refinement of the norm algorithm is indeterminate because the effort is essentially a research and development task; however, an additional cost of about $300,000 is not considered unreasonable. For the 310,000 units of housing, data collection and input, at 6 hours per unit, would be $22,320,000. The first cost for norm implementation would then be approximately $22,320,000 for inclusion as a part of the metering program startup costs.

Maintenance of the data base would require continuing effort at all housing activities, at a per housing unit cost of 2 man-hours at $12. The DoD total annual cost would be $7,440,000. Additional personnel would be required for this function at most activities unless the task was assigned to a contractor.

VII. Alternatives.

As a result of the study of all aspects of establishment of an energy norm for DoD family housing units, several alternatives to the norm with penalty for excess energy usage have surfaced, and will be briefly mentioned in this section. Because these alternatives were outside the scope of Public Law 95-82 they have not been fully studied although some are costed out and arrayed in Chapter 8 for comparison with the basic concept being studied.

Public Law directs DoD to charge a penalty for excessive energy usage. A norm was to be developed to facilitate this. Distribution of consumers on each side of the theoretical norm for an activity suggests that there are a number of highly motivated occupants who may undercut the norm. The need for a confidence factor (of up to $\pm$ 15 percent) of nonbilling above the norm suggests that there will be many more occupants not receiving bills than receiving them. One occupant response field test, discussed in Chapter 4, included rewards for significant underutilization. The results of this test suggest that a penalty and reward system if workable would generate more energy saving than a simple penalty system.

The confidence factor of the norm as now constructed may result in few occupants actually being billed for excess energy, while the negative personnel reaction may be significant. (See Chapter 6.) As a part of this study, a field test was conducted regarding the impact of use of energy consumption data from metering for occupant education and feedback as a part of an aggressive energy conservation program. Use of a norm would enhance the usefulness of the raw consumption data generated by the meter readings, although any data on individual or group consumption, if properly integrated into an occupant education program, will bear fruit to some extent.

At present the confidence in use of the norm algorithm for determination of individual occupant monthly bills is relatively low; however, the present norm models much better on a longer term, say 6 months, or on a broader base, such as several hundred housing units, for a period as short as 1 month. An alternative use of the norm as it now stands could be for the computation of an occupant utility allowance for use in paying costs for all energy consumed, whether equal to, above, or below, the norm. This system would have the advantages of a reward and penalty concept and impact on every occupant in some way; however, significant compensation legislation would be required.

Although not within the scope of Public Law 95-82 or this study there is another alternative involving metering energy for family housing units, which does not require a norm computation of any sort. This would be the simple billing of each occupant

for all energy used over and above the value of the Basic Allowance for Quarters (BAQ) fortified by the occupant. Because of the relative size of the bill compared with any penalty for excess use, the occupant reaction in reducing consumption would be greater. On the other hand massive potential adverse retention and morale impact dictate careful consideration before adopting such a course of action even though there is presently in many cases a difference between total on- and off-base housing costs to the individual service member considerably greater than the likely utility bill.

VIII. Summary and Conclusions.

Prior to the actual enactment of Public Law 95-82, which directed the establishment of a reasonable ceiling for the consumption of energy in any military family housing facility, a task force of utilities engineers and rate specialists from all four services had been established. Included in this technical guidance were criteria broken down by unit bedroom count for appliances and lighting, cooking, domestic hot water, and pilot lights. Heating and air conditioning norms were to be computed for each house based on facility characteristics, using temperature limitations of 68° F for heating and 78° F for cooling. Where available, criteria were drawn from accepted industry sources such as Edison Electric Institute.

The heating and cooling requirements were to be computed on an individual house basis using an energy analysis computer program. The Army Construction Engineering Research Laboratory was assigned this task and after review of available programs selected the Building Loads Analysis System Thermodynamic program for use in the test.

The overall norm formula combines all of the above energy uses and arrives at an estimated energy requirement for the specific house, for a given period of time, considering weather conditions as well as occupant and facility factors. Field survey procedures were developed; data were collected and entered. This norm was then applied to the 10,316 units in the study for testing and determination of basic feasibility. Statistical analysis of the test results yielded generally good gross correlation between consumption and norm curves, although there are many cases of considerable offsets between the two curves. This indicates disagreement between energy values calculated but does not indicate which is the best value. Other results have less consistency of data with variable offsets from month to month and some crossing of the curves. While the mean of all unit consumptions may lie close to the mean of unit norms calculated, the spread of actual unit norms and consumption deviations would make use of the results for individual penalty billing of very doubtful fairness unless a rather large "J" factor were built in. This "J" factor would be approximately ±15 percent around the norm calculated and would by its application greatly reduce the number of occupants receiving a bill because of the distribution of users about the norm. (See Chapter 4.)

The major problems with the norm calculation appear to be modeling appropriate occupant behavior and quality of life as well as correct modeling of the facility requirements. While the latter should yield to detailed case-by-case studies, the matter of quality of life and model occupant behavior are far more complex. The answers to the questions "What is

appropriate?" or "What do we compare with?" are elusive. How does the average American family live? Does even the 68° F heating and 78° F cooling criteria of this study represent unreasonable constraint on departure from the choices of the average civilian? Some test data contained in Chapter 5 tend to indicate this.

While the field test was being conducted, a separate study was ongoing on ways to refine the norm calculation. This study was done by a consultant engineer under contract. The results of this study essentially support the foregoing paragraphs, and predicted that while refinements could be made to improve computer processing time, the individual unit norm calculation accuracy, on a monthly basis, would always have a considerable uncontrolled variation. Introduction of norm variables to model for additional factors would greatly complicate the calculation, but the basic problem of occupant life style and quality of life considerations would remain.

Although of questionable practicality or energy conservation benefit, the steps in future implementation of the norm were planned. Data collection and data bank construction will be a major one-time task of significant cost and must be supported thereafter by continuous updating as factors regarding the occupant, the facility, or the environment change. Some of the occupant data could be considered as an infringement of privacy compared with the private sector.

Several possible alternatives to the prescribed use of the norm and consumption data appeared and though outside the scope of the basic study will be discussed briefly in Chapter 4 for comparison.

In essence the development and use of an energy ceiling or norm as an energy conservation measure appears to be of very questionable feasibility and value.

Chapter 3. BILLING SYSTEM

I. Planning.

A. Requirements.

Every project begins with the identification of broad functional requirements which give impetus to defining project boundaries and investigation of alternatives to satisfy the requirements. The well-defined detailed requirements that a system must satisfy are acquired as a part of the entire planning process. The broad functional requirements for the billing system were defined by Congress; the Office of the Secretary of Defense translated the broadly defined concepts into definitive guidance on all aspects of the system.

1. Congress. On 6 May 1977, legislation was introduced in the FY 1978 Military Construction Authorization Bill (H.R. 6990) which directed OSD to install meters on all military family housing units in the United States and possessions; to develop consumption norms for each type of utility at a housing unit; and to bill occupants for energy consumed over the norms. On 1 August 1977, Congress authorized (Public Law 95-82) the installation of meters, the establishment of norms, and the assessment for consumption over the norms but stipulated that no actual charges would be levied before a 1-year test program was conducted.

The guidelines of the test program were established by the 12 July 1977 House of Representatives Conference Report No. 95-494, which stated the following:

a. A representative cross section of at least 10 000 units from all regions of the country should be included in the test.

b. A part of the test sample should include housing units with varying degrees of energy saving devices.

c. Occupants should receive mock bills for the excess energy consumed, but would not be required to pay for the excess energy during the test period.

d. The test should be conducted on a schedule to include meter installation on test units by 1 January, 1978 and provision of a final report on 1 January 1980.

Items a through d constituted the congressional requirements for the billing system.

2. Office of the Secretary of Defense. On 4 August 1977, an OSD task force was established to translate the broadly defined congressional requirements into detailed guidelines on test design and procedures. The Family Housing Metering Task Force included representatives from the four

services and provided definitive specifications for mock billing procedures and other test parameters. The task force selected the ten activities that would participate in the metering test, approved the format for the mock bills, and guided and monitored all major system design decisions. OSD assigned the Naval Facilities Engineering Command (NAVFACENGCOM) the responsibility for developing the billing system, which became known as the Family Housing Mock Utility Billing System (FHMUBS).

B. Concept Development.

Once the general requirements had been defined by Congress and OSD, the next step was to synthesize and evaluate alternative methods to accomplish the requirements within the specified time frame. This section describes the alternatives that were evaluated and the process of selecting the data processing capabilities that were used to satisfy these requirements.

It was apparent from the beginning of this phase that there were several constraints that would have a significant impact on the methods selected to satisfy the requirements.

1. Constraints.

a. Time. The concept development phase began in late 1977. At that time OSD had established 1 February 1978 as the date to implement the mock billing procedures. Because of slippages in meter installation schedules, the implementation date was extended to 1 October 1978. Even with the extension, however, the time factor played a significant role in decisions made during this phase as well as during later phases of billing system development and implementation.

b. Norm calculations. The algorithm to calculate one norm for one housing unit for a 30-day billing period involves 21 calculations and 289 pieces of data. The latter figure increases if the billing period is extended or if there is more than one utility serving a housing unit.

c. Metering complications. The system had to accommodate indirect metering, multiple meters for one utility, multiple utilities at one unit, and readings in nonstandard units of measure.

d. Personnel resources. There was a limit to the number of people on board who could be assigned full time to the project without having a serious impact on other ADP support efforts of the total NAVFACENGCOM mission. As a result, it was not always possible to investigate all of the details of each proposed alternative in great depth.

e. Central processing. It was decided that a central control point was necessary to collect and process information for management reports, to ensure that established conventions were followed, and to provide to the system users a contact point for assistance and guidance.

2. Software Selection. Every data processing system can be described in terms of two basic components -- hardware and software. Hardware is the physical equipment or devices forming a computer and peripheral equipment. Software is the collection of programs which provide instructions for the computer. This section describes the process that led to the selection of contract programmer/analyst support to develop the FHMUBS software. Section I.B.3 describes the hardware selection process.

Various alternatives were investigated during the software selection process, ranging from the simplest approach (i.e., a manual billing system) to the more complicated step of purchasing and modifying a sophisticated utility billing system.

a. Manual billing system. The first alternative that was evaluated was the possibility of responding to the requirements without the aid of automatic data processing. Norms and bills would have been computed manually and bills and reports would have been typed. This approach was rejected for the following reasons:

(1) Complexity of the norm calculations. Based upon actual experience in computing 40 norms using a hand-held calculator, approximately 15 minutes were required to calculate each norm. Of greater significance was the vast opportunity for manual errors during the calculation process.

(2) Staffing. The monthly processing of bills and preparation of management reports would be impossible without hiring large clerical staffs.

b. Billing by commercial utility companies. Once consideration of a manual billing system had been eliminated, the next most simple approach appeared to be to engage commercial utility companies already in the business to perform the billing services. Discussions were held with representatives of four utility companies in the Washington, D.C., and Southern California areas. Based on these discussions, this alternative was abandoned because none of the companies would consider undertaking the military family housing billing and it appeared doubtful that any other utility company would be interested. The reasons for refusal were twofold:

(1) Extensive modifications would have been required to their existing billing system to incorporate the norm concept as well as some of the unique metering conditions.

(2) The requirement to record consumption and bill for multiple utilities at each unit was outside the scope of operations.

c. Purchase of a utility billing software package. One of the primary objectives of the software evaluation process was to discover the most expedient way to meet the billing system requirements. For this reason, it was decided that the next step should be to investigate Government and commercial sources to see if a utility billing software package existed which could be purchased and modified to meet the billing system needs.

Government sources were investigated by a thorough review of the Federal Software Exchange Catalog, but this review produced no software which could satisfy the requirements. A survey of commercial sources was undertaken and surfaced four possible candidates. Further investigation of the four possible systems resulted in the elimination of three because the FHMUBS requirements exceeded the capability of their software.

The remaining viable candidate was a sophisticated utility billing system which, with modification, could have satisfied the system requirements. The problem with purchasing this system was that the time required for purchasing, modifying, and testing the software and loading the data base, when outlined as shown in Table 3-1, exceeded the 1 September 1978 installation date which was necessary for the system to be fully operational by 1 October 1978. As a result, this alternative was not pursued.

d. Development of software using contract services. The exhaustion of the preceding alternatives meant that the software would have to be developed from scratch. As mentioned before, the in-house personnel resources that would be required to fully support this effort were not available. The remaining alternative was to contract for the required personnel support. Again, a major factor in this selection process was time--the approach selected afforded the greatest time saving.

In researching alternatives for contract support, it was discovered that the General Services Administration (GSA) provides several kinds of contract support with what is called a requirements contract. Under this kind of contract, GSA is able to provide analyst and programmer services to an agency as a result of flexible contracts that GSA maintains with various commercial facilities. The terms of these contracts provide for the definition of the required service, combined agency and GSA performance monitoring, and task approval and acceptance.

It was decided to use the services provided by GSA, Region 9, headquartered in California, in spite of potential

Table 3-1
Estimated Software Procurement Schedule (1978)1/,2/

	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
1. Delegation of procurement authority letter to GSA	23											
2. GSA approval of delegation of procurement authority		18										
3. Prepare specifications	----------3											
4. Advertise contract			-----1									
5. Review responses				----15								
6. Award contract					---1							
7. Make modifications to software						1---------30						
8. Acceptance test by user								---21				
9. Operational test by user										---15		
10. Initial data load and correction											-------15	

1/The time allotted for each of these nine steps is optimistic.
2/This schedule was clearly unacceptable for the required 1 September start date.

management problems posed by the cross-country distance, because of the following:

(1) There was no such contract in existence in the Washington, D.C., area.

(2) The Department of the Navy, tasked with development of the billing system, had a data processing support office in Port Hueneme, California, where resources to acquire and administer the contract were available.

Negotiations were initiated in September 1977 between the Department of the Navy and the GSA. Services were acquired from Potomac Research Incorporated (PRI), and by October 1977, the first contract analyst had reported for duty. Additional

resources were acquired as more details about the scope of the system unfolded. The contract staffing level that was required for system design, implementation, and operations remained constant. This was because even though requirements changed, the overall level of effort remained fairly static.

3. ADP Equipment Selection. Determining the configuration of the hardware for the system proved to be somewhat easier than selecting the software. The reason for this was that two constraints severely limited the possible alternatives. The time constraint (i.e., the system had to be operational by 1 October 1978) made software installation at only one site a necessity; and the requirement for a central control point added emphasis to this approach. These two constraints dictated the selection of one large computer for processing, rather than several minicomputers, one located at each test site.

Once it had been determined that the system would be centrally processed on a large computer, the next step was to determine how each test site would submit data to, and receive output from, the central computing site. A major factor in this decision was the importance of minimizing turnaround time; i.e., the time between the transmission of input data to, and the receipt of output from, the computer. Very fast turnaround time was considered essential to ensure the currency of all the data in a billing system, especially in a billing system that was dependent upon daily weather information for the computation of norms and the production of bills. For this reason, it was decided that each activity would have a remote job entry (RJE) terminal connected to the computer by telecommunication lines which, barring equipment or software failures, would guarantee 24-hour turnaround time. Details on the acquisition of specific hardware to satisfy these processing concepts are provided in section II.A.

4. Administration. In October 1977, NAVFACENGCOM developed management specifications (Appendix G) for the billing system, based upon its understanding at that time of the requirements for the system. The management specifications identified the conceptional design of the billing system, norm data master report, meter reading document, edit report, mock utility bill, delinquent accounts listing, moves-in and moves-out listing, and periodic energy consumption reports.

A numbering system for the utility meters on housing units was developed for permanent identification. A unique seven-digit number was permanently affixed to each meter location. The number consisted of an alpha code followed by four digits, one alpha, and another numeric character. The code identifies the activity, unit, type of utility, and the source of energy consumed.

A mock bill was developed to provide the occupant with a statement of energy consumed, the norm for the billing period and its value, and the value of the energy consumed above the norm. The bill form was designed with carbon spots to enable the computer terminal to print the billing information and addresses on both the outgoing and return envelopes and statements. The specifications for the mock bill were prepared by NAVFACENGCOM and forwarded to the Government Printing Office for contract advertisement and award. It was estimated that a total of 200,000 mock bills would have to be printed for use by the ten test sites. The estimated printing cost was $9,000. A return envelope was provided in the mock bill and both the outgoing and return envelopes were printed with a DoD frank for the test. A copy of the mock bill and an explanation to occupants regarding its use are provided as Appendix H.

C. Preliminary Cost Estimates.

1. ADP. It was originally estimated to cost $1.2 million to implement and administer the ADP system during the test. Table 3-2 shows a breakout of this estimate.

Table 3-2
Estimated ADP Costs

Personnel	$ 400,000
Vendor*	275,000
Computer	225,000
Telecommunications	150,000
Terminals	150,000
Total	$1,200,000

*Cost to purchase and modify a a software package was included in this estimate.

2. Administrative. Costs shown below were initial estimates which reflected the staffing effort associated with reading meters, processing mock utility bills, and supervision.

Air Force	$ 972,000
Army	260,000
Marine Corps	424,000
Navy	206,000
Total	$1,862,000

II. Systems Development.

By the end of the system planning phase, most of the well-defined, detailed system requirements had been identified and it was possible to begin the process of developing the billing system. This development phase is described in sections dealing with hardware and software, respectively, and supplemented by additional sections on requirements, system design, and software development costs.

A. Hardware Acquisition.

A major factor in the hardware acquisition process was again the time constraint and this factor determined the hardware that was acquired for both systems development and production processing.

1. Main Computer. By March 1978, most of the PRI staff was on board and it was imperative to commence developing the software and to find a computer on which the software could reside. Various hardware alternatives were investigated (for example, the various computers which supported the data processing requirements of NAVFACENGCOM) and were found to be unsuitable, because they were operating at capacity and could not assume additional workload. Further investigation surfaced an acceptable solution which was adopted immediately because of the criticality of getting started.

The solution to hardware support was found at the Harry Diamond Laboratory (HDL) in White Oak, Maryland, which has an IBM 370/168 computer with sufficient capacity available to handle the development requirements of FHMUBS. As a result, a contract was negotiated with HDL for the use of its computer. The PRI staff, located on the West Coast, accessed the HDL computer using a remote job entry terminal that was acquired through an existing Department of the Navy ADP equipment acquisition contract.

2. RJE Terminals. During the concept development phase it had been determined that the system would be centrally processed on a large computer with the test activities using terminals to access the computer. Once these guidelines were established the next step was to acquire the hardware. During the course of software development it was decided that the HDL computer would also satisfy the FHMUBS production requirements. As a result, the contract with HDL was extended.

Computer service to the ten test sites was provided using remote terminals and dial-up telecommunications equipment. Establishing this RJE capability required several steps. The use of existing equipment was investigated first. In addition to the one terminal used for systems development, RJE's were found to be available at three of the test sites, and two activities were close enough to share the PRI terminal. These

three RJE's required modifications to enable them to communicate with the HDL computer but this was still considered an effective solution. As a result, only five RJE's had to be acquired solely for the FHMUBS. These five terminals were acquired expeditiously using an existing Department of the Navy contract for ADP equipment acquisition.

B. Requirements.

The utility billing system had to perform the following major functions which are a synthesis of congressional, OSD, and service requirements.

1. Accept input data from, and send output data to, the ten test sites.

2. Conform to the provisions of the Privacy Act of 1974 and the Federal Information Processing Standards.

3. Measure consumption in standard and nonstandard units of measure for electricity, natural gas, oil, steam, liquid propane gas (LPG) and hot water heat. Measure consumption in some cases based on indirect metering. For example, in what is designated the master/slave metering system, as many as eight housing units share a single gas-fired water heater. A single gas master meter measures the total gas consumed by the central water heater. Each unit has a hot water flowmeter (slave meter) which measures the volume in gallons of hot water flowing into each unit. These slave meter readings must be summed to give total hot water consumed. Conversions must be made by using the hot water consumption to determine the proportionate gas usage for each unit.

4. Calculate a norm for each utility at a housing unit based on daily weather information, the physical and thermodynamic properties of the unit, and data on the number of occupants.

5. Compute charges for the norm, the actual energy consumption, and for consumption in excess of the norm using the appropriate billing rate.

6. Generate a monthly mock utility bill for each housing unit, including all energy types, regardless of whether a balance is due.

7. Provide each activity with computer processing support daily.

8. Produce upon request meter-reading documents, which identify and locate a meter and which, at a minimum, include an allowable range of meter-reading values.

9. Retain in machine readable form (e.g., on magnetic tape), 1 year of norm, actual consumption, and financial history for each housing unit.

10. Produce statistical reports providing detail and summary level data on energy consumption.

11. Produce monthly, quarterly, and annual reports for each activity and for all activities combined.

C. System Design.

The preceding requirements dictated many features of the system design; however, another factor--time--played an equally important role in two ways.

First, because of the necessity to have software available to edit and store information for the initial data collection and validation phase, the first major effort was directed towards designing and writing the programs required to load and edit the data to establish the system files. After this software had been tested and installed, attention was directed to designing the software to calculate norms, generate bills, and produce reports. As a result of this necessary piecemeal approach, the total software configuration was not as efficient as it could have been.

Second, in order to meet the 1 October 1978 startup date, the software was developed to meet the minimum essential requirements. Enhancements and desirable features were left for later incorporation into the system, and this meant that continued design modifications were made to the software during the test period. Both of these conditions caused problems which required considerable effort to resolve and which could have been avoided had sufficient time been available to effect a more complete systems design.

The software that was developed was written in COBOL, a widely used programming language which, with minor modifications, is transportable from one computer to another. The system software consists of 5 primary and 35 minor programs and conforms to the conventions outlined in the Federal Information Processing Standards.

III. System Implementation.

The evolution from broad concepts to detailed requirements and the development of software to satisfy these requirements was a time-consuming process, especially since many of the concepts were complex. As a result, by the time this process had been completed for the FHMUBS, it was late April 1978 and only 4 months remained to implement the system. Three main implementation tasks had to be accomplished within that time frame: (1) RJE equipment had to be installed; (2) initial housing, meter, occupant, and base meter reading data had to be loaded; and (3) users had to be trained to operate and maintain the system. Time constraints played the primary role in deciding the way all three tasks were performed.

A. Implementation Schedule.

The FHMUBS was scheduled to begin producing mock bills on 1 October 1978. To achieve that objective, the detailed schedule shown in Table 3-3 was adopted. The schedule reflects the latest time that individual tasks could be completed and still have the system operational on time.

Many of the schedules were not met and some slipped by as much as 4 months because the total schedule was so constrained by time that any unanticipated problem resulted in unrecoverable slippage. Scheduled tasks were necessarily neglected because the available personnel resources were diverted to correcting the problems. Major factors which contributed to the implementation schedule slippage were (1) difficulty encountered in modifying existing RJE equipment, (2) delays in hiring personnel at the activity level, and (3) delays in meter installation. A more complete explanation of these factors appears in the following sections.

B. ADP Equipment Installation.

A decision was made by NAVFACENGCOM during the systems development phase that the test activities would access the central computing site using remote job entry terminals (RJE's). The Army activities had RJE's at their test sites that, with modifications, could support the FHMUBS. Two Navy activities shared an RJE; five new RJE's were procured. After determining what equipment was to be used, facilities for the new equipment had to be readied. Air conditioning, telephone service, and electrical facilities were installed and, in one case, the office space itself had to be modified. Installation of the new equipment stayed close to schedule, except at Beaufort, South Carolina, where a combination of noisy telephone lines, inadequately trained installation personnel at the local telephone company, and defective RJE components caused a 3-month delay.

Table 3-3
FHMUBS Implementation Schedule
Proposed and Actual Completion Dates (1978)

	May	Jun	Jul	Aug	Sep	Oct	Nov
Proposed schedule (all activities):	-	-	E,L	T	B	-	-
Actual completion (By activity):							
Beaufort	-	-	-	L,T	-	E,B	-
Cannon	-	-	-	E,T	L	B	-
Eustis	E	-	-	L,T	-	B	-
Gordon	E	L	-	T	-	B	-
Great Lakes	-	E	-	L,T	-	-	B
Hueneme	E	L	-	T	-	B	-
Little Rock	-	-	-	E,L,T	B	-	-
Mugu	E	L	-	T	-	B	-
Quantico	-	E	-	L,T	-	B	-
Yuma	-	L	-	T	B	-	E

E-Equipment (installation of RJE equipment).
L-Load (data load for housing survey, meter descriptions, occupancy).
T-Training (user classroom training).
B-Base reading (collection of the initial meter readings).

A more serious problem occurred with regard to the existing RJE's. Two of the three terminals which were already at the activities were quickly modified to communicate with the IBM computer at HDL, but the third required a series of changes which took 6 months to effect. Because the problem occurred at an activity with only 290 housing units, it was possible to mail data to the control site at Port Hueneme, California, for processing and still keep the activity on schedule for billing with a minimum of delay and problems.

C. Data Conversion.

Implementing the FHMUBS required that approximately 1.2 million pieces of information be collected and placed on

computer files in a period of 3 months. At the same time that data were being collected, computer programs were developed and standard operating procedures (SOP's) for completing data load forms were written. The only way that this could be accomplished was to complete one section of detailed program design, write and disseminate the SOP for that section, and, while data load forms for that section were being completed, begin programming the next section. This inefficient method was instituted because of the time constraints. Had time been available, classroom training could have been given before the data were collected, and activities could have completed only a small number of forms and waited for review of the results before completing the remainder. These two steps would have significantly reduced the error rate of the data conversion stage.

1. SOP's. The SOP's were intended to explain to personnel at the activities the peculiarities of data collection tasks and to provide an understanding of the system. In addition to descriptions of the load forms for collecting weather, water temperature, meter description, and occupancy data, details such as keypunch instructions and processing schedules had to be included. The first SOP's, 5 and 6 pages in length, were simple and effective, but by the last, a 37-page document, it was apparent that this approach was not as straightforward as envisioned.

2. Collection and validation. Similar methods were used to collect and validate the various types of initial data, but the crucial difference in effectiveness was the users' varied ability to detect invalid data. Norm data presented problems because users could not readily discern if an error had been made. Three load forms of norm data were completed, two at the activity and a third at the U.S. Army Construction Engineering Research Laboratory. Each activity mailed a copy of the first two pages of data to CERL in Champaign, Illinois, for their thermodynamic analysis, and the original sheets to the central site at Port Hueneme, California. At the central site these data were keypunched, edited, and placed on computer files. Because there was not time to mail error lists to the activities for correction, errors found during the edit process were resolved over the telephone by coordination between personnel at the activities and the error control technician at Port Hueneme. This was the first effort to validate the data. The CERL data was subsequently mailed to Port Hueneme for keypunching, editing, and loading on computer files. Error correction was once again coordinated by phone, this time between the error control technician and CERL.

The data describing meters and occupants was collected from the activities after the norm data and was handled in much the same way. The only difference occurred as a result of schedule slippages, and some initial load data was keypunched and processed at the activity rather than at Port Hueneme.

The last step in the initial data collection process was to take the base meter readings. These were processed at the activities because the training was complete and the requisite resources were available. As each section of data was completed, a file listing was produced for review by the appropriate personnel at the activities. This was the second effort to validate the data. Even after this second level of validation, much data remained incorrect. With 289 data items required for the calculation of a single norm, it was a foregone conclusion that the earliest norms and meter readings would be questionable. As a result, a prior base reading date was established and base readings (with the current base reading date) were processed. By establishing a prior reading date, it was possible to generate norms which were provided to the activities for review. This was the third and final effort to validate the initial data prior to prototype production.

D. User Training.

It was not possible to provide user training, prior to initial data load, because further prerequisite program specifications were being completed at the same time that the data load process was beginning. For initial data load, SOP's and telephone assistance had to suffice. However, both classroom presentations and a user manual were provided in August 1978 to instruct activity personnel in how to operate the system. A copy of the original user manual is provided as Appendix D, but because of subsequent report modifications and system enhancements, many portions are no longer pertinent.

Users traveled from their activities to one of two classes. Each 3-day class covered in detail the parts of the system for which users were responsible. The SOP's were reviewed, operational procedures and schedules were explained, and questions were answered. The users' manual was distributed in class and the RJE operation was demonstrated. For some activities, additional material was presented describing the handling of indirect metering, common usage metering, and other subjects specific to only their locations.

Because it was recognized that a great volume of material was covered in the 3 days, a trouble line was instituted and maintained at the central site throughout the life of the billing system. The trouble line was swamped through the early stages of the test; at its peak it consumed all of the time of the error control technician and half the time of a programmer/analyst. As the test progressed its use decreased but it was a valuable tool in solving many problems.

E. Staffing.

1. ADP staffing. In addition to the in-house management staff, commitments of contract personnel were made for data load and training. The software development group

at Port Hueneme consisted of six people who also maintained the trouble line, researched problems, operated the system during data load, and assisted with much of the training effort. From 1 March to 1 October 1978, more than 40 manmonths of effort were devoted to FHMUBS development and operation.

2. Activity staffing. Personnel had to be recruited, hired and trained at each of the test sites to perform the myriad of duties associated with meter reading and mock billing. Among the duties performed were daily weather data collection, meter reading, data transmission, publicity, occupant relations, mock billing and processing, and report editing and analyzing. A sample position description specifying the functions required of a GS-1173-07 Housing Management Assistant was written by NAVFACENGCOM and given to the services for use in their classification and recruitment efforts. An average of two personnel were hired at each of the test sites. The personnel assigned to read meters experienced many of the same problems and delays that utility company personnel face daily. These include menacing dogs, meters located behind shrubbery or fences, meters too high or low, meters indoors, and at one location meters were installed on furnaces which were located in a bedroom thus requiring readings while some occupants were still in bed.

F. Implementation Problems.

Four related problems caused the 1 October implementation date to be only partially met.

The first, a tight schedule, contributed to the severity of the others. From the test, it was learned that the system could be implemented and, more importantly, that the task took more time than was allowed. Most activities were unable to meet their schedules. Two activities had a significant number of unmetered housing units at the end of the implementation period, two were behind schedule in RJE installation, and two were behind in hiring personnel during the data collection stage. Two choices were apparent by the end of September 1978. Either production could be delayed until all activities were ready or each activity could proceed into production at its own pace. The latter choice was taken to acquire as much consumption and norm data as possible.

The second problem was that more user training was needed, and it was required before the initial data collection stage. If more training had been given it would have significantly reduced the data error rate.

The third problem was that the software contained errors. There were a number of minor and two major software problems that were undetected during software development. The implementation of the norm calculations embodied a misunderstanding

about the permissible values of one regression coefficient, and some master/slave consumption calculations were incorrect. These errors were not detected even though the software had been tested against a laboriously constructed set of test data. The alternative of running one set of live data to test the system was considered but abandoned because no activity could generate live data in time to be of use. This live data test would most probably have surfaced the errors.

The fourth problem was that the initial load data was not accurate enough for so sensitive a system. The data was checked to the maximum extent possible before ever being sent for keypunching; computer edits were performed, file listings were reviewed, and finally the results of norm calculations were verified.

However, in spite of all efforts, about half of all the initial bills which were generated contained data errors. The overall effect of these problems was to cast serious doubt upon the validity of the first quarter system results.

G. Implementation Costs.

Table 3-4 provides a breakout of costs that were incurred for FHMUBS implementation.

Table 3-4
FHMUBS Implementation Costs
(1 Oct 1977 - 30 Sep 1978)

Personnel	$ 85,000
Computer	39,600
RJE Equipment	15,070
Telecommunications	7,760
Keypunching	15,225
Training/travel	13,910
Space and facilities	8,455
Administrative	700
ADP supplies	3,398
Data load forms	3,630
TOTAL	$192,748

It should be noted that in some cases implementation costs are approximations derived from total costs.

IV. System Operation.

The FHMUBS began operations on 1 September 1978. At that time only two activities were able to submit the base meter readings, from which the first bills would be generated, because not all meters and local terminals were in place. A description of the operations processes and problems of the test system follows.

A. Operation from 1 October 1978 to 31 December 1978.

On 18 October, bills were generated for the first two activities. Other activities were able to generate bills for most of their accounts in the following two billing cycles on 2 and 17 November.

The plan for system operation was that each activity maintain weather and norm data, keep occupancy information current, and read meters for all accounts monthly. Keypunching support and RJE's were available at each site, and the central computer was available 10 of 11 workdays for the activities to have scheduling flexibility. The computer was reserved for use by the control staff on the 11th day, when bills were generated.

After each billing cycle, both the activity and the control staff reviewed billing registers to identify problems. The 11-working-day schedule provided billing cycles roughly twice a month, a cycle for processing original readings, and a cycle for corrected readings. As a refinement, some activities read and submitted data for half their accounts and processed corrections from the other half in each cycle, allowing them to evenly distribute their workload.

Reports that were generated for the activities included quarterly summaries, monthly detailed reports, and a variety of status reports. The detailed and status reports were intended to enable users to review and control processing for their activity.

By the time the first three billing cycles had been processed, and almost all accounts had been billed, review disclosed large disparities between norm and actual consumption for a large number of accounts. Research was initiated immediately to determine if:

1. The software was failing to generate norms in accordance with specifications.

2. The software was failing to calculate consumption properly.

3. The data on file was incorrect.

Over a period of time isolated instances were found where the software was not properly calculating consumption, and where the data used to determine both norm and actual usage was sometimes incorrect. While the data error rate was not exceptionally high, the requirement that 289 pieces of data be correct to yield a single correct norm meant that relatively few data errors resulted in many incorrect norms. Table 3-5 illustrates the diversity of possible errors, as well as the weaknesses in system design and implementation procedures.

Table 3-5
Common Data Problems

	Data problems	Estimated frequency
1.	The efficiency for heating (a norm factor) was incorrect	7%
2.	The infiltration rate (a norm factor) was incorrect	3%
3.	The meter-reading constant (a factor adjusting for nonstandard units of measure) was incorrect	2%
4.	The fuel content (a factor which provided Btu equivalents in a standard measure of fuel) was incorrect	10%
5.	Data which was rejected by computer edits was not corrected and reentered	1%
6.	Meter readings were assigned to the wrong occupant	5%
7.	Meter readings were inconsistent; too few or too many meter readings were processed for an account, or the meter readings were not higher than earlier readings	5%

Because incomplete and largely incorrect results had been obtained from the first 3 months of operation, two corrective actions were contemplated. First, some reprocessing could have been done. Second, the test period could have been changed from 1 October 1978 through 30 September 1979 to 1 January 1979 through 31 December 1979. Because of numerous complications, including inadequate rerun procedures and the large amount of additional effort that would have been required, the reprocessing choice was abandoned. It was estimated that operating the test until early 1980 could be done within the existing budget. Accordingly, OSD requested extension of the test and

the congressional subcommittees agreed to change the test period.

However, because it was possible that further problems might be uncovered which would dictate future reprocessing of data, a complete reprocessing capability was developed. Beginning in late December 1978, all system files were established in a form that facilitated reprocessing, and contingency reprocessing procedures were instituted.

B. Operation from 1 January 1979 to 31 March 1979.

Operations did not continue on schedule in the first quarter of CY 1979. First, it was discovered that at two activities, major correctable problems existed. One activity had been generating norms based upon an incorrect fuel content value for oil, so all housing units using oil received incorrect bills. Another activity determined an infiltration rate based upon a concrete type with substantially different physical properties from the kind actually used. Two activities suspended day-to-day meter reading and billing tasks for a period of approximately 45 days and corrected the above problems. The control site personnel then reapplied the corrections to an earlier edition of the files and reprocessed the data for the first months of 1979, generating new management reports but not new bills.

At about the time this reprocessing was completed, it was discovered that the norm calculation for heating was being performed incorrectly for many housing units at most activities. This necessitated the use of the same reprocessing procedure extended from 2 to 10 activities. For a time, personnel at every activity devoted their efforts to identifying and correcting all data errors in their files. The actual reprocessing involved thousands of corrections and tens of thousands of meter readings. Controlling and monitoring the rerun was a tedious and time-consuming task, demanding 3 man-months of effort. Activities had finished making corrections long before reprocessing was completed and were allowed to proceed with current system functions. For the interval when concurrent reprocessing of old data and processing of current data were performed it was necessary to have twice the normal computer capacity.

The effort expended to reprocess was justified by the results. The reprocessed norm and actual consumption data, based upon better quality input data, improved from an estimated 30 percent to 85 percent reliability.

C. Operations from 1 April 1979 to 31 January 1980.

The primary objective during this period was to improve the quality of norm and actual consumption results. Based upon a review of the most common problems, three approaches were

developed to improve operations. First, procedures at the activities were developed to simplify and standardize tasks. Second, computer edits were extended and improved so that fewer errors would pass through the system. And third, additional reports were developed to spotlight unusual differences between norm and actual consumption, so that locating remaining errors would be easier. However, the level of confidence in the norm and consumption data remains at about 85 percent. This level of accuracy is insufficient for any billing procedure; therefore, any billing on this data would have to eschew requiring payments from families with a consumption less than or equal to 115 percent of calculated values.

D. Staffing.

The level of staffing for the ADP and activity efforts remained stable from the development phase through the operation phase.

E. Operational Costs.

Table 3-6 provides a breakout of costs to operate the FHMUBS from the beginning of FY 1979 through the conclusion of the test.

Table 3-6
FHMUBS Operational Costs
(1 Oct 1978 - 28 Feb 1980)

Personnel	$265,568
Computer	89,000
RJE Equipment/Telecommunications	227,620
Keypunching	40,275
Space and facilities	9,825
Administrative	2,650
ADP supplies	11,083
Data load forms	2,045
Total	$648,066

V. Projected Billing System

A. Introduction.

One of the goals of the Defense Family Housing Metering Program test was to determine the feasibility of preparing and distributing bills to the occupants of military family housing for consumption in excess of an established norm. The test billing system established the feasibility on a small scale although the correctness of the bill was dependent on accuracy of norm and consumption data. However, NAVFACENGCOM decided that additional research was required to fully substantiate the feasibility on a much larger scale. As a result, additional contract personnel were hired and a study was initiated, concurrently with the operation of the test system, to investigate the feasibility of implementing a utility billing system for all military family housing units in the U.S., Guam, and Puerto Rico. This study confirmed the feasibility of full-scale implementation; however, it also proposed that the DOD-wide billing system would differ significantly from the test system for the following reasons:

1. There are additional requirements which would have to be satisfied to effect the transition from mock to actual billing. For example, in order to maintain financial accountability the billing system would have to interface with existing accounts receivable systems.

2. The lessons learned during the test phase provided insight into improved methods for system development, implementation, and operations. However, this experience also surfaced problems (explained in paragraph D.1) which would be compounded if a system identical to the one used during the test was selected for full-scale implementation.

3. The increase in the number of housing units from 10,000 to 310,000, with the accompanying geographic dispersion, could dictate local or regional (i.e., distributed) versus central processing.

This section will address in detail the requirements of the projected billing system, present two possible alternatives to meet the requirements, and recommend an approach to use to select the best possible alternative should full-scale metering be directed.

B. Assumptions.

At the outset of the effort to investigate full-scale system implementation, it was determined by NAVFACENGCOM that some assumptions had to be made in order to define the research

boundaries. Based on the most comprehensive knowledge and guidance that were available, the following assumptions were made:

1. Each military service would desire and would assume responsibility for developing, implementing, and operating its own billing system.

2. The norm concept would be an integral part of the billing system.

3. All live billing of occupants would begin at the same period in time.

4. A congressionally directed implementation schedule could affect, and possibly determine, the billing system selected by eliminating systems which cannot be implemented in the time frame specified.

5. It would be acceptable, and even desirable, to postpone some decisions. For example, determining the details of the billing system interface with existing accounts receivable systems would be more appropriately done in the future by each individual service when requirements for full-scale implementation, together with the accompanying implementing regulations, have been fully defined.

C. Requirements.

The requirements that must be satisfied by any future billing system are presented to show requirements that are identical to those of the test system, deletions from the test system, and new requirements. The changes and new requirements for a live billing system emerged as a consequence of the knowledge gained during the test and are printed in all capital letters. Deletions from the test system are lined through in parentheses.

1. Accept input data from, and send output data to, (~~the ten test sites~~) ACTIVITIES IN THE U.S., GUAM, AND PUERTO RICO.

2. Conform to ALL APPLICABLE LAWS AND STANDARDS INCLUDING (~~the standards of~~) the Privacy Act of 1974 and the Federal Information Processing Standards (FIPS).

3. Measure energy consumption in standard and non-standard units of measure for (~~electricity, gas, oil, steam, liquid propane gas~~ (~~LPG~~), ~~and hot water heat~~) ALL TYPES OF ENERGY IN MILITARY FAMILY HOUSING UNITS.

4. Calculate a norm for each utility at a housing unit based on daily weather information, the physical and

thermodynamic properties of the unit, and data on the number of occupants.

5. Compute charges for the norm, for actual energy consumption, and for consumption in excess of the norm using the appropriate billing rate.

6. Generate a (~~mock~~) utility bill for each housing unit, including all energy types, once a month, regardless of whether a balance is due.

7. Provide an activity with computer processing support daily or at least MONTHLY DEPENDING ON THE VOLUME OF ACCOUNTS AT THE ACTIVITY.

8. Produce meter reading documents, upon request, which identify and locate a meter and which, at a minimum, include an allowable range of meter reading values.

9. Retain in machine readable form (e.g., magnetic tape) (~~one~~) SEVEN years of norm, actual consumption and financial history for each housing unit.

10. Produce statistical reports providing detail and summary level data on energy consumption WITHIN TWO WEEKS OF REQUEST.

11. Produce monthly, quarterly, and annual reports for each activity, and for all activities combined, WITHIN FORTY-FIVE (45) DAYS OF THE END OF THE PERIOD.

12. Edit all input data and MAINTAIN ERROR CORRECTION AND CONTROL PROCEDURES.

13. PROVIDE A MEANS TO CHANGE/CORRECT ANY INFORMATION CONTAINED IN THE SYSTEM.

14. PROVIDE UTILITY BILL ADJUSTMENT STATEMENTS.

15. INTERFACE WITH THE REQUIRED ACCOUNTING SYSTEMS NO LESS THAN ONCE A MONTH.

Some of the system requirements are broadly defined and the reasons for this are twofold. First, some requirements definition tasks would have required more time and resources than were available. For example, it will be necessary for the system to have the capability to correct billing errors and issue adjusted bills (requirement Nos. 13, 14, and 15). However, forthcoming legislation may dictate the <u>time allowed</u> for the correction process, and this, in turn, could be an additional requirement that will dictate what capabilities the system must have. Second, it was anticipated that the full process of requirements definition would follow the pattern established with the test system, i.e., Congress and OSD would dictate

certain broad requirements for full-scale implementation but the synthesis into detailed system requirements would be a quad-service effort.

D. Full-Scale Implementation.

The method selected for full-scale development and implementation of the utility billing system for military family housing, if directed, will depend upon two primary factors: First, the requirements of the system as they are ultimately defined; and second, the decisions made by each service during the system development process. For example, a requirement to resolve erroneous bills within 15 days could dictate a need for a small system configuration located at each activity; and a decision that surplus hardware was available could result in the use of existing equipment rather than a new purchase.

As a result, the scope of the research into full-scale implementation did not include formulation of a recommendation. What it did include was the presentation of possible alternatives based on the experience gained from development and operation of the FHMUBS system, combined with ideas which surfaced during the research process.

This section discusses some important lessons learned which should be considered in any future decisionmaking regarding the billing system, and also describes alternatives that were investigated as possible methods for billing system implementation.

1. Lessons Learned. Much experience was gained by the conditions and problems encountered during the test period. Some of this experience is merely of interest, some pertains to limited functional areas, and some is of sufficient import to warrant detailed attention in any future decisionmaking sessions. The experience that merits very careful consideration is discussed in the following paragraphs.

a. The billing system must be responsive by providing for data adjustments with ease, and for the rapid transmission of information to and from the computer. The right of the individual to have access to current information about his account and quick resolution of errors is paramount in any billing system, and it is absolutely critical in this billing system where accuracy can be affected by an error in the daily high or low temperature reading. The most far-reaching effect that would be provided by a system geared to customer satisfaction would most probably be a faster and easier acceptance of the metering and billing concept on the part of the occupants of military family housing.

b. The billing system development and implementation schedules should be realistic and permit decisionmaking

that is based on a thorough evaluation of all alternatives. During development of the test system many decisions were restricted, if not determined, by congressionally imposed deadlines. This resulted in later problems which could have been avoided.

c. The system software should be thoroughly tested and validated at all activities for a minimum of 1 year with live data before the system becomes operational. This is considered necessary to ensure maximum accuracy of all aspects of the software, but most importantly, to validate insofar as possible the consumption requirement that is calculated. In conjunction with this test, norm data collection and validation should be performed, and should be followed by, an intensive period of sampling and auditing data by knowledgeable personnel to detect and resolve discrepancies that are transparent to personnel at the activity level. An appropriate billing margin must be established, consistent with the level of confidence in the norm to predict requirements.

d. Training for all personnel who will be involved with the system operation should be thorough and should be provided well in advance of system implementation (i.e., in sufficient time for personnel to acquire an in-depth understanding of the data collection and validation process).

e. It is necessary to have contingency plans for providing adequate backup, both for personnel and equipment, to ensure uninterrupted and efficient system operations.

f. Measuring consumption with master/slave meter networks, as performed during operation of the test system, presented significant operational problems and is considered infeasible on a large scale. A worst-case situation, encountered at PWC Great Lakes, is depicted in Figure 3-1. If all six housing units were vacated and reoccupied in a single billing period, the number of meters to read would be (the 26 meters in the network) X (6 move-out readings + 6 move-in readings) = 312 readings. Assuming an error rate of 5 percent on any meter reading, the probability of successfully reading the entire network would be $(0.95)^{26} = 0.264$ or only about once in four attempts. Therefore, from both a programming as well as an administrative standpoint, this method should not be utilized.

g. The billing system should provide a net bill for each household based on total energy consumption when multiple energy sources are involved. That is, if consumption of electricity exceeds the norm by $10 and consumption of gas is $5 below the norm level, an excess consumption billing system should assess the household a net bill of $5, rather than assessing the full $10 electricity average. Otherwise, occupants of multiple-source housing units would suffer unique and inequitable financial penalties compared to occupants of

MASTER/SLAVE NETWORK — WORST CASE

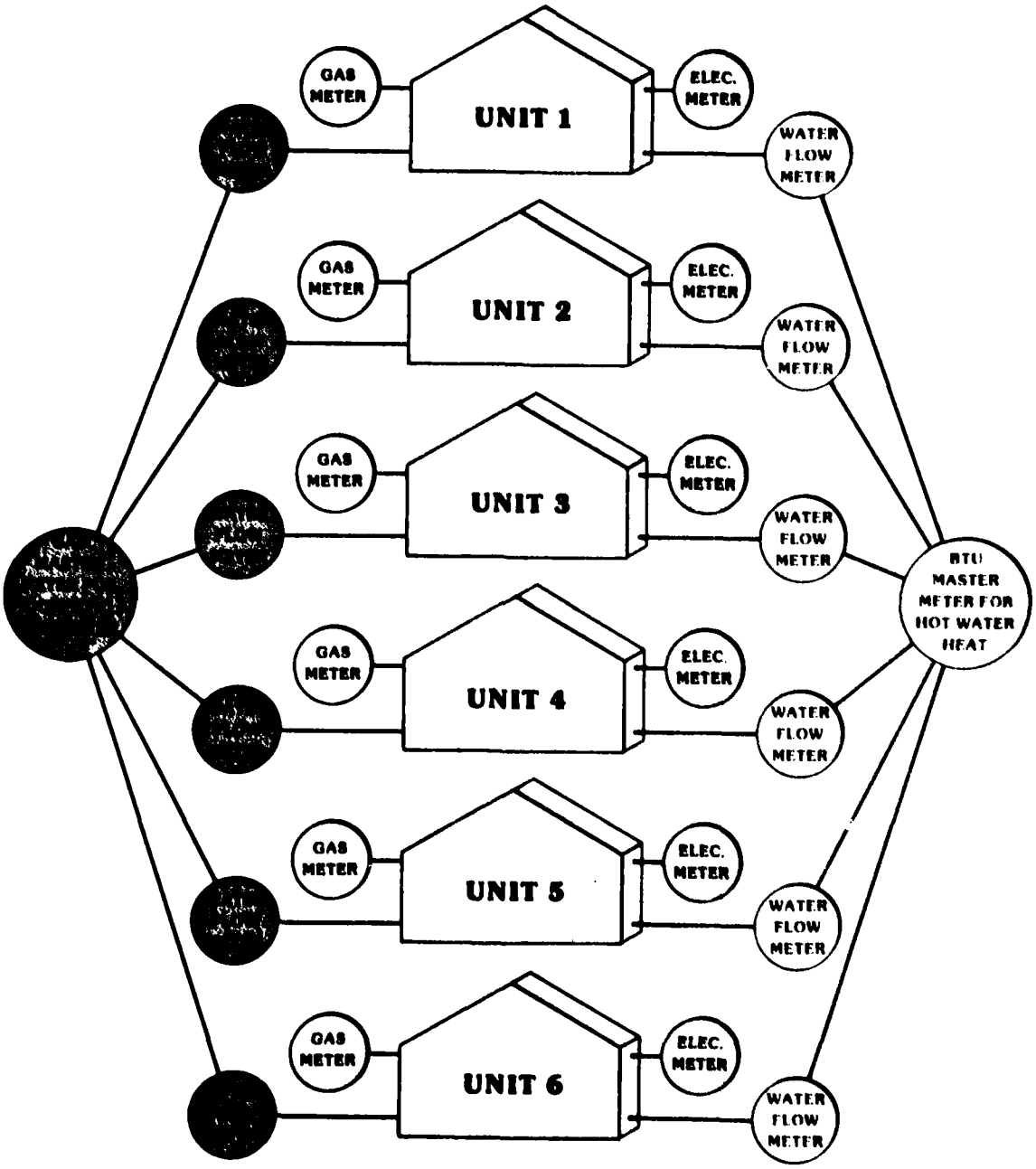


FIGURE 3-1

single-source (all electric) units where sacrifices in lighting and appliance usage would permit raising the room temperature a degree or two without exceeding the total norm.

2. Alternatives. As was the case with the test system, two alternatives for implementation--a manual billing system and billing by commercial utility companies--were eliminated from the outset. A manual billing system was ruled out because of the complexity of the norm calculations and the problems of collecting detail level information for summary reporting in a timely manner. The formula to calculate one norm for one housing unit for a 30-day billing period involves 21 calculations and 289 pieces of data. This latter figure increases if the billing period is extended, or if there is more than one utility at a housing unit. In any case, manual calculations of this magnitude are considered infeasible. As for the reporting requirements, it is anticipated that intensive data analysis will be required during the initial years of system implementation in order to show the effects of metering. Effective data collection and analysis on such a large scale would be virtually impossible without automated support.

Billing by commercial utility companies was not considered a feasible alternative for two reasons. First, hundreds of utility companies would be involved because most housing units have at least two sources of energy, for example, electricity and gas. Tremendous modifications on a large scale would be required to incorporate the norm concept into all the existing billing systems, and it is doubtful that any utility companies would agree to make the changes and assume responsibility for the metering. Additionally, it is assumed that the Federal Government would desire to retain some degree of management control, and the logistics of retaining any control over such a widespread private enterprise would be prohibitive. Secondly, it is anticipated that extensive, costly upgrading of utility distribution systems for housing units would be required to meet a variety of state and local standards before utility companies would accept maintenance responsibility.

Two potentially feasible alternatives for full-scale system implementation did surface, however, as a combined result of the test system and research effort. Each of these alternatives will be discussed in terms of the following criteria:

- Cost. Cost is defined as the 8-year system life cost of the computer system developed using SECNAVINST 5236.1A Specification Selection, and Acquisition of Automatic Data Processing Equipment as a guideline.

- Responsiveness. Responsiveness is defined as the speed with which data adjustments can be made and data transmitted to and from the computer site.

- Reliability. Reliability is defined as the ability of the system to function without failure and the amount of credence that can be placed in the results.

- Implementation Time. Implementation time is defined as the time to ready the system for a production environment.

- System Flexibility. System flexibility is defined as the ability of the hardware and software to process greater volumes of data as needed and for the software to be modified as required.

In reviewing these alternatives it should be noted that:

- All supporting detail data for quoted costs is provided in Appendix I.

- All costs (with the exception of the minicomputer purchase costs which are given in 1979 dollars) are based on constant 1978 dollars.

- All costs were computed based on the best information available in mid-1979 and could vary significantly if any aspect of an alternative is changed.

- All costs should be reevaluated prior to the final decision making process as a result of the rapid changes in the field of ADP technology.

In addition, each alternative is discussed in terms of two stages, implementation and operation.

a. Alternative 1. This alternative is an interactive, minicomputer approach. (The interactive mode bypasses punched cards, tapes, or disks; information is immediately transmitted to a computer via a terminal, the data is edited, and the results sent back to a screen on the terminal.)

A procurement of computer hardware by each service would provide a family of compatible minicomputers which would be placed at the approximately 168 activities which have 500 or more housing units. These sites would share their resources with the approximately 235 activities that have less than 500 accounts. The communications method between the activities (mail service or telephone lines) would depend on the number of accounts at the site and the geographical location. For the purposes of costing this alternative, a Digital Equipment

Corporation PDP 11/23 minicomputer was assumed to be the minicomputer that was purchased. The PDP 11/23 was chosen as representative of a class of small business computers. It was felt to be an acceptable choice based upon central processing unit capacity, peripherals, and operating system software.

The software for the minicomputers and all system operating procedures would be developed by each branch of service according to its unique requirements.

In addition to the network of minicomputers, each service would purchase computer time at a Government data processing time-sharing facility for the purpose of producing its management reports. It was assumed that one service would accept responsibility for all services in compiling the higher level reports required by OSD and Congress.

(1) Implementation.

(a) Management Requirements. Each service would need one project manager (GS-14) and one assistant project manager (GS-13) to control and coordinate the implementation process and one contract specialist (GS-13) to supervise contracting procedures. In addition, two systems analysts (GS-12) would be required to guide and monitor system design and programming. All these personnel would work at the Headquarters level.

(b) Minicomputer Acquisition. The minicomputer purchase could be phased. Each service would need one at the outset for software development, and the acquisition of the remainder could be scheduled to coincide with the readiness of an activity to begin collecting data and loading files.

(c) Software Development. The development of new software would be more economical than purchasing and modifying a commercial software package. (See Appendix I, Table 4, page 14.) Two contractor analysts and four programmers would be required by each service to support the software development effort. In addition, each service would contract for a technical writer to work with the software development staff to ensure proper system documentation.

(d) User Training. A large part of the control of, and responsibility for, the system will be at the activity level. For this reason, the references and training materials developed and the user training should be thorough. Each service would use the services of the technical writer to prepare the reference and training materials and additionally contract for three instructors to give the training.

Approximately 800 users would be trained (see Appendix I, Table 7, page 28). Assuming that users would be exposed to

both classroom lectures and computer processing labs for practice sessions, two groups of students could be trained concurrently. One instructor could give the lecture sessions, while two would be needed to assist students in the practice sessions.

(e) Data Collection. At the activity level the implementation process would begin with personnel completing initial data load forms. Each service would award one or more contracts for data transcription services and the activities would mail the data load forms to their respective data transcription facility. The data would be transcribed to tape and the tapes would be returned to the appropriate activity for processing through the minicomputer.

(f) Mock billing. After the initial data is loaded at an activity, mock billing will begin at that activity. This procedure will allow a period for debugging the system before doing any live billing.

(g) Implementation Schedule. As shown in Table 3-7 this alternative would require 50 months to implement before mock bills could be generated. It must be noted that month 1 of the 50 months does not begin until all requirements have been fully defined and management personnel are on board and fully indoctrinated.

(h) Implementation Costs. It is estimated to cost $20,461,000 to implement this alternative. Table 3-8 presents a breakout of the implementation costs.

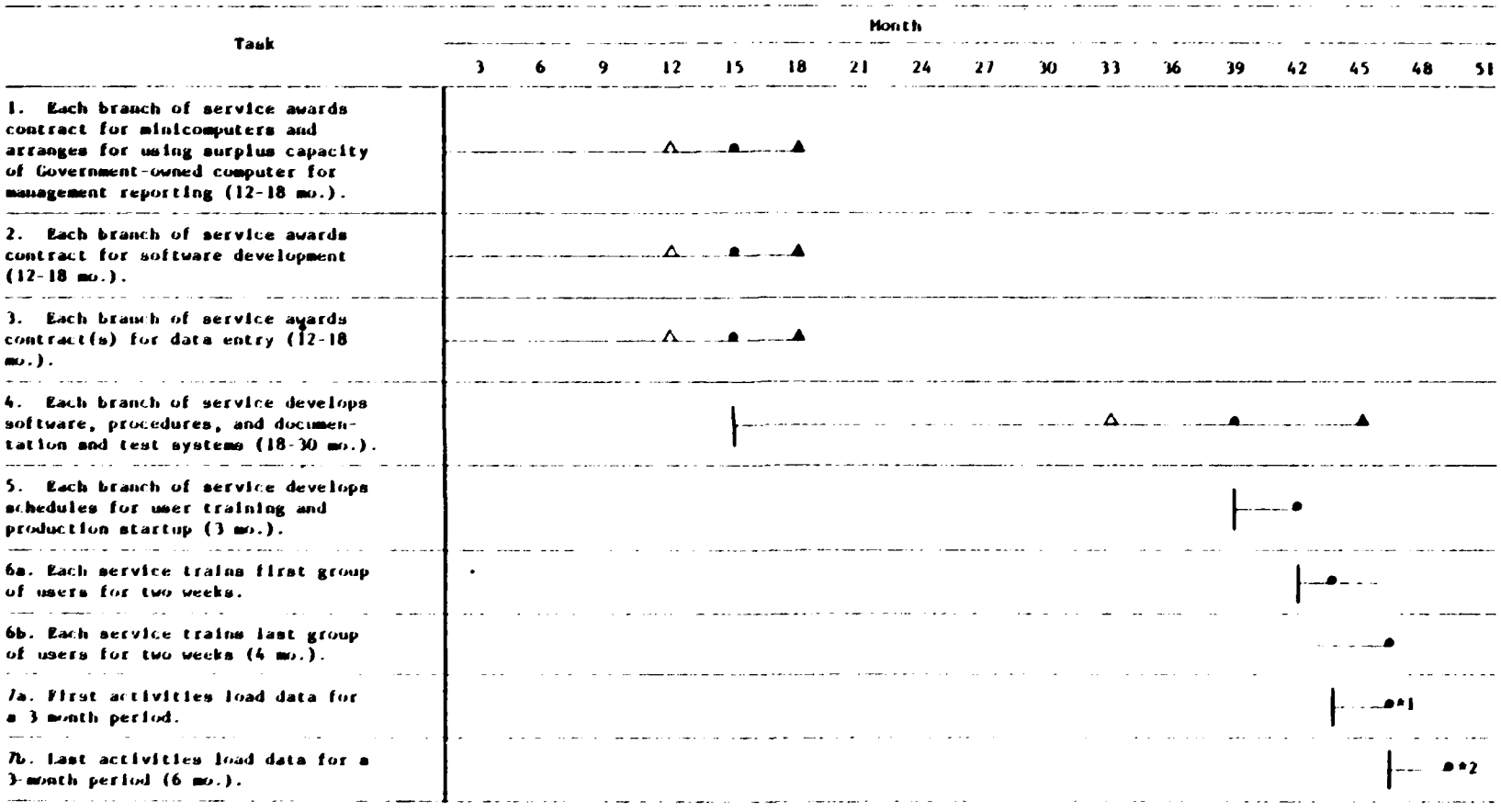
(2) Production.

(a) Management Requirements. The management support could be reduced from that of the implementation stage to one project manager (GS-14) and two systems analysts (GS-12).

(b) System Maintenance. It would be necessary to maintain an adequate maintenance capability as requirements would be undertaken and system requirements would change. One contractor analyst and one programmer would be retained by each service to make software modifications based on direction provided by the management staff.

(c) Data Collection. Personnel at the activities would be responsible for updating files. Each activity would determine its own billing schedule. Billing registers could be transmitted to the appropriate accounting office in a machine-readable format and the accounting office could provide receipt data to the billing system in a similar manner. Data for management reporting would be transmitted in a machine readable format to the larger computer site for processing.

Table 3-7
Minicomputer Alternative Implementation Schedule



Legend: ● - expected completion time △ - minimum completion time ▲ - maximum completion time

*1 - first activities begin mock billing. *2 - last activities begin mock billing.

Table 3-8
Minicomputer Alternative Implementation Costs*
(Thousands of dollars)

		Skill Level	Length	Cost
Management Staff:				
Projected managers	(3)	GS-14	50 mos.	675
Assistant project managers	(3)	GS-13	50 mos.	571
Contract specialists	(3)	GS-13	15 mos.	171
Systems analysts	(6)	GS-12	50 mos.	960
			Subtotal	2,377
Hardware:				
Minicomputer acquisition				8,653
Maintenance of computers (34 mos.)				1,598
			Subtotal	10,251
Software:				
Development:				
Programmer/analysts	(6)	Contract	24 mos.	998
Programmers	(12)	Contract	24 mos.	1,696
Technical writers	(3)	Contract	24 mos.	349
Computer supplies			24 mos.	29
			Subtotal	3,072
Maintenance:				
Programmer/analysts	(3)	Contract	10 mos.	208
Programmers	(6)	Contract	10 mos.	354
Computer supplies			10 mos.	12
			Subtotal	574
User Training:				
Instructors	(9)	Contract	7 mos.	306
Technical writers	(3)	Contract	3 mos.	44
Users (2 wk. each)	(800)	GS-05	4 mos.	542
Travel				576
Typing and graphics				20
			Subtotal	1,488
Data Load:				
Data entry		Contract	6 mos.	487
Implementation forms				47
Computer support			6 mos.	66
			Subtotal	600
Mock Billing:				
Forms				49
Computer support				9
			Subtotal	58
Miscellaneous:				
Space and facilities				1,922
Mail				120
			Subtotal	2,042
	Total implementation cost			20,461

*These costs are explained in greater detail in Appendix I, page 27, paragraph 7.

Table 3-9
Minicomputer Alternative Production Costs*
(Thousands of dollars)

		Skill Level	Cost
Management Staff:			
Project managers	(3)	GS-14	$ 162
Programmer/analyst	(6)	GS-12	230
		Total	392
System Maintenance:			
Programmer/analysts	(3)	Contract	250
Programmers	(6)	Contract	424
Computer supplies			14
		Subtotal	688
Billing:			
Equipment maintenance			564
Forms			296
Central reporting costs			28
		Subtotal	888
Miscellaneous:			
Space and facilities			643
Mail			573
		Subtotal	1,216
Total 1-year production cost:			$3,184

*These costs are explained in greater detail in Appendix I, page 29, paragraph 8.

(d) Production Costs. It is estimated to cost $3,184,000 for 1 year of production. Table 3-9 presents a breakout of the 1-year production costs.

(3) Discussion. The interactive minicomputer alternative would present a system that is responsive, has a high data reliability, is flexible, and secure. The disadvantages to this alternative are a long implementation schedule and the problem of effecting software modifications at so many sites. The 8-year system life cost of this alternative (in 1978 dollars) would be approximately $38,291,000 or $124.00 per each of the 310,000 housing units. Table 3-10 depicts a breakout of this total.

This system would be very responsive to user needs. Data adjustments to files can be effected quickly and easily and

Table 3-10
Minicomputer Alternative System Life Cost
(in 1978 dollars, in thousands)

Year	Cost	Discount Factor	Net Present Value
0 (Implementation)	20,461	1.00	20,461
1 (Production)	3,184	.95	3,025
2	3,184	.87	2,770
3	3,184	.79	2,515
4	3,184	.72	2,292
5	3,184	.65	2,070
6	3,184	.59	1,879
7	3,184	.54	1,719
8	3,184	.49	1,560
Total	45,933	-	38,291

information can be transmitted rapidly to and from the computer. The ability to query the files and receive information back in a matter of minutes means that customer and user questions can be answered quickly and problems resolved in the minimum of time. Because of the high degree of system responsiveness, the information kept in the files would be very current and accurate. As a result, management reports would reflect highly accurate information. Good system responsiveness and high data reliability would result in user and customer credence in, and acceptance of, the system and the data it generates.

This alternative provides a great amount of flexibility. If the volume of housing units at an activity is substantially altered, the minicomputer hardware configurations can be installed (or removed) with relative ease. Additionally, if a minicomputer is not being used to capacity by the billing system, it may be used to support other applications at the activity.

Installing minicomputers with the appropriate level of physical security (e.g., in rooms where access is limited and controlled) and with appropriate degrees of software security (e.g., passwords) will help ensure a reputable and reliable system. The control of security for the system will be facilitated in this kind of environment.

The two disadvantages of this alternative are not considered significant enough to offset what are viewed as the substantial advantages. The 50-month implementation schedule, while 10 months longer than that of alternative 2 (discussed in the next section) is not long enough to render this approach infeasible. Also, the implementation time could be reduced by as much as 6 months to 1 year if exemptions could be granted by

Congress which would permit a shortcut in the contract award process.

The problem of maintaining the software at so many test sites is not insurmountable. Stringent administrative and audit procedures would have to be instituted. If such procedures are enforced responsibly, system integrity and reliability will be maintained.

In summary, this alternative offers the lowest cost approach for a very responsive and reliable system.

b. Alternative 2. This alternative is oriented to time sharing on three government computers using software that is a modified version of the FHMUBS software. There would be one processing site for the Navy and Marine Corps, one for Army, and one for Air Force. Remote job entry (RJE) stations would be placed at activities that have 500 or more housing units. These 168 activities would communicate with the appropriate processing site using telecommunications facilities and would share their data processing facilities with the 235 activities that had less than 500 housing units. It was again assumed, as with alternative 1, that one service would accept responsibility for all the services in compiling the higher level reports required by OSD and Congress.

Computer programs and operating procedures would be built upon the test billing system (FHMUBS) but each service would modify the software to satisfy its unique requirements.

(1) Implementation.

(a) Management Requirements. Each service would need one project manager (GS-14) and one assistant project manager (GS-13) to control and coordinate the implementation process, and one contract specialist (GS-13) to supervise contracting procedures. In addition, two systems analysts (GS-12) would be needed to guide and monitor detailed system design and programming. All these personnel would work at the Headquarters level.

(b) Hardware Acquisition. The purchase of the RJE equipment could be phased. Each service would require one at the outset for software modification and the acquisition of the remainder could be scheduled to coincide with the readiness of an activity to begin collecting data and loading files.

(c) Software Modification. The services of two contractor analysts and four programmers would be required by each Service to modify and ready the FHMUBS software for full-scale production. In addition, each service would contract for a technical writer to work with the ADP staff to ensure proper system documentation.

(d) User Training. Each service would use the services of a technical writer to prepare the reference and training materials, and additionally contract for three instructors to give the training. Approximately 800 users would be trained (see Appendix I, page 34). Assuming that users would be exposed to both classroom lectures and computer processing labs for practice sessions, two groups of students could be trained concurrently. (The format and schedule for user training for this alternative is identical to that of alternative 1.)

(e) Data Collection. Personnel at the activities would fill out initial data load forms. Each service would award one or more contracts for data transcription service to be performed at the activity level. The keyed output would then be transmitted by RJE equipment to the appropriate processing site, and error reports would be sent back to the activities for resolution.

(f) Mock Billing. After the initial data is loaded at an activity, mock billing will begin at that activity. This will allow time for debugging the system before any live billing is done.

(g) Implementation Schedule. As shown in Table 3-11 this alternative would require 40 months to implement. Again, as with alternative 1, it must be noted that month 1 of the 40 months does not begin until all requirements have been fully defined and management personnel are on board and fully indoctrinated.

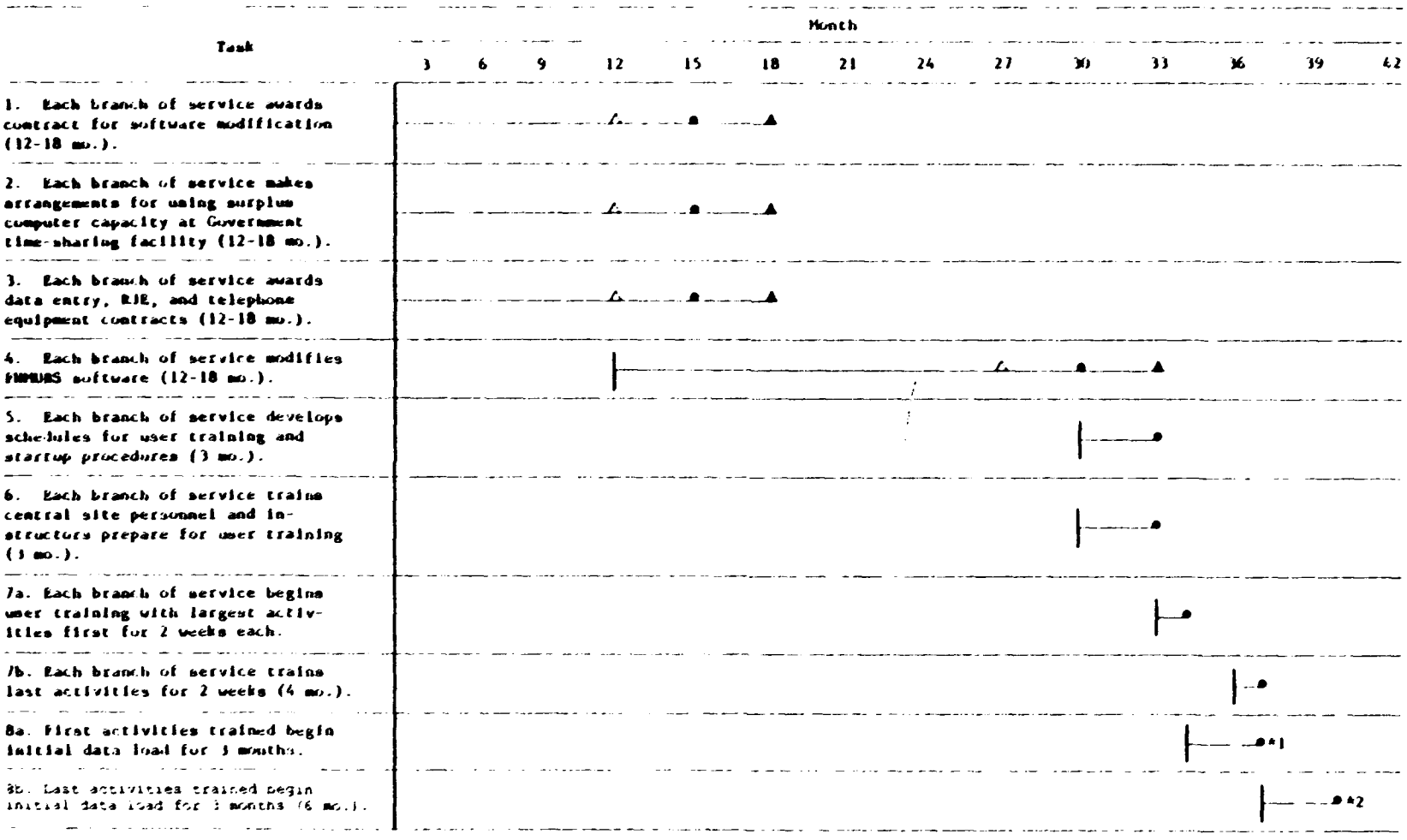
(h) Implementation Costs. It is estimated to cost $19,757,000 to implement this alternative. Table 3-12 presents a breakout of the implementation costs.

(2) Production.

(a) Management Requirements. The management support level could be reduced from that of the implementation stage to one project manager (GS-14) and one systems analyst (GS-12). (One less systems analyst (GS-12) is proposed with this alternative than alternative 1 because the software is maintained at one processing site (per service) and the analysis effort would not be as detailed as that required for the diffused minicomputer approach.)

(b) System Maintenance. As with alternative 1, it would be necessary to maintain an adequate maintenance capability. One contractor systems analyst and two programmers would be retained by each service to make software modifications based on direction provided by the Headquarters management staff.

Table 3-11
Multiple Mainframes--RJE Alternative Implementation Schedule



Legend: △ - expected completion time ● - minimum completion time ▲ - maximum completion time

*1 - first activities begin mock billing. *2 - last activities begin mock billing.

Table 3-12
Multiple Mainframes---RJE Alternative Implementation Costs*
(Thousands of dollars)

		Skill Level	Length	Cost
Management Staff:				
Projected managers	(3)	GS-14	40 mos.	540
Assistant project managers	(3)	GS-13	40 mos.	457
Contract specialists	(3)	GS-13	40 mos.	457
Systems analysts	(6)	GS-12	40 mos.	768
			Subtotal	2,222
Hardware:				
RJE acquisition				9,396
Maintenance of RJEs			25 mos.	1,892
			Subtotal	11,288
Software:				
Development:				
Programmer/analysts	(6)	Contract	15 mos.	624
Programmers	(12)	Contract	15 mos.	1,061
Technical writers	(3)	Contract	15 mos.	218
Computer support (including supplies)			15 mos.	167
			Subtotal	2,070
Maintenance:				
Programmer/analysts	(3)	Contract	10 mos.	208
Programmers	(6)	Contract	10 mos.	354
Computer support (including supplies)			10 mos.	111
			Subtotal	673
User Training:				
Instructors	(9)	Contract	7 mos.	306
Technical writers	(3)	Contract	3 mos.	44
Users (2 wk. each)	(800)	GS-05	4 mos.	542
Travel				576
Typing and graphics				20
			Subtotal	1,488
Data Load:				
Data entry		Contract	6 mos.	487
Implementation forms				47
Computer support			6 mos.	77
			Subtotal	611
Mock Billing:				
Data entry		Contract	4 mos.	239
Forms				51
Telephone and telecommunications				212
Computer support			4 mos.	30
			Subtotal	532
Miscellaneous:				
Sapce and facilities				753
Mail				120
			Subtotal	873
	Total implementation cost			19,757

*These costs are explained in greater detail in Appendix I, page 34, paragraph 7.

(c) Data Collection. Personnel at the activity level would be responsible for updating files. Data collected would be transcribed into machine-readable format by contractors at the activity level. The keyed data would then be transmitted via RJE to the appropriate processing site. A 2- to 24-hour turnaround time could be expected.

Because of the large number of activities which would be competing for access to the computer site, a data transmission schedule would have to be established by some central authority. Activities would be required to conform to this schedule to ensure a reasonable and steady flow of work and data through the computer processing center. While activities could still establish their own billing schedules, the timing of the billing cycles would probably coincide with the heaviest access schedule.

Billing registers could be transmitted to the appropriate accounting office in a machine readable format and the accounting office could provide receipt data to the billing system in a similar form. Data for higher level management reports would be transmitted in a machine readable format to one of the computer sites for processing.

(d) Production Costs. It is estimated to cost approximately $6,194,000 for 1 year of production. Table 3-13 presents a breakout of the 1-year production costs.

(3) Discussion.

This alternative would present a system that is fairly responsive to user needs, has good data reliability, and is relatively flexible. The disadvantages to this alternative are the problem of security and the high yearly production cost. The 8-year system life cost of this alternative (in 1978 dollars) would be approximately $54,482,000 or $176 per each of the 310,000 housing units. Table 3-14 depicts a breakout of this total.

The main differences in cost between alternative 1 ($124 per housing unit) and alternative 2 ($176 per housing unit) is found primarily in the production costs and is a result of the cost of the telecommunications lines and the data transcription support associated with alternative 2.

This system, while fairly responsive, would not be as responsive to user needs as alternative 1. Fast turnaround is a feature of this system once access to the computer site has been granted, but access would be according to a centrally decreed schedule and customer and user questions that were dependent on file query could only be resolved on a scheduled basis. Access schedules would be frequent, however, and the data maintained on file would be relatively current and accurate. Again, while not as responsive as alternative 1,

Table 3-13
Multiple Mainframes--Alternative Production Costs*
(Thousands of dollars)

		Skill Level	Cost
Management Staff:			
Project leaders	(3)	GS-14	$ 162
Systems analyst	(6)	GS-12	230
		Total	392
System Maintenance:			
Systems analysts	(3)	Contract	250
Programmers	(6)	Contract	424
Computer support			133
		Subtotal	807
Billing:			
Data entry			1,434
Forms			306
RJE maintenance			908
Phone and communications			1,270
Computer support			177
		Subtotal	4,095
Miscellaneous:			
Space and facilities			330
Mail			577
		Subtotal	907
Total 1-year production cost:			$6,201

*These costs are explained in greater detail in Appendix I, page 36, paragraph 9.

this approach should result in user and customer credence in, and acceptance of, the system and the data it generates.

This alternative provides an acceptable level of flexibility in that the RJE's can be installed (or removed) with relative ease if the volume of housing units at an activity is substantially altered. The problem is that even a small amount of computer downtime at a processing site can limit all access and affect previously established schedules.

The problem of software maintenance associated with alternative 1 does not exist with this approach. The software is maintained at one site (per service) and modifications and control are easily effected.

Table 3-14
Multiple Mainframes--RJE Alternative System Life Cost
(in 1978 dollars in thousands)

Year	Cost	Discount Factor	Net Present Value
0	$19,757	1.00	$19,757
1	6,201	.95	5,891
2	6,201	.87	5,395
3	6,201	.79	4,898
4	6,201	.72	4,465
5	6,201	.65	4,031
6	6,201	.59	3,658
7	6,201	.54	3,349
8	6,201	.49	3,038
Total	$69,365		$54,482

There are security problems with remote job entry terminals. Because of their physical size and nature, security is normally more lax with RJE terminals than with interactive terminals. The RJE is usually comprised of a number of separate devices such as a card reader/punch, printer, disk or tape handler, console keyboard, and display (printing or CRT), communications modem, and CPU. Many of these require their own separate floorspace and are therefore grouped together in a separate enclosure or room usually remotely located to minimize the noise factor. Security normally consists of just locking the door. Most RJE devices do not have individual locks. System security is obtained by controlling physical access or provided by the host computer. As the identity of the remote terminal operator cannot be adequately confirmed by the host computer, some degree of security can be imposed by controlling the dissemination of program and file names and the use of specific passwords for invoking their use. However, in larger host installations programs and files are usually named in accordance with some standard pattern or convention which can be discerned with little exposure and breached with sufficient effort. Although passwords are significantly superior, they are infrequently employed on a routine basis because of the additional system overhead in continually validating them with each use.

In summary, while this is considered a feasible approach, it is very costly and not as responsive and reliable as the minicomputer alternative.

E. Billing System Implementation.

If billing for excess energy consumption is to be executed, several significant requirements for personnel and annual funding support will be created. In addition to the procurement and installation of ADP equipment, and preparation of software, personnel will be required to read meters and record and enter consumption data, as well as collect and account for penalty funds. Information has been sought from various public utility companies to serve as a basis for estimating these requirements; however, conditions are not exactly analagous because of differences in the basic concept of the billing procedure, in norm with penalty vice full consumption billing. Actually, the proposed norm and data accuracy, since the system is not self-correcting on a month to month basis as is a public utility bill where a high reading one month will result in a low apparent consumption the following month.

1. Meter reading and data entry. The dual purposes of the metering program would be provision of consumption feedback to all occupants and assessment of penalties for over-consumption to excessive users. Frequency of feedback in both forms is important for behavior modification. Although many utility companies estimate consumption some months, actually reading meters less frequently, this will not be possible with the norm system. Therefore while the costs of meter reading incurred by the public utilities are of interest, they are not directly applicable in this case.

Each DoD activity with family housing must make provision for meter reading and data input on a near monthly basis, with ability to make interim readings in case of occupant changes or complaints regarding a bill. At very small activities this will be a part-time job, and at large activities, more than one reader will be required. For the 424 DoD activities with housing, there will be a requirement for 487 new civilian positions of GS-5 or GS-7 Meter Readers, using the criteria as follows:

Units per activity	GS-7	GS-5	Total
0 - 50	0	0	0*
51 - 500	1	0	1
501 - 2000	2	0	2
2000 - 4000	2	1	3
6000 +	2	2	4

The cost of this effort at FY 1980 pay levels is estimated at $8,107,656 and may be projected to approximately $13,000,000 for FY 1987.

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*Perform on part-time basis, existing personnel.

2. Penalty collection and accounting. The cost of collecting and accounting for penalty funds would be to a great extent dependent upon the number of occupants receiving bills for excess consumption; however, all DoD activities must develop the capability to handle this task. It is not possible to estimate accurately the incidence of penalty bills, but based on test data, a figure of 15 percent has been assumed for purposes of estimating requirements in this area. This function could be expected to vary significantly seasonally and possibly decrease over time as more occupants bring their consumption within the norm.

The usual procedure for payment would be by personal delivery or mailing of the record copy of the bill together with payment to the designated receiver. Personnel would have to be bonded to handle cash as well as checks, and qualified to second payments received into designated accounting systems.

In view of experience of public utility companies, about 15 percent of accounts payable can be expected to become overdue prior to payment, and a much smaller percent, about 3 percent may for one reason or another fail to pay. Procedures must be established to pursue appropriate administrative actions in these cases, because nonpayers are likely to also be major energy over-consumers. At present there is considerable variation among the services of means available to recover damages or funds due from housing occupants. It is considered desirable that pay checkage be available as a last ditch stop in collecting overdue penalties.

The expected incidence of penalty bills is fairly small (15 percent), and in most cases, the total number of housing accounts will be very small in comparison with public utilities, who use highly sophisticated collection-recording equipment. To estimate collection and accounting costs, a factor of 1/4 man-hour per bill received has been assumed. This has yielded an estimate of $1,118,000 for 1987; however, this estimate is known to be quite rough, especially in view of the part-time nature of the task at all but the largest activities.

VI. Summary and Conclusions.

This chapter addresses the development, implementation, and operation of the automated test billing system and reviews various alternatives for full-scale implementation of a utility billing system for all military family housing units in the U.S., Guam, and Puerto Rico.

The automated test system was developed and implemented at a cost of $840,814. Various constraints determined the course of systems development and implementation. The time allotted by Congress for both functions was insufficient and resulted in the selection of the most expedient, and not necessarily the best, means to the end. The complexity of the norm calculations and the unique metering complications eliminated unsophisticated solutions to the billing requirements. The ADP investigation effort was hampered by the limited number of on-board personnel who could be assigned full time to the task. A final constraint was the necessity of having a central control point to collect and process data for management reports, to ensure that established conventions were followed, and to provide to the system users a contact point for assistance and guidance.

The Family Housing Mock Utility Billing System was developed by contractor systems analysts and programmers, was processed on a large computer, and each of the test activities accessed the computer using a remote job entry (RJE) terminal. The utility billing system was designed to receive unit consumption data for all utilities involved in the test, to calculate a norm for each utility at a housing unit, to generate a monthly mock utility bill for each housing unit regardless of whether a balance was due, to produce statistical reports providing detail and summary level data on energy consumption, and to generate monthly, quarterly, and annual reports for each activity and for all activities combined.

The FHMUBS was scheduled to begin producing mock bills on 1 October 1978. The system began operations on 1 September 1978, but at that time only two activities were able to submit base meter readings, from which the first bills would be generated. The slippage in meeting the implementation schedule was due to initial slippage in meter and RJE installation. On 18 October, bills were generated for the first two activities. Other activities were able to generate bills for most of their accounts in the following two billing cycles on 2 and 17 November. The first 3 months of system operation resulted in incomplete and largely incorrect results because of data errors and inconsistencies in the system software where consumption was not being calculated correctly. As a result of these problems, OSD requested that the test program termination date be moved from 30 September to 31 December 1979.

System operations did not continue on schedule in FY 1979 because of a variety of data errors and processing problems. However, as a result of developing a very good reprocessing capability, the estimated validity of data reached 90 percent.

One of the goals of the Defense Family Housing Metering Program test was to determine the feasiblity of billing the occupants of military family housing for consumption in excess of a calculated norm. The test billing system established the feasibility of doing so on a small scale. However, the NAVFACENGCOM decided that additional reasearch was required to fully substantiate the feasibility on a much larger scale. As a result, additional contract personnel were hired and a study was initiated, concurrent with the operation of the test system, to investigate the feasibility of implementing a utility billing system for all military family housing units in the U.S., Guam, and Puerto Rico. This study confirmed the feasibility of full-scale implementation; however, it also proposed that the DoD-wide billing system would differ significantly from the test system for the following reasons:

1. There are several additional requirements which would have to be satisfied to effect the transition from "mock" to actual billing. For example, in order to maintain financial accountability the billing system would have to interface with existing accounts receivable systems.

2. The lessons learned during the test phase provided insight into improved methods for system development, implementation, and operations. However, this experience also surfaced problems (explained in paragraph D.1 of this chapter), which would be compounded if a system identical to the one used during the test was selected for full-scale implementation.

3. The increase in the number of housing units from 10,000 to 310,000, with the accompanying geographic dispersion, could dictate local or regional (i.e., distributed) versus central processing.

The method selected for full-scale development and implementation of the utility billing system for military family housing will depend upon two primary factors: first, the requirements of the system as they are ultimately defined, and second, the decisions made by each service during the system development process. For example, a requirement to resolve erroneous bills within 15 days could dictate a need for a small system configuration located at each activity, and a decision that surplus hardware was available could result in the use of existing equipment rather than a new purchase.

This section discusses some important lessons learned which should be considered in any future decisionmaking regarding the billing system and also describes alternatives that were investigated as possible methods for billing system implementation.

1. Lessons Learned. Much experience was gained by the conditions and problems encountered during the test period. Some of this experience is merely of interest, some pertains to limited functional areas, and some is of sufficient importance to warrant detailed attention in any future decisionmaking sessions. The experience that merits very careful consideration is discussed in the following paragraphs.

a. The billing system must be very responsive by providing for data adjustments with ease and for the rapid transmission of information to and from the computer.

b. The billing system development and implementation schedules should be realistic and permit decisionmaking that is based on a thorough evaluation of all alternatives.

c. The system software should be thoroughly tested and validated at all activites for a minimum of 1 year with live data before the system becomes operational. This is considered necessary to ensure the accuracy of all aspects of the software and most importantly to validate the consumption and norm data that is calculated. In conjunction with this test, norm data collection and validation should be performed and followed up by an intensive period of sampling and auditing by knowledgeable personnel to detect and resolve discrepancies that are transparent to personnel at the activity level.

d. Training for all personnel who will be involved with the system operation should be thorough and should be provided well in advance of system implementation.

e. It is necessary to have contingency plans for providing adequate backup for personnel and equipment to ensure uninterrupted and efficient system operations.

2. Alternatives for Full Scale Implementation. As was the case with the test system, two alternatives for implementation--a manual billing system and billing by commercial utility companies--were eliminated from the outset. A manual billing system was ruled out because of the complexity of the norm calculations and the problems of collecting detail level information for summary reporting in a timely manner.

Billing by commercial utility companies was not considered a feasible alternative for two reasons. First, hundreds of utility companies would be involved because most housing units have at least two sources of energy, for example, electricity and gas. Tremendous modifications on a large scale would be

required to incorporate the norm concept into all the existing billing systems, and it is doubtful that any utility companies would agree to make the changes and assume responsibility for the metering. Additionally, it is assumed that the Federal Government would desire to retain some degree of management control, and the logistics of retaining any control over such a widespread, private enterprise would be prohibitive. It is also anticipated that extensive, costly upgrading of utility distribution systems for housing units would be required to meet a variety of State and local standards before utility companies would accept maintenance responsibility.

Two potentially feasible alternatives for a full-scale system implementation did surface, however, as a combined result of the test system and research effort.

Alternative 1 is an interactive minicomputer approach. This would present a system that is responsive, has a high data reliability, is flexible, and secure. The disadvantages to this alternative are a long implementation schedule and the problem of effecting software modifications at so many sites. The 8-year system life cost of this alternative (using 1978 dollars) would be approximately $38,291,000 or $124.00 per each of the 310,000 housing units.

This system would be very responsive to user needs. Data adjustments to files can be effected quickly and easily and information can be transmitted rapidly to and from the computer. The ability to query the files and receive information back in a matter of minutes means that customer and user questions can be answered quickly and problems resolved in minimum time. Because of the high degree of system responsiveness, the information kept in the files would be very current and accurate. As a result, management reports would reflect highly accurate information. Good system responsiveness and high data reliability would result in user and customer credence in, and acceptance of, the system and the data it generates.

This alternative provides a great amount of flexibility. If the volume of housing units at an activity is substantially altered, the minicomputer hardware configurations can be installed (or removed) with relative ease. Additionally, if a minicomputer is not being utilized to capacity by the billing system, it would be possible to use it to support other applications at the activity.

Installing minicomputers with the appropriate level of physical security (e.g., in rooms where access is limited and controlled) and with appropriate degrees of software security (e.g., passwords) will help ensure a reputable and reliable system. The control of security for the system will be facilitated in this kind of environment.

The two disadvantages of this alternative are not considered significant enough to offset what are viewed as the substantial advantages. The 50-month implementation schedule, while 10 months longer that alternative 2, is not long enough to render this approach infeasible. Also, the implementation time could be reduced by as much as 6 months to 1 year if exemptions could be granted by Congress which would permit a shortcut in the contract award process.

The problem of maintaining the software at so many test sites is not insurmountable. Stringent administrative and audit procedures would have to be instituted, and, if enforced responsibly, system integrity and reliability would be maintained.

In summary, this alternative offers the lowest cost approach for a very responsive and reliable system.

Alternative 2 is oriented to time sharing on three Government computers; there would be one processing site for the Navy and Marine Corps, one for the Army, and one for Air Force.

This alternative would present a system that is fairly responsive to user needs, has good data reliability, and is relatively flexible. The disadvantages to this alternative are the problem of security and the high yearly production cost. The 8-year system life cost of this alternative (using 1978 dollars) would be approximately $54,482,000 or $176.00 per each of the 310,000 housing units.

The main difference in cost between alternative 1 ($124 per housing unit) and alternative 2 ($176 per housing unit) is found primarily in the production costs and is a result of the cost of the telecommunications lines and the data transcription support associated with alternative 2.

This system, while fairly responsive, would not be as responsive to user needs as alternative 1. Fast turnaround is a feature of this system <u>once</u> access to the computer site has been granted, but access would be according to a centrally decreed schedule, and customer and user questions that were dependent on file query could only be resolved on a scheduled basis.

This alternative provides an acceptable level of flexibility in that the RJE's can be installed (or removed) with relative ease if the volume of housing units at an activity is substantially altered. The problem is that even a small amount of computer downtime at a processing site can limit all access and affect previously established schedules.

The problem of software maintenance associated with alternative 1 does not exist with this approach. The software is maintained at one site per service where modifications and control are easily effected.

There is no doubt that an acceptable billing system could be developed for use in all military family housing areas. The exact system to be developed and implemented must be fully investigated once definitive congressional guidance has been handed down. All research to date should be reviewed in light of the guidance and of the state of the art of ADP technology at the time decisions are being made.

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Chapter 4. OCCUPANT RESPONSE

I. Introduction.

In Public Law 95-82 Congress directed the Secretary of Defense to assess a resident of military family housing for any energy consumption in excess of a reasonable ceiling. The purpose of such a direction was to stimulate energy conservation, not to reduce the cost of energy to the cognizant service department. Congress expected tenants who receive bills for overuse to act quickly to bring their consumption within the range allowed by the norm. However, such a program would affect only a small number of residents who abuse the privilege of free energy which they receive along with free housing. There are additional broader implications and possibly unforeseen consequences of the program.

The household in a military family housing unit varies widely in size and age, with the service member's dependents as the primary consumers of energy. Although cost is not now a direct factor, utility consumption is determined by a number of personal factors common to both military and civilian populations, such as the following:

- Lifestyle (e.g., activities, appliances, number of hours the house is occupied each day, occupants on shift work)
- Past experiences (e.g., paying utilities, accommodation to similar or different climate)
- Attitudes and perceptions (e.g., reality of the energy crisis, concern regarding their children's future, feelings that they have control over their consumption)
- Expectations (e.g., the "contract" for military fringe benefits implied at entry into service or evolved over time)
- Motives (e.g., patriotism, thrift)
- Health and age (e.g., allergies requiring air filtration)
- Special circumstances (e.g., visitors staying in their house)

In addition, the household's energy consumption is determined by the design and construction of the unit occupied, the type of energy supplied, the type of energy-consuming equipment provided to them and how well all of these are maintained. Norms and charges for overuse would be superimposed on these factors and take some of them into account. Each family would

then consider a unique combination of factors in determining their future consumption behavior. To ensure that consumption differences relative to the norm were based solely on factors under the occupant's control, each unique size, style, and construction type of unit could be analyzed with the BLAST system, rather than by sample analyses such as those conducted during the test program.

It is very likely that the results obtained from the metering and billing program will differ from what would be expected initially. Any changes in energy consumption would require that the information regarding overuse and the consequent billing cost be large enough to cause family members to change their energy consumption practices appropriately. To make relevant changes, families must know what behavior to change and must practice the new behavior diligently.

One possible result of the program is that no energy would be conserved. Although families which are above the norm may reduce their consumption, families which have been vigorously holding their consumption down and are way under the norm may increase their usage (unless there were credit for additional savings within the norm). They would observe that because the norm reflects good conservation practice, it is, therefore, a legitimate level of use. It is common experience in industrial settings that production standards (norms) become not only the minimum accountable performance but also the maximum ever attained. Indeed, the proposed billing procedure will be the first time most housing residents have received information about how much energy they consume and what acceptable conservation levels are.

An unintended effect of the metering and billing program might be to raise the issue of how fair a new policy of charging for utility use (or overuse) is. This issue may be linked to the present concerns and perceptions over the erosion of military benefits. Because establishing norms is primarily a political rather than technical issue, it cannot represent good conservation practices perfectly. In some cases it will be liberal and in others constraining. To achieve conservation goals, the norm must be realistic, but in actuality it may have to be somewhat generous in order to allow for legitimate variations in structural, maintenance, and climate factors which cannot be perfectly accounted for. A slightly generous norm would likely arouse additional efforts to conserve, if it creates opportunity to pocket any of the monetary savings. However, the larger the proportion of tenants who find the norm seriously constraining the greater will be the negative response and limitations on possible savings. Some unintended effects which may ensue are: (1) a decrease in the occupancy levels of family housing as the economics of civilian and military housing become more equal due to utility charges; (2) resistance to the program in the form of vandalism of meters, the theft of utilities, or class action suits; and (3) a

decrease in personnel retention in military service resulting from service members' perceiving that the cost of a military career outweighs the benefits. Morale, retention, and other personnel impacts are discussed more fully in Chapter 6.

II. Military Experiences.

A. Military-Civilian Field Comparisons.

The results of comparisons between the consumption of energy in military housing and "comparable" civilian residences vary widely. Some military residents overuse utilities because they are free. Others are more conscientious. If possible, the military-civilian differences should be reconciled so that savings from the reduction of waste can be realistically evaluated.

Valid comparisons require military and civilian housing residents to be similar in a large number of factors, including (1) the climate and data-gathering period, (2) building structural characteristics (size, layout, insulation, maintenance, etc.), (3) utility applications (energy source used for space heating and cooling, water heating, cooking), (4) occupants (number, age), (5) occupant lifestyle (appliances, usage patterns), and (6) the method which the residents use to pay for their utilities.

It is extremely difficult to find identical populations to compare, but some characteristics can be corrected or adjusted to approximate comparability. In other cases effects remain indeterminate. For example, calculation of degree-days (heating or cooling) may be a basis for equating consumption data from different time periods or different geographic locations. Use of norms which consider structural, occupant, and climate factors to establish a common point of reference for differing housing units and populations is more sophisticated. Corrections are usually relatively crude, and conclusions drawn under such conditions should be considered to have a large potential margin of error.

It should also be noted that most military-civilian comparisons are on electricity consumption only. The few available civilian studies of natural gas consumption suggested that the savings to be expected from elimination of overusage of gas are considerably different from electricity.

The available military-civilian comparison studies are listed in Table 4-1 with their key characteristics and results. Only one comparison considered both gas and electric utilities; all others assessed only electricity usage. Furthermore, all comparisons but one contrasted military-utilities-included-in-rent situations with civilian-resident-paid-utilities; the exception reversed this payment situation.

Table 4-1
Relative Utility Usage of Military and Civilian Housing Residents Under Direct (Resident-Paid) or Indirect (Landlord-Paid) Payment

Study	Size of Sample(s)	Data Year(s)	Comparison Period	Utilities Compared	Type of Payment Situation[1]	Military Usage[2]	Comment
Zinder, 1957	mil. 211 civ. N/A	1955-56	2 yrs.	E	M/D vs C/I	1.09	Only compared cooking & water heating; occupants not equated.
Naval Audit Service A 61134 (1975)	mil. N/A civ. N/A	FY74 N/A	1 yr. N/A	E	M/I vs C/D	1.50	Civilian comparables may not have had air cond.
Booz, Allen & Hamilton, 1973	mil. 600/1255 civ. N/A	197.	N/A	E	M/I vs C/D	1.10 - 1.20	Assumed reduction based on qualitatively estimated difference.
Air Force Institute of Technology, 1976	mil. 58 AF, Navy & MC hsg sites survey; 31 returned. civ. 31 utilities surveyed; 13 returned.	1970 - 1975	6 yrs.	E	M/I vs C/D	1.23	Questionable comparability of samples on unit size, construction, etc.; "good" data from only 4 sites.
NWS Charleston, SC 1977-1979	N/A	FY78-FY79	21 mos.	E	M/I vs C/D	1.08	Units were all electric Matched for square footage but not occupants or appliances.
NAVFACENGCOM, 1979 (Port Hueneme, Oxnard)	mil. 200 civ. 114	1979	6 mos.	E & NG	M/I vs C/D	0.86	Comparison is to norm prediction of reasonable allowance for each kind of structure and family.
Science Applications, Inc.	mil. 20 civ. 26	1979	6 mos.	E & NG	M/I vs C/D	0.88	Comparison is to a common base of reference (norm algorithm) considering reasonable consumption for each structure and family.

[1] M/D vs C/I: Military/direct vs Civilian/indirect
M/I vs C/D: Military/indirect vs Civilian/direct

[2] Civilian = 1.00

1. Zinder & Associates*. Brandt compared military and public housing gas usage rates for cooking and water heating over a 2-year period (usually 1955 to 1956). Utilities were included in the rent in public housing, but residents were billed directly in military housing. Military housing residents were estimated to use 8.9 percent more gas annually for cooking and water heating than public housing residents.

The higher usage by military residents was attributed to higher income and standard of living, more children, and higher saturation of automatic washing machines. Further comparisons on space heating were not offered, possibly due to lack of corrections available for differences in type and construction quality of housing units.

2. Naval Audit Service. This review of electric usage in Hawaiian Navy family housing concluded that Navy residents used 50 percent more electricity than comparable civilian housing. The difference was partially attributed to Navy units having central air conditioning, which not only accounted for a sizable proportion (30 percent) of electric consumption during the cooling season, but was suggested to be a possible area of abuse when carelessly used.[1] (See Appendix J for excerpt of report.)

3. Booz, Allen and Hamilton. In 1973 a comparison was made between military (Pensacola NAS and Great Lakes NTC) and civilian (Pensacola, Florida, and Waukegan, Illinois) electrical consumption. They concluded "electricity consumption levels for naval housing appear to be substantially higher than those for comparable civilian housing." They further concluded that "individual metering will certainly produce some amount of electrical savings," and "reductions of 10 to 20 percent were postulated as being well within the possible saving range."

*Criteria for Determining Costs of Gas and Electric Service in Military and Public Housing Projects, prepared by Clifford A. Brandt, H. Zinder & Associates, Inc. 195? Library of Congress Catalog Number 57-14900.

[1]Comment: Most comparable civilian housing units on Oahu do not have air conditioning, although air conditioning of the Navy units was judged necessary because of location (relative to prevailing winds and topography) or construction features, and the question arises of whether the occupants should be held responsible for this decision. Analysis of a hypothetical monthly consumption comparison would be as follows. If the average civilian home uses 300 kWh, then the military home uses 300 kWh x 150 percent or 450 kWh. But 36 percent of this 450 kWh, or 162 kWh, is apparently the result of air conditioning. The difference, 288 kWh, compares most favorably with the 300 kWh originally ascribed to the civilian house.

Based on a 20 percent savings the payback period for installation of meters Navy-wide was estimated as 1.2 years. They also noted institutional, legal, and regulatory problems to be overcome. (See Appendix K.)

Examination of Booz, Allen & Hamilton's analyses reveals the utilization of numerous assumptions to fill gaps in data and make corrections. Their conclusions were qualified by statements like the following:

> "A definite comparison clearly cannot be made without correlating such factors as: floor area per unit; heating, hot water, major appliance, and air conditioning information; housing construction parameters; relative family affluence; family size . . . The purpose of the bar graphs is to illustrate qualitatively that Navy consumption levels in general are higher than comparable civilian levels."

Many of the factors necessary for comparability of the civilian and military samples were not controlled or examined.

With respect to the savings due to switching from master metering to individual metering, the Booz, Allen report notes that "a definitive . . . controlled experiment apparently has never been performed." The best available study obtained an initial drop of 20 percent, but long-term results were not reported.

4. Air Force Institute of Technology. In a thesis prepared at the Air Force Institute of Technology, in 1976, Bjerke and Brown surveyed the electrical consumption of 58 Air Force, Navy, and Marine Corps housing sites over the period 1970 to 1975. Comparable data were sought from public utilities near each military site, but only four provided information of acceptable quality. They concluded that "over a 5- or 6-year horizon since 1970, consumption of electrical energy in military housing at these four installations has exceeded consumption in comparable civilian housing by approximately 23 percent." Considering high-quality data from eight sites for the single year 1975, "consumption of electrical energy in military housing . . . exceeded consumption by comparable civilian housing by approximately 1[illegible] percent." With respect to change over the period 1970 to 1975, the authors conclude "the difference between military and civilian electrical energy consumption is diminishing."

The validity of these conclusions is reduced because the initial selection of representative housing units at the military housing sites and the matching of those units from the surrounding communities by the local public utilities was not controlled. The authors were also not able to consider possible different costs for installing physical improvements in

the military and civilian communities or the key matter of the number of occupants per unit, which varies widely between military and civilian units. Thus, it is highly unlikely that the process Bjerke and Brown used resulted in comparable units for comparison. In addition, they cited that some of their data from military sites were based on engineering estimates, allocating or projecting usage. Such data cannot be relied upon for accurate comparisons.

5. Naval Weapons Station, Charleston, SC. Throughout FY 1978 and the first 9 months of FY 1979, energy consumption data were obtained on 200 Category "C" units at NWS Charleston. This housing was of brick veneer, slab on grade construction with an average floor area of 1,290 square feet and had electricity as the sole energy source. South Carolina Electric and Gas Company provided average consumption data from all-electric civilian homes of like size, construction, and equipment located in the Charleston area. The civilian housing qualified for "total electric" rates, were constructed in compliance with minimum FHA standards, and had an average floor area of 1,350 square feet. No information was available on the occupants and the appliances used in either set of homes. In FY 1978 the military residences consumed 7.8 percent more energy each month per square foot than the civilian homes. In the first 9 months of FY 1979 the difference was 8.1 percent each month. For the full 21 months the military consumption averaged 7.95 percent above the civilian usage. However, other research has shown that the average Navy family is larger and has more electric appliances than residents in comparable civilian housing. Therefore, it appears that the average Navy family's consumption of energy is very similar to the civilian counterpart.

An aggressively administered energy conservation program was the major contributor to a 22 percent reduction in energy consumption at NWS Charleston over a 2-year period. The program consisted of the following:

- Monthly inspections of the housing area with notices given to a resident when energy conservation practice violations are spotted. Repeat violators receive a letter from the CO.

- Energy conservation signs are posted throughout the base and housing area.

- Every mailing to housing residents includes energy conservation tips.

- The housing newsletter contains a monthly energy conservation notice.

6. Science Applications, Inc. (SAI). In 1979, SAI was tasked to provide a comparison of energy norms to actual energy consumption in both military and civilian housing. The sites

selected had the same climatic conditions, but the civilian residents were billed directly for their utilities while the military received their utilities as part of their quarters benefit package. Twenty houses at the Navy's CBC Port Hueneme were compared to 26 adjacent civilian residences in Oxnard, California. Both groups used both electricity and natural gas as sources of energy. The period studied was January to July 1979.

In contrast to studies summarized previously in section A, each of the 46 units was placed on a common base of reference. Heating load requirements were determined by a computer program using structural and onsite survey data. Information regarding the occupants and their energy consuming equipment and appliances were also accumulated. Then the basic survey data were normalized on an average per occupant and average per dwelling basis. The average floor area and number of occupants per dwelling were larger for the military sector than the civilian sector. Thus the average number of occupants per square foot of floor area and per bedroom was almost identical for both civilian and military sectors. There were more adults in the civilian residences, and both they and their children were younger. The military dwellings contained more personally owned appliances and had less insulation. None of the units were air conditioned.

To standardize the base of reference, a norm algorithm was used, similar to the one described in Chapter 2, "Norm Development." After standardization, military residences used 22 percent <u>less natural gas</u> than the civilian and <u>44 percent more electricity</u>. Since the percent of total energy consumed as natural gas was greater in the military units, the <u>total</u> standardized energy consumption of military personnel was 12 percent less.

If the dwellings and occupant data had not been standardized to force them onto a common base of reference, only actual consumption could have been compared and the military residents would not have received equitable treatment. In this instance the military used 69 percent more electricity and 4 percent more natural gas than the civilian for a composite excess usage of 14 percent. Thus it appears that military personnel do not really consume more energy than their civilian counterparts even when the civilians are paying their own utilities. (See Appendix F for the field study report.)

7. <u>Naval Facilities Engineering Command</u>. In 1979 the Naval Facilities Engineering Command initiated a study comparing energy consumption in military and civilian housing. In contrast to the previous studies by Zinder & Associates; Naval Audit Services; Booz, Allen and Hamilton; Air Force Institute of Technology and Naval Weapons Station, Charleston the total residential energy consumed in the form of electricity and natural gas was contrasted. Two hundred fifteen units from CBC

Port Hueneme were assessed against 130 houses from two developments in nearby Oxnard, CA during the first 6 months of 1979. A common base of reference for all 345 residences was established using the norm algorithm described in Chapter 2 of this report.

The results clearly demonstrate that total energy consumption in a home must be evaluated and not just one source when multiple sources are present. Natural gas accounted for 77 percent of the total energy requirement for military residences compared to 72 percent for civilians. If only electrical consumption had been compared, the military housing would have been evaluated unfairly as excess consumers of energy.

Actually, the average military resident consumed less total energy during every month of the study than the norm algorithm indicated that his house and its occupants required. Throughout the major heating seasons in January and February, the average civilian residence was well above the norm, but it dropped below the norm as heating requirements waned. During the heating season, the military appeared to be much better conservers of energy while the two groups converge as the heating requirements disappeared in May and June. Throughout the 6-month period the average military resident consumed 86 percent of his average monthly total energy requirements (norm) while the average civilian resident consumed 100 percent, 14 percent more than the military. (See Appendix F for the field study report.)

8. Summary. It must be concluded from the examination of the above military-civilian comparisons that specification of any overusage by military residents is still imprecise. The results of those studies ranged from 15 percent less usage by military to 33 percent more than civilians. It is most unlikely that the overall savings will be as high as the 35 percent originally projected from installing meters on military family housing. So far adequate comparability of samples and situations has not been obtained. Further, energy conservation programs initiated in the past few years were not present when four of the six studies were made, and it is especially noteworthy that all studies within the past several years show military consumption falling below comparable civilian units.

B. Military Conservation Programs.

Since the 1973 oil crisis, there has been a high degree of consciousness and concerted effort on the part of military housing administrators and base commands to reduce energy consumption in family housing. A large variety of methods have been used, appearing to have achieved varying degrees of success. Assessment of individual programs has been judgmental since comparison groups, weather corrections for different data collection periods, and careful, thorough measurement of consumption and all related factors have not been available. However, Defense Energy Information System (DEIS) data show a

7.7 percent reduction in energy consumption in family housing from 1975 through 1979, adjusted for inventory changes. Specific judgments should not be drawn from this experience regarding what programs or program components are most effective. However, the overall reduction is recognized as an element of occupant preconditioning (prior energy conservation actions) when attempting to project the effects of various metering alternatives engendering further occupant behavior changes.

C. Scientific Studies.

A number of surveys and scientific studies conducted within DoD have bearing on the issues of utility consumption and energy conservation in family housing.

1. Navy Family Housing Survey. A 1978 survey of residents of Navy family housing probed attitudes and practices with regard to residential energy conservation. Residents at the following six Navy housing locations spanning a wide range of climatic conditions were surveyed: Point Mugu and Port Hueneme, California; Whidbey Island, Washington; Whiting Field, Florida; Great Lakes, Illinois; and San Diego, California. Usable responses were received from 2,760 families.

It was found that military families generally regarded themselves as energy conservers, and they felt that residential conservation can improve the situation during the energy shortage. The majority felt that the U.S. faced a long-term energy shortage and that the mid-1978 energy situation was sufficiently serious to call for changes in behavior. A majority of respondents endorsed changes in U.S. way of life, such as resetting thermostats and reducing personal comfort to save energy, to cope with the energy situation.

Causes of the energy situation which might have motivational (or demotivational) implications were believed by military residents to be (1) profiteering by oil and electric companies, (2) commercial or industrial overuse, (3) overdependence on oil, (4) environmentalist interference, and (5) waste.

Most military residents felt they were well informed about household energy conservation practices.

A majority of military residents endorsed both positive incentives for conservation (rewards, tax breaks) and negative incentives (higher rates to overusers). Many residents (44 percent) believe that people who pay their own utilities use less than those who do not but 31 percent disagreed. About half of the military residents believe that military family housing residents conserve less than civilian families. Only one-fifth of military residents felt their neighbors were trying to conserve energy. Regarding their past energy

conservation behaviors, most military residents (72 to 86 percent) had sought additional information about conservation practices, instructed their families in ways to conserve, and discussed the energy situation with their friends. From one-half to three-quarters of residents had implemented specific practices, such as resetting their refrigerator thermostat, replacing light bulbs with ones of lower wattage, lowering their water heater thermostats, raising their air conditioning thermostat setting, and controlling their space heating thermostat.

Increasing age of the service member, pay grade, and length of time in service were associated with increased frequencies of reported energy conservation behaviors. Greater frequency of conservation behavior was reported in milder climates than in harsh climates.

These findings reveal a large portion of family housing residents who are generally aware of the energy situation and its implications to their daily lives. They are concerned and many have taken conservation-oriented actions or changed some of their behaviors to adapt to these new situational demands; however, most residents do not realize their neighbors' similar attitudes and actions. Energy waste would not likely be condoned in public attitude or action and would be expected to be relatively unpopular. (See Appendix L.)

2. Field Trials. Past experience has found that information, typically in the form of pamphlets, articles, or even speakers, is insufficient to produce significant change of behavior. Several techniques, such as feedback, incentives, and goal setting, may be introduced to increase the effectiveness of information as an inducement for change. Several methods were chosen for experimental evaluation in individually metered and in master-metered military family housing.

Two individually metered sites (Port Hueneme and Point Mugu, California), and one master-meter site (Corry Station, Pensacola, Florida) were selected. Studies were conducted by NPRDC. Final results will be included in the supplement to this report, to be published separately.

a. Multifamily Groups with Individual Meters. Early in 1979, 240 families, representing a cross section of base housing residents at each of the two California sites, were contacted about participating in research designed to assess an energy conservation program. Sixty families at each site volunteered to participate in an intensive 3-month education program which started in March. The 60 families were divided into six groups of ten families and met every other week over a 10-week period. The groups were competing with each other for monetary awards to be presented at the end of the 10 weeks to those groups averaging at least 5 percent less

energy use than a carefully matched group of 60 nonparticipating families from their site. Each meeting included: (1) presentation of energy conservation suggestions by extremely professional group facilitators; (2) feedback of separate gas and electric consumption from the previous 2-week period for each member of the group, each family's percent consumption above or below the average of the 60 nonparticipating families at the same site, and the rank ordering of the six groups at each site; and (3) discussions among group members of the tips and consumption feedback.

During the 3-month program, participants consumed an average of 24 percent less energy as a composite of both gas and electricity than the non-participants did. Significant reductions occurred at both sites during all five periods, ranging from 14 percent during the first period to 31 percent during the last period.

Considering gas consumption alone (approximately three-fourths of the energy consumed during the period), savings ranged from 16 percent (Port Hueneme) and 21 percent (Point Mugu) during the first period to 31 percent and 34 percent, respectively, during the fifth period.

Electricity savings were more modest, especially at Point Mugu. Point Mugu achieved 2 percent savings during the first period and 13 percent during the fifth, while Port Hueneme saved 9 percent and 24 percent, respectively.

Extensive data analyses showed that utility consumption was partly related to the number of occupants in the housing unit, the floor area of the unit, the estimated pay of the service member, and weather conditions.

In relation to the effectiveness of the educational program, it was found that short-timer families at both sites (those with less than 2 years left in service and not intending to reenlist) did not reduce their consumption as much as those with more service time remaining. This factor is thought to reflect motivation to conserve. Attendance at group meetings was also found to be related to service time remaining and (inversely) related to energy consumption.

In corroboration of other energy conservation studies, it was found that participants became very sensitive about the responsiveness of the housing management office to requests for energy conservation-related maintenance. Any lack of responsiveness by the effective landlord had negative effects on participant motivation and was interpreted as a lack of real management concern over the conservation issue.

Although the educational program is highly successful in energy conservation terms, it requires individual metering, the presence of a highly skilled consultant, and funds for the

administration of monetary rewards. Because it is very intensive and costly, the program would require considerable adaptation, possibly compromising its effectiveness, to make it feasible for implementation on a national scale.

b. Individual Families with Master Meter Feedback. In the summer of 1979, an ancillary project was initiated to assess how an education/energy advocate program would affect the energy consumption of military personnel with different attitudes toward energy conservation. Corry Station, Pensacola, Florida, consisting of 200 duplexes individually metered for electricity, was chosen for the study. Although the program was conducted as though the site was master metered, individual metering permitted each family's electrical consumption to be tracked and related to family characteristics and attitudes about energy consumption. Although residential utilities operated on both gas and electricity, only electrical consumption was observed, because natural gas was only master metered. The housing site was divided into two groups of 100 residences each, with one group (participants) randomly chosen to be involved in the education/energy advocate program while the other (nonparticipants) was not.

Family demographic, household appliance, and energy-related attitude information was collected from all 200 families. The 100 participating families were involved in the following 2-month program:

- An energy advocate, serving as the program administrator, made up to three household visits per week. She explained the program, enlisted residents' support, and provided energy-related information.

- A biweekly newsletter was sent out covering feedback regarding participant energy consumption as a group in comparison to the nonparticipant control group. The newsletters also provided energy conservation tips and activity information.

- Activities such as a poster contest and field trips were planned for both adult and children residents.

All 200 families were statistically divided into three subgroups according to their attitudes about conserving energy. Group A, 42 percent of all families, did not see themselves as conservers and felt that it was not important or easy to conserve. They did not see that there was any energy crisis and felt that they should be able to use all the energy they wanted because their comfort was important. The Group A members who participated in the test program were initially average consumers and stayed that way. The Group A nonparticipants actually increased their consumption somewhat during the test period.

Group B, consisting of 16 percent of all families, believed there was an energy problem and felt that they could and should conserve energy. Group B, like Group A, was willing to pay for their energy but, in addition, wanted credit for any savings they made. Both the participants and nonparticipants in Group B were initially low consumers of energy and stayed that way.

Group C, consisting of 42 percent of the families, strongly acknowledged the presence of an energy problem, stated that household conservation was important and worth the effort, and saw themselves as energy conservers. They placed primary blame for the problem on the oil companies and utilities, felt that air conditioning was important for their work and relaxation, reported that they had the right to use as much energy as they wanted and did not want to pay for utilities. Both the participating and nonparticipating members of Group C were initially high consumers of electricity, but the participants lowered their consumption to average during the 2-month period.

Considering all three groups, the families participating in the program undercut the nonparticipants by more than 5 percent in electricity consumption. However, this change took place only in those participants who most vociferously identified themselves as conservers, felt that conservation in the home was possible and important, and were initially the highest consumers of energy.

c. Individual Families and Meters. Research was designed and initiated at NAS Whidbey Island, Washington, and NTC Great Lakes, Illinois, to assess the effect of monetary rewards and feedback on energy consumption. From civilian experience, it would appear that such a strategy would produce the greatest reduction in the amount of energy consumed; however, administrative and procedural problems made it impossible to complete the work effectively.

3. Conclusions. The programs described in detail cover a range of intensity, from very high (incentives and feedback for family groups meeting biweekly for educational input) to relatively low (individual families in an education/energy advocate program). The individual meter and family incentive program described in section II.C.2.A could be considered to be of moderate intensity. It appears from the results of the studies that large savings in energy consumption require a very intensive program. Preliminary cost-benefit analyses suggest that the education/energy advocate program could be cost effective and that refinement of the program could increase its effectiveness.

The individual feedback and incentive program described in section II.C.2.A is felt to have very high promise and an excellent rating for feasibility of implementation on a national scale but could not be tested during the scheduled test period.

The completed studies demonstrated a strong sensitivity among participants with regard to structural and maintenance factors that interfered with their energy conservation efforts. These factors are expected to be quite pervasive in a tenant-paid utilities situation. Thus, if tenants must pay for their own utilities, military family housing offices can be expected to encounter very strong complaints regarding weatherproofing; maintenance response time; and layout and design, construction quality, and condition of the units. To the extent that these complaints could not be responded to adequately in the eyes of the occupant, a significant (and justifiable) level of resentment could be expected among family housing occupants.

III. Civilian Experiences.

Two types of comparisons have been conducted on civilian populations: (a) master-metered households with utilities included in rent were compared to individually metered households with self-paid utilities, and (b) comparisons of a single group of households before and after a change from master metering to individual metering. The former procedure suffers difficulties in establishing comparability among occupants and housing units for the different samples. The metering conversions control occupant and housing unit factors by holding them constant, but must cope with differences in weather, because of the fact that data are drawn from two different time periods (preceding and following the metering conversion). Adjustments for weather differences should be based on degree-days recorded for different periods.

A. Field Comparisons.

Three reports provided multiple comparisons of civilian utility consumption under alternative metering and payment arrangements. As before, most of the comparisons involve electrical consumption. The individual studies listed in Table 4-2 with their key characteristics results and are summarized in the following paragraphs.

1. Midwest Research Institute (MRI).* This report compared relative electrical consumption of comparable master-metered and individually metered civilian multifamily dwellings for 1-year periods in 10 large cities across the United States. Master-metered dwellings were found to use an average of 35 percent more electricity than individually metered dwellings.

Caution is required in interpreting these figures, because comparisons were often based on different years, and corrections for temperature variations during comparison periods were not incorporated because of insufficient data and lack of "sufficient basis for precise analytical correction." In addition, very small samples were sometimes used and percentage changes were calculated on very low base levels of usage. Nevertheless, MRI felt the data provided support for their "subjective test" of "conclusions regarding energy use."

2. San Diego Gas and Electric Company. The company compared master-metered mobile home parks in the vicinity of individually metered parks. No corrections were used for possible differences in unit size, age, occupancy, or other factors. They found individually metered parks had 37 percent lower average electricity consumption than similar master metered parks.

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*Energy Conservation Implications of Master Metering, Vol. I, Midwest Research Institute, 1975; FEA Report No. FEA/D-76/110.

Table 4-2
Comparison of Civilian Utility Consumption Under Master Metering (Landlord Payment) and Individual Metering (Tenant Payment)

Study	Size of Sample(s)	Data Year(s)	Comparison Period	Utilities Compared	Type of Comparison[1]	Usage Under Tenant Payment[2]	Comment
Midwest Research Institute, 1975	18 samples from N=6 to N=1683	1969-74	1 yr	E	SG	0.65	Lacks corrections for different years (weather) differences; percentage changes sometimes calculated on very low base levels; possible nonrandom sampling of apartments in a complex, with small sample sizes for valid generalizations; application of selection criteria may not have yielded truly comparable units.
San Diego Gas & Electric, 1979	71 units in 6 samples of N=10-12	1973-75	1 yr	E	MC	.79	Data for same residents before & after conversion from master to individual metering payments; no corrections for differences in weather.
	294 units in 9 mobile home parks	1973-75	13 mos	E	SG	.63	3 master metered parks each having 2 nearby submetered parks for comparison; unit size, age, occupancy, etc. not equated.
Booz, Allen & Hamilton, 1979	20 cases from 9 utilities	1976	N/A	E	MC	.81	Master to individual meter/payment conversions; multi-family residences.
	272 units in 2 cases from a condo complex	1977	N/A	E	MC	.77	
	3 cases from B,A, & H	1973-78	1 yr	E	MC	.76	
	3 cases from utilities	1976		NG	MC	.94	
	2 cases from B,A, & H	1976-77	1 yr	NG	MC	1.05	

[1]Similar groups with different metering/payment arrangements (SG); metering conversions from master to individual with self payment (MC).

[2]Master metering (landlord payment) = 1.00.

SDG&E also compared electricity consumption before and after meter conversion in 71 selected units of six apartment complexes. This comparison involved the same residents under indirect billing (utilities included in rent) and later direct billing of each tenant. A 21 percent decrease in electricity usage was found from a comparable period the previous year, but no correction was used for climate differences between the two periods.

3. Booz, Allen and Hamilton.* In a 1979 report for the Department of Energy, this consulting firm reviewed civilian experiences with alternatives to master metering. In a number of cases where conversions had taken place from master metering to individual metering, a pattern emerged which indicates that the savings from conversion to individual metering were different for natural gas than those derived from electricity, and they are partly dependent upon the function for which the energy is used. Where space and water heating were nonelectric, electric conversions were found to produce savings of 20 to 26 percent (attributed to reductions in usage of lights, appliances and air conditioners). A study by the Electric Power Research Institute (1977), using data from nine utility companies covering 20 cases, indicated from 2 to 36 percent savings in cases where heating is nonelectric and from 13 to 35 percent in cases with electric heat. One case was reported where a condominium converted nonelectrically heated apartments and townhouses to individual meters and experienced 27 and 19 percent savings, respectively. These studies support Booz, Allen and Hamilton's conclusion that "For electricity, the average savings is approximately 15-20 percent."

The savings for gas utility conversions** from master metering are significantly less. Savings reported by utility companies in three cases ranged from 5 to 7 percent. Booz, Allen and Hamilton's own case studies found increased consumption after gas conversions, ranging from an additional 3 to 8 percent. Considering all these cases, they concluded that savings on gas conversions averaged 1 percent.

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*Alternative Metering Practices: Implications for Conservation in Multifamily Residences. Prepared by Booz, Allen, and Hamilton under Contract Number EC-77-C-03-1693 for the U.S. Department of Energy, June 1979.

**At the time these studies were done, the cost of natural gas per Btu was much lower than the cost of electricity. As the price of natural gas catches up with the price of electricity, the savings in consumption for each may become comparable. The Navy study conducted at CBC Port Hueneme and PMTC Point Mugu indicates that such an expression of economic theory is taking place.

Booz, Allen and Hamilton argue that there are two requirements to motivate residential energy conservation: (1) consumption feedback, and (2) financial responsibility. They raise the issue that once the financial responsibility is shifted to the tenant, there is no incentive for the landlord to improve thermal, appliance, or lighting efficiency of the units. In their view, this might call for the establishment of a thermal efficiency standard for structures to be met prior to their conversion to separate meters. They note that financial responsibility of the tenant requires that tenants possess control over utility consumption (e.g., by thermostats). They also cite possible negative effects of metering conversion, such as tenant resistance and turnover or reduced occupancy levels.

In summary, the comparisons of separate groups appear to have inadequate controls for important factors affecting utility consumption, so the comparability of the sample groups is unknown. In the comparisons of periods preceding and following metering and billing conversions, the corrections for differences in weather during different periods (degree-days), where used, are of indeterminate accuracy.

Bearing in mind the tentativeness of any conclusions drawn from these data, it appears that (1) civilian electricity consumption appears to be lower under individual metering and tenant payment of bills than under master metering and landlord bill payment by approximately 20 percent; and (2) civilian natural gas consumption fails to show large differences under alternative metering and billing arrangements, in contrast to electricity consumption.*

However, the applicability of these numbers to the military family housing situation may be questionable. At most military installations, direct or indirect pressures to reduce consumption have already been placed on occupants. These range from directives concerning maximum and miniumum thermostat settings to physical shutting off of all unit air conditioners except for peak summer months. At some installations, monitoring has been carried to the extent of employing "energy monitors" to drive through housing areas at night to identify families whose air conditioners are running. Taking such measures into consideration, a good case can be made that the 20 percent savings cited in the preceding studies would not be applicable to the military environment, because military families are already experiencing considerable pressures to conserve energy and thus would have already curtailed their use to a much greater extent than the civilians studied in master-metered environments.

The Department of Housing and Urban Development (HUD) rules and regulations for projects owned by the Public Housing Agency

*Ibid.

(PHA) address metering in sections 865.401 through 865.410. HUD promotes energy conservation two ways. One is by proposing that a master-meter system be provided with submeters operated by the PHA. Tenants would be surcharged for utilities consumed in excess of reasonable energy consumption as determined by the PHA. No tests of this strategy to manage energy consumption were found. The second strategy proposed by HUD is to have the utility supplier directly bill tenants for utilities with PHA providing the tenants with a reasonable allowance for the tenant-supplied utilities.

The first HUD technique may be perceived as punishment for excess consumption while the second would be a reward for conservation and punishment for excess usage. The rules are being challenged in court by the National Consumer Law Center and the Natural Resources Defense Council as (1) inimical to human environment (2) counter to rational process and (3) against HUD's national goal to provide housing at low cost.

B. Scientific Studies.

Several energy conservation studies have been conducted in the civilian setting to consider methods which can be used in conjunction with or in place of metering individual family units and charging residents for the energy used. Although they will be discussed separately, most of this work deals with more than one of the following strategies: information, feedback, incentives, group participation, and other related approaches.

1. Information. Three different strategies were evaluated by Hayes and Cone to get four volunteer student families to reduce their electrical consumption over a 3-1 2-month period. Information about their appliances and lighting did not have any impact on consumption. Heat and hot water were provided by natural gas. Another study of 129 volunteer Texas households found that information alone did not reduce electrical energy usage in the summer months.

It appears that the dissemination of information alone has little impact on energy use patterns.

2. Consumption Data Feedback. The effect of feedback on electrical energy consumption was tested by Seligman and Darley with 29 families living in physically identical three-bedroom townhomes. Feedback to these residents was presented 4 times a week for 1 month in terms of percent of energy consumed over predicted consumption rates. Results indicated that the feedback group achieved an energy consumption 10.5 percent below that of a comparable group which did not receive any feedback. Moreover, it was found that households using less energy initially were able to further reduce their consumption. These findings suggest that energy conservation may be achievable across a wide range of energy

consumption levels through feedback. In a study of feedback and demand elasticity involving 173 residential energy users, Kohlenberg, Barach, Martin, and Anschell found that when weekly feedback on electricity conserved was provided, consumption dropped by 8.6 percent. In their study of student families, Hayes and Cone found that individual feedback alone reduced consumption 4 to 10 percent .

In a triple replication of the effects of feedback on residential electricity consumption, Winett and his coworkers found that group feedback produced negligible reductions compared to individual feedback. No competition between groups was initiated.

In a study on the joint effect of feedback and goal setting among 100 families, Becker found that the use of feedback with the establishment of a difficult goal produced a reduction in residential electric consumption of 13 to 15 percent. Residents who received no feedback or set an easy goal did not reduce their consumption significantly.

Generally, feedback to families on an individual basis appears to produce a positive effect in promoting energy conservation behavior. However, the effective use of group feedback may be dependent upon the establishment of a competitive situation. Reduction in consumption due to feedback without the establishment of a goal appeared to vary between 0 and 10 percent.

3. Incentives. Winett and Nietzel conducted a study using two matched groups of volunteer families, both receiving information on energy conservation techniques and one receiving monetary incentives scaled to their reduction in consumption. The group receiving monetary incentives reduced their consumption 15 percent more than the group receiving only information. Hayes and Cone demonstrated that monetary payments to their four families produced immediate and substantial (20 to 40 percent) energy reduction even without feedback and information. When the payments were combined with feedback or information, the effects were no greater than those produced by payments alone.

In a study designed to reduce energy consumption during peak usage periods of the day, three families curbed their electrical peaking by approximately 50 percent when a combination of feedback and monetary incentive was used. Information alone had no impact and the effect of feedback alone was minimal, about 15 percent. As soon as feedback or incentive conditions were stopped, families reverted to their previous consumption pattern.

A fuel oil supplier supported a study of conservation in 180 households. Instead of a monetary reward, social recognition was used as an incentive with a decal stating "We

Are Saving Oil," displayed by conservers. Feedback alone produced savings of 9 percent compared to a nonparticipating group while feedback plus the social recognition incentive produced a drop in usage of 13 percent. A preexisting energy crisis (1973) may have magnified the acceptance of energy conservation practices and increased the effectiveness of the decal as an incentive.

In a master-metered, natural gas-serviced apartment complex, Slavin and Wodarski (1978) tried out a delayed form of feedback and a group rebate procedure. Individual families and landlords shared in the savings that resulted from their collective energy conservation effort. Over one winter the amount of natural gas consumed was reduced by 3.3 percent.

It appears that various forms of incentive, predominantly but not exclusively monetary, can serve to motivate or enhance energy conservation behavior. The incentives are most effective when provided to individual families for whom reductions of 13 to 20 percent in energy conserved have been observed; however, this is heavily dependent on any energy conservation actions previously taken as well as the relative level of consumption of the family before the advent of the instant incentive.

4. Group Participation. Group participation introduces several elements which may further enhance energy conservation behavioral strategies. Public commitment appears to be one aspect of group participation that potentially would affect energy conservation behavior. Pallak and Cummings found that homeowners who had made a public commitment to conserve energy showed a lower rate of increase in consumption of natural gas and electricity than those under private commitment or no commitment.

Annis & Associates conducted energy conservation projects in Atlanta and Los Angeles involving the use of group discussion programs. Although considerable effort was made to encourage and recruit tenants to participate in the group meetings, attendance was about 10 percent. As a result, the efficacy of group participation remains unconfirmed.

5. Other Studies. A variety of studies that do not specifically address the topics of feedback, incentives, information or group participation are nevertheless pertinent to the scope of this study and warrant inclusion herein.

The study of demand elasticity (the relationship between price and consumption) by Kohlenberg and his associates found that when electrical energy rates were increased by 150 percent, consumption dropped 6 percent. Consolidated Edison of New York has observed that the rate of theft of energy also increases in direct relation to increases in the price of energy.

The effects of fear appeals upon attitudes towards energy conservation were reported by Hass, Bagley and Rogers. They found that although increases in the perceived likelihood of an energy shortage had no effect, increments in the perceived noxiousness or severity of an energy crisis strengthened intentions to reduce energy consumption.

C. Summary.

The civilian experiences appear to demonstrate that charging individual families for all of the energy they consume reduces their consumption 15 to 20 percent over what is consumed when the cost of energy is included in their monthly rent. However, such savings cannot necessarily be achieved in the present military environment because many military occupants with greater voluntary or involuntary constraints on energy consumption than their civilian counterparts have already shown considerable overall consumption reduction in recent years.

It also appears that the energy consumption of residents who pay directly for the energy consumed can be reduced further by effective energy conservation programs. Programs which include an incentive for conserving may obtain a 10 to 20 percent reduction in energy used. Individual family feedback may help with a 5 to 10 percent reduction while group feedback produces a lesser effect, 0 to 5 percent. Information alone will not contribute additional savings beyond the installation of individual meters, but group participation may be a valuable addition to any program.

trying to conserve energy. Regarding their past energy

IV. Impact of Mock Billing.

Ideal conditions for determining what effect the mailing of mock bills had on energy consumption were not present. This would have required one activity with two identical groups of individually metered housing units where only the test group received mock bills. The effects of base energy conservation programs, weather conditions, media coverage of the energy shortage, and personal awareness through waiting in gasoline lines would thereby be eliminated.

An alternate study was attempted at two test activities. Using historical weather data and readings from master meters, the study would have compared the deviation of monthly consumption from the norm for the year before the individual meters were installed with the deviation during the test. Unfortunately, the master meters at the first activity, owned and read by the local utility company, were not consistently read each month--sometimes going 4 months without being read. Additionally, the reading for 1 month was so erratic that a credit adjustment of 5 times the normal monthly energy usage was made 2 months later.

At the second activity, it was learned that storm windows and doors, insulation for water heaters, and limiting thermostats were installed just prior to the test. This significantly reduced the energy requirements for the units during the test period and invalidated the planned comparisons with pretest consumption.

Because of these factors, it was impossible to make any valid statistical comparisons to determine the effectiveness of the mock bills in reducing energy consumption.

V. Summary and Conclusions.

Although considerable experience has been gained in the past several years examining the question of conservation savings resulting from various metering and payment arrangements, the quality of most of the data and analyses remains poor. When comparing either the consumption of residents before and after education or metering, or both, or the consumption of a metered group with an unmetered one, adjustments for factors such as size of home and weather must be made. Often these are not included or are corrected for in a very crude manner. Thus the results obtained by investigators vary so widely that extreme allowances must be made when savings are projected.

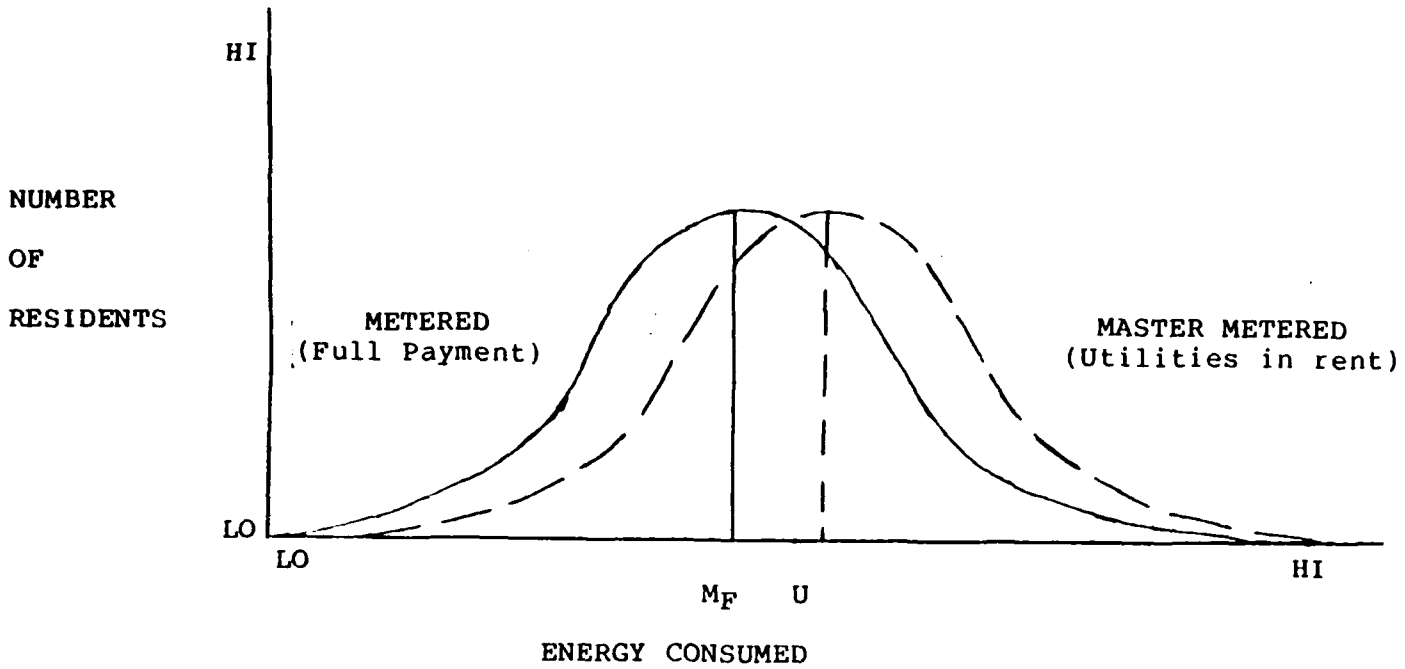
A. Metering Strategy Effects.

When master-metered housing is converted to individually metered units and the occupants are billed for all of the energy they consume, energy savings may not occur. Most of the studies summarized in this chapter have dealt with electricity. Studies of civilian occupants indicated potential energy savings of 15 to 20 percent by converting to an individually metered environment. (See Figure 4-1.) However, potential savings in the military environment would probably be lower because of the consumption constraints already placed on military occupants. To the extent that norm and consumption validity is questionable, savings would be further reduced by the necessity for an additional margin for error above normative consumption for billing purposes.

Relatively few studies have dealt with natural gas. Until recently these comparisons had moderate variation (± 8 percent). The latest study indicates a 25 to 27 percent savings achieved under very intensive field trial conditions. Probably no change in consumption can be expected unless the price of natural gas increases materially and conditions approximating those of the field trial are created. These conditions include individual metering, incentives, and active group participation in an educational process, using frequent feedback but did not require charging the occupants for any consumption.

The field trials as well as practical military experience have established that some savings are possible without metering. The size of the savings depends upon the intensity of the educational program, the amount of personal contact, the frequency of group feedback of energy consumption, and so forth.

Savings, at the large capital and operational expenditure, are possible with metering. Individual housing unit meters may serve two separate functions: (1) consumption feedback, and (2) enforcement of accountability through billing. From the studies available it appears that significant savings are possible from either use of meter, but billing would result in



ASSUME M_F= (Average for resident-paid utilities)

$U = 1.2M_F$ (Average for utilities-included-in-rent)

Figure 4-1
Metered vs Unmetered Consumption
(Civilian Sector Conversion Experience)

the larger amount. The amount of savings achieved is likely to depend on the strength of the educational component of the programs, the degree of acceptance of the program by housing residents, and the active involvement of the residents and housing management.

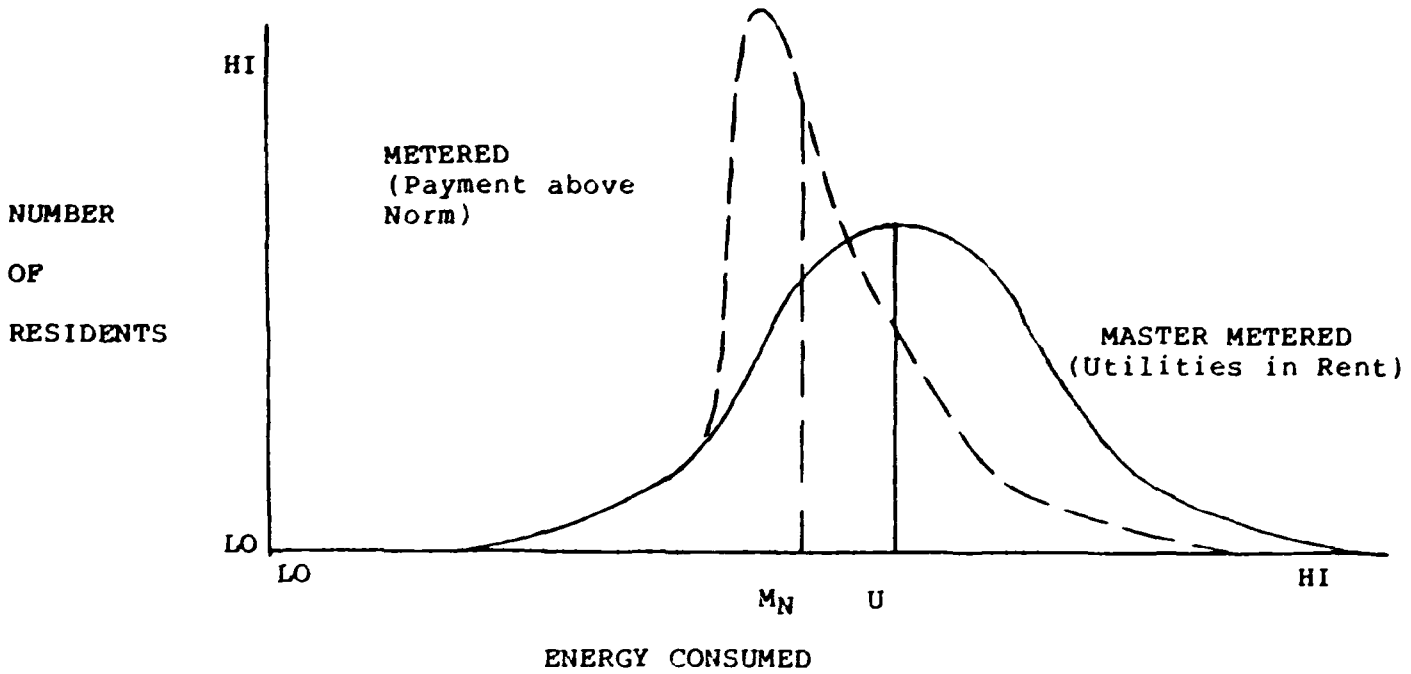
B. Payment Strategy.

If a policy of having residents pay for the consumption of excess energy, i.e., above some norm, were followed, the savings would not be as great as for the civilian full payment of utilities. Figure 4-1 contrasts the consumption of individually metered, full-payment units with master-metered payment in rent or no payment units, assuming a normal distribution of consumers above and below the norm. The latter consume 20 percent more energy than the former. If the latter group is metered and required to pay for consumption above the norm, the group already below the norm will not be affected. The group above the norm will shift towards the norm and become comparable to the metered, full payment group above the norm. The previously master-metered group which was 10 to 20 percent above the norm will tend to cluster right around the norm. This change in the consumption distribution is shown in Figure 4-2. Thus the savings would not be 20 percent but probably between 10 and 15 percent. However, data from field tests indicates that a larger number of military consumers are already below the norm so that relatively fewer will shift consumption, resulting in a savings between 5 and 8 percent. (See Figure 4-3.)

If a policy of providing residents with an allowance for energy and having them pay for all energy consumed is followed, it would be anticipated that the savings would be greater than for the civilians' full payment of utilities. Figure 4-4 contrasts what might occur. The allowance would serve as an incentive for low consumers to conserve even more since they would retain any of the allowance that did not go to pay for utilities. Savings as high as 12 percent might occur if the allowance is seen as fair, the norm is accepted, information and feedback are provided to residents, and incentive payments are frequent and tied directly to energy savings.

C. Education.

A highly involving educational process is a necessary component of an effective conservation program. Such education must go beyond distribution of information pamphlets, appeals to conserve, or mass conservation campaigns which produce no effect as demonstrated in multiple studies. These campaigns are ineffective, because they do not achieve the attitudinal and behavioral changes required to alter energy consumption habits. Changes in habits require much more personal, participative approaches to obtaining commitments for working at saving energy. These factors should be supported by goal-setting

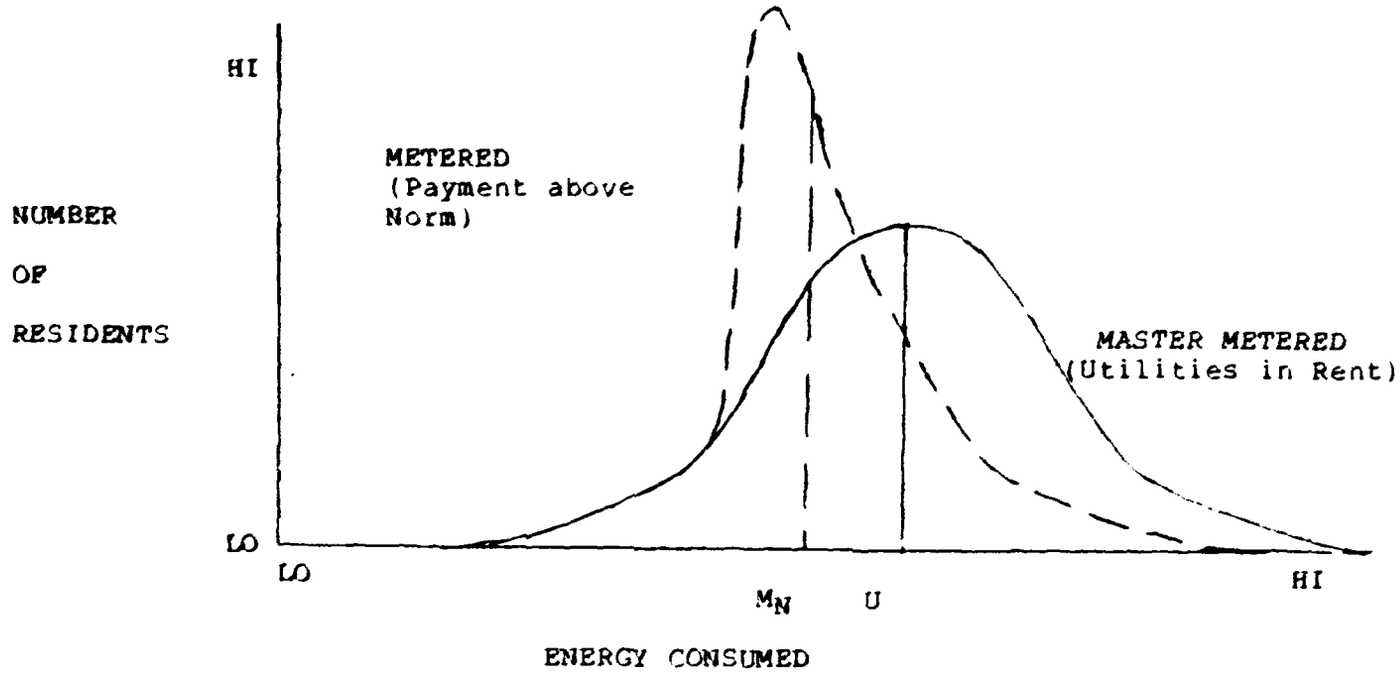


ASSUME

M_N= NORM (Average for payment of utilities above norm)

U = 1.12MN (Average for utilities included in the rent)

Figure 4-2
Master-Metered Consumption vs Payment Above Norm

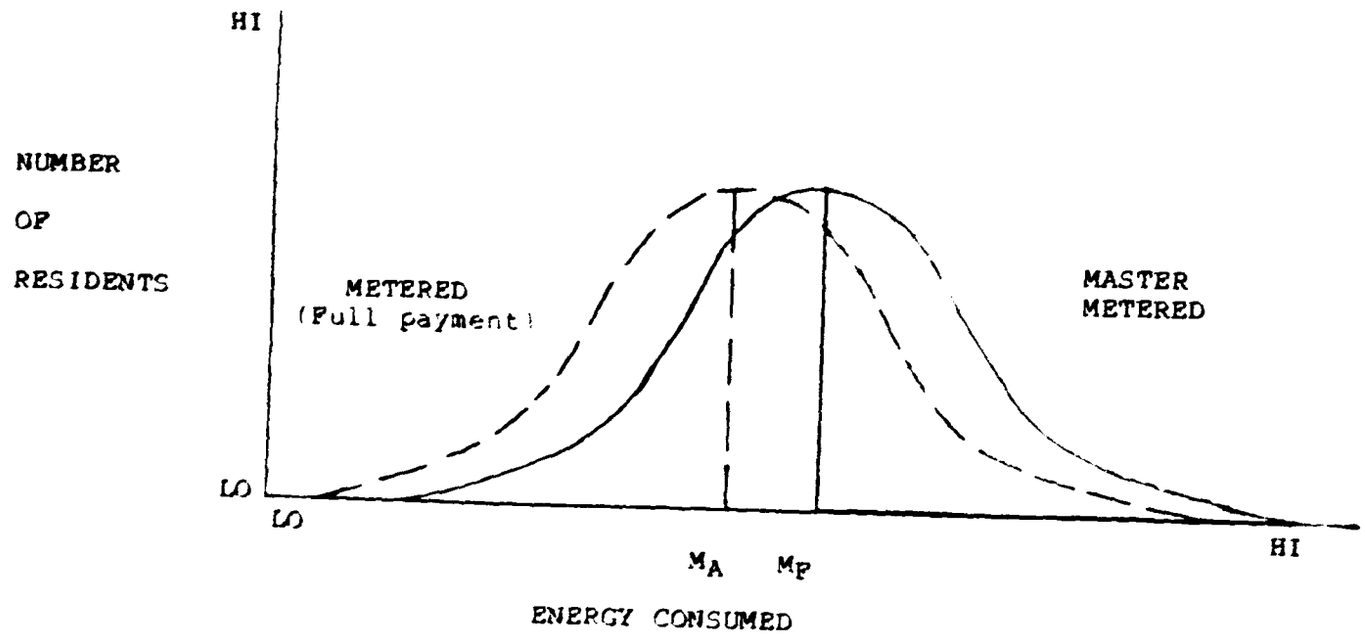


ASSUME

M_N = NORM (Average for payment of utilities above norm)

U = 1.06MN (Average for utilities above norm)
(DOD 1979 consumption per unit more than 6% less than 1975 level)

Figure 4-3
Master-Metered Consumption vs Payment Above Norm
(DoD Family Housing)



ASSUME M_P= (Average for master metered utilities)

M_A= 0.88 M_P (Average for utilities-included-in-rent)

Figure 4-4
Metered Consumption With and Without an Allowance

processes, consumption feedback, and reinforcement for success in achieving savings. Such an educational program could be linked to the housing office's self-help program. Although the educational program would incur continuing operational costs, these would likely be more than offset by additional energy savings yielded.

D. Acceptance.

Acceptance of the conservation program by housing residents is an especially critical problem under program alternatives which use billing. Acceptance would be expected to vary according to the billing plan chosen (see later discussion). In descending order of acceptance the alternative billing plans are (1) charging for excess consumption and rewarding for savings beyond a norm allowance; (2) charging for all energy consumed, with a monetary energy allowance for quarters (EAQ); (3) charging only for excess consumption beyond a norm allowance; (4) charging for all utilities consumed.

Some of the factors which would govern the acceptance or resentment of conservation programs by housing residents include: (1) the perceived fairness of the program in relation to the civilian community and within the services; (2) residents' perceived control over their consumption performance; (3) the perceived consistency of the services and housing management in its support and concern for energy conservation through an active, quickly responding maintenance program for housing and GFE; (4) the availability of education and knowledge for residents to use in conserving energy; and (5) residents' concern over possible extension of billing to a further degradation of entitlements.

VI. Major Alternatives.

Drawing on studies, comparisons, field trials and human behavioral considerations in light of the present DOD housing situation, a number of alternatives may be distilled. These are set forth briefly below and evaluated thereafter.

A. Alternative Consumption Control Systems.

(Refer to Table 4-3 for a contrast among the alternatives which are numbered the same as the following.)

1. Master Meters. This is essentially the status quo, in which residents are usually not advised of their usage. When they are so advised, their individual consumption cannot be identified since it is buried within a base total comparing present with past usage. Energy conservation campaigns vary in their intensity, but have demonstrated potentially significant consumption reductions.

2. Master Meters With Energy Advocate. A person in the role of an energy conservation advocate administers a program of conservation education. The program emphasizes personal contact to obtain individual family commitments to conserve, elicit establishment of explicit personalized conservation goals, and provide behavioral information and group consumption feedback aimed at achieving the goals. Under this control system, individual charges are not possible because individual consumption data is lacking.

3/4. Individual Metering With Feedback Only. Intensive education/energy advocacy may (4) or may not (3) be present. This control system could use the norm or average base consumption as a reference point for individual feedback; however, a norm instead of use of average base consumption would probably not be justified, especially in view of the low accuracy of the norm. Excess consumption could receive a wide range of nonmonetary consequences, such as notices and warnings, "remedial sessions," and ultimate eviction. Education and advocacy, as described in paragraph A.2, above, would be highly desirable in order to maximize conservation effectiveness of the control system and gain tenant involvement and identification with conservation goals. Attention to recommended conservation behaviors and immediate application would be quite likely, because the learning would be useful and applicable to residents' situations.

5/6. Individual Metering With Charges for Excess Consumption. Intensive education/energy advocacy may (6) or may not (5) be present. These consumption control systems assume an accurate, usable norm and a supporting data handling, billing, and collection system. The charge for excess energy consumed would be the rate paid by the base. From the standpoint of producing conservation behavior (frequently

Table 4-3
Cost-Benefit Comparisons of Housing Utility Consumption Control Systems[1,2,3]

	CONSUMPTION AND CONTROL SYSTEM								RATED EFFECTS				
	METERING					UTILITY CHARGES			BENEFITS	COSTS			
ALTERNATIVE	MASTER w/GROUP FDBK	INDIVIDUAL w/INDIV FDBK	EDUCATION, ENERGY CONSERVATION ADVOCATE	NON-MONETARY CONSEQUENCES	FOR EXCESS CONSUMPTION	FOR EXCESS & REWARD FOR SAVINGS	FOR ALL CONSUMPTION w/o EAQ	ENERGY SAVED	START-UP METER INSTALLATION WIRING INSTALLING BILLING	ADM/OVER'L COMPUTER METER MAINT SALARIES EDUC BILL COLLECT	FACILITIES UPGRADING/EQ RETROFIT NEW DEVICES NEW STANDARDS; SPECS	TENANT ACCEPTANCE ABSENCE OF VANDALISM TREFT/LOWER OCCUPANCY RATE ATTRITION
1	X							0	0	0	0	0
2	X		X					+	-	-	0	0
3		X		X				+	-----	---	-	--
4		X	X	X				++	-----	----	-	--
5		X			X			+	-----	---	-	---
6		X	X		X			++	-----	----	-	---
7		X				X		++	-----	---	-	---
8		X	X			X		+++	-----	----	-	---
9		X					X	++	-----	---	-	-----
10		X	X				X	+++	-----	----	-	-----

[1]Ratings are relative to status quo (usually master metered with low intensity energy conservation campaigns); symbols are defined as:

+ - Better than status quo
0 - Same as status quo
- - Worse/greater cost than status quo

[2]Since structural energy conservation improvements are already part of existing DoD policy, their effects are omitted from these analyses

[3]Utility charges for all consumption with an energy allowance in the BAQ is expected to have effects similar to charges for excess and reward for savings

requiring changes in habits), the higher the charge, the more effective it would be in motivating behavior changes; however, operational, as well as energy, costs will change with time and require updating. This would probably entail formal public review and approval processes of the type conducted by public utility commissions which could be quite burdensome. Residents who are initially above the norm would be expected to reduce their consumption while little change would occur among those who are below the norm unless alternative (6) is used. This strategy as well as (7/8) below are totally dependent on the feasibility and application of an energy requirement norm computation, which appears unfeasible without the inclusion of such a large confidence factor as to virtually negate the savings potential.

7/8. Individual Metering With Charges for Excess Consumption and Incentives for Extra Savings. Intensive education/energy advocacy may (8) or may not (7) be present. As noted under alternatives (5) and (6), conservation of energy among residents who are initially below a realistic norm may be minimal. Using the funds acquired from excess consumers as rewards to excellent conservers for additional savings could yield disproportionate conservation effects, because in the larger sense, energy not consumed is available for future or alternative uses. Rewards for extra savings would have very beneficial effects on participation and cooperation in the education/advocacy program, with the likelihood that the largest energy savings would be obtained. The handling of funds in this pair of alternatives could be equivalent to the provision of an energy allowance for quarters (EAQ) and charging for all energy consumed, if norm computation to an exact point value were feasible.

9/10. Individual Metering with Charges for All Energy Consumed. Intensive education/energy advocacy may (10) or may not (9) be present. This pair of alternatives would impose the greatest hardship on family housing residents, because it would instantaneously switch all utilities costs to them, without any EAQ to offset the shift. This would likely lead to a major increase in personnel attrition, because the spouse is the strongest single influence on career decisions, and would be heavily impacted by this alternative.

In addition to the 10 strategies discussed above, all of which are pointed at achieving savings through occupant behavior alteration, which for many reasons is difficult to estimate, there remains another major avenue to achieve savings. This avenue is the basic facility (house) itself, where, by use of the engineering parameters, savings resulting from specific improvements may be better estimated.

B. Rating Criteria.

1. Conservation Effect. An important criterion is the system's effectiveness in producing residential energy savings.

2. Startup Costs. Startup costs include meter installation, hiring and training personnel for meter reading and billing system operation, and installing equipment and software for consumption feedback and billing systems.

3. Administrative and Operational Costs. These costs include computer time, meter maintenance, salaries, bill collection, and education program costs.

4. Facilities and Equipment Upgrading Costs. These costs are for retrofitting present devices, purchase and installation of new devices specifically due to intentions to reap energy savings, and additional costs of devices due to higher conservation standards or specifications.

5. Tenant Acceptance. This criterion refers to absence of vandalism, theft, lower occupancy rates for military housing, and additional attrition. This criterion is key, because lack of acceptance, or resentment, can not only negate otherwise reasonable energy conservation potential, but also lead to personnel attrition.

C. Conservation Control System Effects.

Rated effects of conservation control systems are shown in Table 4-3.

1. Master Meters. Modest savings compared to the status quo (system No. 1 in Table 4-3) are obtainable from intensive education and group feedback in master metering (system No. 2 in Table 4-3). Savings on the order of 5 to 6 percent were actually obtained in an initial controlled study. Higher savings are possible with improved procedures and more pervasive involvement over longer periods of time. Cost is relatively low.

2. Individual Metering and Billing. All individually metered conservation control systems have high startup costs and continuing administrative and operational costs. Also some relatively constant future costs will result from upgrading of facilities and maintenance due to resident pressures to realize the full potential of their conservation efforts.

Different conservation effects of these control systems will primarily be caused by including or excluding the intensive education/conservation advocacy component and the nature of the charging policy.

Education/advocacy will have a beneficial effect in obtaining full potential of the consumption feedback and the charges. As noted above, education/advocacy will improve residents' knowledge and acceptance of the program's

conservation goals. This is expected to result in greater cooperation and positively motivated, knowledge-based changes in residents' consumption behavior.

The charge policy is likely to have differential effects on both conservation and tenant acceptance. Nonmonetary consequences (Nos. 3 and 4) (rather than charging) are likely to produce moderately high utility savings, with all other attendant costs relative to the status quo (No. 1) except those of tenant acceptance.

Charging only for excess consumption (Nos. 5 and 6) is likely to produce moderately high savings, with an increase in frequency of problems of tenant acceptance.

Charging for excess with reward for additional savings (Nos. 7 and 8) is likely to produce higher savings, with about the same increase in the frequency of problems of tenant acceptance.

Charging for all consumption with an energy allowance in the BAQ would be essentially like charging for the excess and rewarding savings.

Finally, charging for all consumption without an energy allowance in the BAQ (Nos. 9 and 10) would be expected to yield high savings accompanied by relatively severe problems of tenant acceptance, increased attrition rates, as well as actual vacancies of military housing because mandatory assignment could not reasonably be practiced, though it is now allowed.

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Chapter 5. OTHER CONSIDERATIONS

I. Legal Implications of Submetering.

When Congress directed DoD to install energy consumption metering devices on military family housing and to assess occupants for energy consumed in excess of a ceiling, many alternatives and both primary and secondary consequences were reviewed. One of the secondary consequences considered was the combination of legality and rates paid for the energy. The energy consumed on most military bases is master metered, and the base pays the utility for the energy at a commercial rate which is typically lower than a residential rate. The base then distributes the energy throughout its facilities to individual consumers, including military family housing. If meters are added to individual family housing units, the combination of a master meter owned by a local utility and individual, subordinate meters owned by the base is called submetering. Submetering for resale is prohibited by the Public Service Commissions (PSC's) of 30 states and the District of Columbia.[1] Two public utilities, Arkansas Power and Light Co., and Commonwealth Edison Co., have apprised local service department personnel that submetering for resale on military bases may result in conflict with the rates and tariffs of their firms. No action was taken when the metering test program was initiated, because the tenants were not actually charged for utility service.

The Department of Housing and Urban Development (HUD) has accepted the positions of the majority of PSC's and advocates that the utilities read and administer the meters on individual public housing units where feasible. Under this condition residents lose the favorable commercial rate for energy and pay the more expensive residential rate.

A. Tariffs and Rates for the Bases.

Public Law 95-82, directing the Secretary of Defense to submeter and bill military family housing occupants, did not change any existing state jurisdictions. The relationship and entitlements, economic or otherwise, between the Federal sovereign and the occupants of Federal military housing have always been beyond the purview of the states to regulate. Once power is purchased by an agency of the Department of Defense at an installation master meter, no further state interest exists in its metering or use for any Federal purpose. Any question concerning this principle of "Federal supremacy" in the instant

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[1] Alternative Metering Practices: Implications for Conservation in Multifamily Residences. Prepared by Booz, Allen, and Hamilton under Contract Number EC-77-C-03-1693 for the U.S. Department of Energy, June 1979.

case is laid to rest by the enactment of the Federal Law (sections 506 and 507, of Public Law 95-82) requiring the Secretary of Defense to do exactly what is proposed. Clearly, no State or State-regulated instrumentality may interfere with this direction of the Federal Government to its Federal officers.

The Department of Defense has consistently advocated and practiced the policy that a DoD department or agency has complete authority for the procurement and regulation of utility services which it provides to others on Federal enclaves. Such sole jurisdictional authority takes precedence over the rules, regulations and policies of state regulatory bodies as reflected in the tariffs of public utility companies. The authority for this position stems directly from the Constitution of the United States, Article 6. If a public utility company insists upon individual metering and billing of military family housing, litigation against such action may be initiated.

Such litigation should take the form of appeal to the Courts in which the power of the State would be challenged under the "Federal supremacy" clause of the Constitution. A legal action before the Federal Energy Regulatory Commission would also be undertaken, in which wholesale rate treatment and service would be sought.*

The "Federal supremacy" issue has been dealt with on numerous occasions, most notably in McCulloch v. Maryland, 4 Wheat. (17 US) 316 (1819), in which Chief Justice Marshall noted "that the constitution and laws made in pursuance thereof are supreme; that they control the constitution and the laws of the respective states, and cannot be controlled by them." There has been no court test which deals directly with the question of DoD rights to submeter and bill for the natural gas and electric services which are purchased from public utility companies, but the following citations deal with some basic issues which would be present:

- United States v. Georgia Public Service Commission, 371 U.S. 285 (1963)

> "...We have then a Federal procurement policy of negotiated rates for transporting household goods of Federal employees...The Georgia policy, which is opposed to this Federal policy, must accordingly give way. For as we noted in Public Utilities Commission v. United States, supra 355 (U.S. at 544), a State is without power by reason

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*California Electric Power Company, 10 FPC 152 (1951); California Electric Power Company v. FPC, 199 Fed. 2nd 206 (9th Circuit, 1952); United States v. Public Utility Commission, 345 U.S. 295 (1953); Cert denied, 345 U.S. 934 (1953).

of the Supremacy Clause to provide the conditions on which the Federal Government will effectuate its policies..."

- United States v. Public Utilities Commission of California, 333 U.S. 334 (1938)

It was noted that Army, Navy, and Air Force regulations promulgated to carry out Federal statutes providing comprehensive policy governing procurement have the force of law. Mr. Justice Douglas in this opinion stated:

> "...the conflict between Federal policy of negotiated rates and state policy of regulation of negotiated rates seems to us to be clear...The conflict seems to us to be as clear as any that the Supremacy Clause, Art. 6, cl. 2, of the Constitution was designed to resolve. As Chief Justice Marshall said in McCulloch v. Maryland (U.S.) 4 Wheat. 316, 427, 4L ed 579, 606, 'It is of the very essence of supremacy to remove all obstacles to its action within its own sphere, and so to modify every power vested in subordinate governments, as to exempt its own operations from their own influence.'"

In all such determinations, a clear distinction is made regarding the timing and method in which the Federal enclave was acquired or created. For the United States to have and maintain exclusive jurisdiction over Federal enclaves, it may be necessary that such enclave be created prior to the establishment of the State's regulatory function from which the Government desires exemption. Clearly, exclusive jurisdiction would not exist in situations in which the Federal facility had agreed to accept and yield to State jurisdiction. In all other cases, Federal supremacy would apply and should be asserted, as necessary.

The total dollar impact of individual metering by the utility companies as compared to submetering and billing by DoD elements would vary among installations. It is safe to estimate that the cost for such services to the base and family housing customers would escalate between 20 to 40 percent depending upon locale.

B. Rates for Residents.

One of the major reasons* the state PSC's restrict submetering is to prevent the landlord from making a profit

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*Alternative Metering Practices, ibid.

from the resale of energy. Such a potential criticism of DoD may be alleviated if the family housing resident is billed for excess consumption at the average rate paid by the base. The latter alternative is similar to the practices of private utilities and would include charging the specific individual for any additional costs incurred in collecting delinquent or late accounts. This procedure would be consistent with guidelines provided by the Comptroller General.

II. Theft and Vandalism Problems.

No verified incident of theft of energy was identified, and an insignificant amount of vandalism was recorded during the DoD metering test program. However, such results may not be representative of what may occur under the proposed metering program. During the test program, residents were not charged for any energy consumed. In addition, a significant percentage of the meters were not out of warranty so that any problems with them could not be assumed to be the responsibility of residents or the base. To provide an estimate of the theft of energy and vandalism experience which may be experienced in a DoD metering program, 12 public utilities and several meter manufacturers were contacted.

The information available from most public utilities was very sketchy. Until recently the incidents of each problem area were not significant. In addition, public utilities have not had the incentive to control such factors, because the costs could be recovered by passing them on to all customers through proposed rate increases, and, as regulated monopolies, cost savings could not be retained as company profits if they exceeded statutory limitations.

A. Theft.

With the recent dramatic increase in the cost of energy, the problem of theft of energy has been brought to the attention of many public utility companies. For the first time, some firms have collected data to use in determining the extent of the problem and how it might be reduced. One firm's study has shown that the incidence of theft has increased at the same rate as the price of energy. In the past customers concentrated on stealing electricity, but, as the cost of natural gas increased, the incidence of natural gas theft has approached that of electricity. Although the annual incidence of thefts varied from 0.05 percent to 10.0 percent of a company's residential meters, the majority reported a rate near 1.0 percent. The only firm reporting on steam consumption described its experience at a 2.0 percent rate.

The cost of energy theft can be broken down into four components. The largest of these is loss of revenue. If the experience of an eastern public utility is relevant and residential rates are adjusted to commercial ones, $8.70 in revenue would have been lost through theft for every DoD meter in 1978. It would have cost DoD $0.33 per meter to correct bills and prosecute those caught; $0.41 per meter would have been spent on a program to control theft; and $0.13 per meter would have been spent correcting the meter installations after the theft was discovered.

The most common method of stealing energy is to pull the meter out and reverse it, causing the recording dials to rotate

backwards. It is also possible to remove the meter and make an unmetered connection with a jumper cable (electricity) or flexible connection (other energy sources). Even a substitute meter is used at times. Of course, the correct system is reinstated before the meter reader arrives.

Another common approach to theft is to bypass the meter by connecting part of the energy consumption of a house to the line before the energy is metered. For example, unmetered natural gas is often used to heat a swimming pool or spa, and condensate from a steam heating system is bled off to a drain before it goes through a meter.

The procedure which is most difficult to spot is to tamper with the meter itself. The gears which record consumption can be altered or slowed down to indicate lower than actual usage.

The trend for theft of energy is upward, and the consumer is getting help which graphically illustrates how to cheat. An underground New York newspaper, TAP, details methods to steal energy and offers advice on how to escape detection. Williams has published a book, "Stopping Power Meters," which describes and illustrates methods to stop or slow down meters. It is advertised in a nationally distributed magazine for $4.95. Alex Haley's new book, "The Overload," provides some useful guidance to would-be thieves. With all of this information available, it is essential that a program for controlling theft of energy be included in the DoD plans.

A very complex program could be initiated to control theft of energy in DoD family housing areas. However, such a program may not be required as long as a systematic approach is used. Some of the following steps may be instituted to alleviate the problem of theft:

1. Design the installations with theft control in mind.

    a. Locate meters on the exterior of buildings. Theft appears to decrease as meters are moved outside the building. Although vandalism increases under this condition, the incidence of vandalism is only 1/5 to 1/10 that of theft, and the cost is even less.

    b. Place master meters over sections of the housing so that comparisons can be made to spot possible locations of theft.

    c. Install seals on all meters. All presently installed meters should be sealed if a decision is made to actually bill of residents since the incentive to tamper with meters would then increase greatly.

2. Develop and use computer programs to detect changes in consumption patterns which are not attributable to seasonal or other factors.

3. Train and hold responsible meter readers, service representatives and bill collectors for the identification of theft techniques.

4. Place stickers on meters and provide other education about the consequences of theft.

5. Develop and administer policies and procedures for use in identifying and following up on theft cases. Maintain a record system of theft incidents.

6. Inspect for tampering all meters removed for periodic meter changes.

7. Initiate an inspection program to follow up on possible incidents of theft.

8. Engage in periodic, unannounced inspections of meters outside the meter reading cycle.

9. Install special meters and associated equipment designed to make theft more difficult.

B. Vandalism.

Very little data were available from public utilities on the frequency and cost of vandalism. The estimates provided from the best judgments of the respondents ranged from 0.1 percent to 2.0 percent of the electric, natural gas, and propane meters damaged annually, but one company reported a documented annual vandalization rate of 0.2 percent of its electric meters. The estimated costs to repair/replace the vandalized meters ranged from $5.00 for natural gas to $28.00 for electric. Electrical meters are usually replaced while natural gas meters can usually be rebuilt.

Electric and natural gas meters are usually damaged by being hit with something or shot. Therefore, as the meter casing and glass are strengthened, the incidence of vandalism for those meters is maintained or reduced. A 2 percent rate was reported by a propane distributor, because the soft copper tubing associated with the meter was easily and frequently damaged. Where the incident rates are highest, i.e., for high density, low-income areas, special enclosures may be built around the meters, but this approach is infrequent because of its high cost.

No special programs to deal specifically with the problems of vandalism were found. Only two companies reported an increase in vandalism. The rest reported stable rates.

However, it was felt that the installation of new meters outside the building made them more accessible to vandals. As the cost of energy increases, it is thought that the rate of vandalism will also increase.

No public utility experience with residential steam, hot water, kerosene, or fuel oil meter vandalism was found.

Vandalism appears to be partially controllable by the design of the metering system and the purchase of hardened meter casings and glass. The design could limit the opportunity for vandalism by minimizing the presence of unreinforced materials such as copper tubing. In extreme cases special housings could be placed over the meters, but such an approach is very expensive.

If an effective program to control theft of energy is instituted, it would be a simple process to include vandalism as an additional component in the recordkeeping and educational portions. If the incidents increase, then a more complete program could be initiated.

III. Physical Improvements.

Energy conservation initiatives may be pointed toward causing the housing occupant to use less energy directly by encouraging such steps as moderating space heating and cooling objectives, using less hot water, installing lower wattage light bulbs, and generally using less primary energy. Where there is genuine waste, and to some extent across the board, this strategy will result in reduced energy consumption; however, there is a subjective threshold beyond which further effort in this area will result in real as well as perceived adverse impact on the "quality of life" within the home. (Even the OSD direction on space conditioning, 68° heating and 78° for cooling for the norm for this test may in fact represent a derogation of quality of life compared with civilian homes where the acceptance of these standards is more voluntary.)

To achieve further savings, without unwarranted derogation on quality of life in military housing, a different approach is necessary. This alternate concept is not new; however, there is considerable room for further application. The physical improvement of family housing units to make them more energy efficient has been ongoing for some time as a part of the DoD Energy Conservation Investment Program (ECIP). An additional aspect of this program has been the limited use of solar energy as a true alternative to more conventional heating. This effort represents use of a new energy source rather than concentrating on conservation of increasingly more difficult additional percentage increments of current energy resources.

The DoD ECIP was established subsequent to the energy crisis during the winter of 1973. Initial funding of ECIP projects occurred during FY 1976, and the program has continued, although FY 1980 funding was severely reduced by OMB action.

Original criteria for funding of projects for facility improvements included a maximum payback period of 6 years, and many projects for increased insulation, storm windows and storm doors were completed. Approval was based on a certain dollar payback that is sensitive to errors in estimates of the future cost of energy and that assumes the actual availability of energy at some cost. The approval threshhold of 6 years' payback left many potential energy conservation improvements unfunded. Such improvements include direct-spark igniters, flue dampers, limited-range thermostats, additional insulation up to optimum levels, and solar domestic hot-water heating.

Presently an economic analysis based on present worth techniques is required to determine the benefit/cost ratio of a proposed project as a criterion for funding. The project must amortize itself in savings over its economic life, i.e., have a benefit/cost ratio greater than 1.0. This approach may result in funding more energy conservation improvements, but has the

same problems of projecting future energy costs and assumes basic energy availability.

A separate measurement of prospective benefit of a given improvement is the energy to cost (E/C) ratio which compares projects on the basis of actual energy to be saved per unit of acquisition and life cycle maintenance cost, such as millions of Btu (MBtu) per $1,000 of cost. This ratio is not sensitive to future energy cost variations, nor does it directly assume future energy availability. We consider essentially the present cost of effecting future energy conservation, which appears most consistent with the intent of Congress within the housing metering program.

Heretofore specific requirements for facility improvements, in the form of projects, have been developed by various DoD field activities in consonance with broad direction and only where prospective payback periods, benefit/cost ratios, and energy/cost ratios were judged to be at or above the established threshholds. As a result we have done those improvements that had the highest or quickest payback, i.e., skimmed off the cream. Intuition, as well as some specific knowledge, supports belief that there is far more that can be done to actually conserve more energy throughout the entire DoD family housing inventory. Development of such all-encompassing data was beyond the scope of this study; however, because of its cost, development and comparison with the energy conservation potential and estimated cost of metering of all housing units is strongly recommended before proceeding further with meter installation.

A. Little Rock AFB.

Just prior to initiating the data collection phase of the metering test program, the Air Force completed several ECIP projects on the 1,535 all-electric (heat pump) housing units at Little Rock AFB. These projects included the following: installation of additional attic insulation, completed 31 May 1977 at a cost of $87 per unit; connection of the bathrooms to the house air distribution system and removal of the originally installed electric resistance bathroom heaters, completed 14 December 1978 at $83 per house; addition of insulating jackets to water heaters, completed 14 December 1978 at $52 per water heater; replacement of thermostats of new minimum/maximum type, completed 14 December 1978 at $43 per residence; establishment of outside temperature controls for more efficient heat pump operation, completed 14 December 1978 at $133 per installation; provision of storm doors and windows, completed 26 December 1978 at $719 per dwelling.

This $1,117 investment per family unit reduced the average annual energy consumption per square foot for these structures by 18 percent. An annual kWh per square foot figure of 23.5 in October 1978 decreased to 19.2 in October 1979.

In 1979, the energy consumed in the same units was compared with that used in three houses randomly selected from the adjacent Little Rock civilian community. The Arkansas Power and Light Company (AP&L) supplied detailed metering data for these all-electric homes, which were heated and cooled with heat pumps. The houses were surveyed and subjected to the same computer norm simulation procedure used in the metering test program for the 1,535 military family housing units located in Little Rock AFB.

Although the size of the sample is very small, an interesting comparison with housing which had not received the extensive modifications included in the ECIP was provided. The three AP&L heat pump houses deviated 158 percent to 69 percent from their individual monthly norms over winter and summer respectively. The average consumption over the entire period of time was 24 percent above the average monthly norm calculated for each house. The 1,535 on-base Little Rock AFB heat pump houses deviated from their norms by 138 percent and 86 percent between winter and summer for an average of 7 percent above their norms. It appears that the occupants of the on-base military family housing with extensive energy improvements used 14 percent less energy than did their civilian counterparts.

The LRAFB sample of 1,535 all-electric homes may be large enough to serve as a norm representative of units with extensive energy conservation improvements. During the 12 months of November 1978 through October 1979, the average per unit energy use was 21,172 kWh. AP&L provided data for the same period from 4,002 all-electric homes in the Little Rock Division (Little Rock, Pulaski, and Saline counties). The average consumption for those civilian houses was 25,626 kWh, 121 percent of the LRAFB housing usage. Thus the energy-efficient military housing units used 17 percent less energy than AP&L's division-wide, all-electric customers.

B. Naval Weapons Station, Charleston.

In FY 1978 and the first 9 months of FY 1979 data on the electricity consumption for 400 all-electric houses at NWS Charleston were collected. Two hundred of the houses had been built between 1950 and 1969 and had an average floor area of 1,290 square feet. The other 200 had been built in 1970 or after and had an average floor area of 1,152 square feet. The latter group of houses differed from the former not only in age but also because they were of multi-unit, two story construction and had storm windows and better insulation. Over the 21-month study, the amount of electrical energy consumed in the newer units was 38 percent less per square foot than in the older units without the energy conservation improvement. All occupants in the 400 units had been involved in an aggressively administered energy conservation program.

C. Potential Savings.

As a measure of the potential energy savings and cost of such a concept we may consider that the approximately 310,600 DoD family housing units, with an aggregate area of 403,780,000 square feet, consume an average of 200,000 Btu/square foot annually. The accomplishment of a combination of actions by occupants and a structured program of improved energy performance by the family housing unit should maximize savings. While metering and educational techniques seek conservation on the part of the occupant, the ECIP approaches the reduction of energy usage via improvements in the housing envelope. Because the effects of the interrelationship between subjective (people) and objective (facilities) are obscure and complex, some assumptions have been made in order to measure potential for accomplishment. Restated as a measurement of the total energy saved by a 1 percent reduction, i.e., $(.01)(4.0378 \times 10^8 \text{ SF})(2.0 \times 10^5 \text{ Btu/SF}) = 0.080756 \times 10^{12}$ Btu, say 0.81 trillion Btu annually.

A further assumption is that a reasonable ratio of MBtu saved per $1,000 invested (E/C = N ratio) would be an N of 30, resulting in a total investment of $1,000 x 800,000/30 = $26,600,000, say $27,000,000.

So, over the range of all possible improvements with an average energy/cost ratio N of 30, we can expect to save 810,000 MBtu per year for every $27 million invested. As the "cheaper" projects are completed, the cost to achieve each additional percent of saving will increase until the average N for the projects will go below 30. However, within military family housing much remains to be done to meet the average E/C ratio of 30 used in this example. From the experience at Little Rock AFB, it is reasonable to assume that a reduction of up to 12 percent, where the total cost would be on the order of $324,000,000, could be achieved with an average N of 30 across the projects. This energy conservation goal is comparable to the best percentage saving predicted by the three metering alternatives described in Chapter 8 of this report.

The most significant opportunity for energy conservation lies with reductions in the space heating and cooling load because it generally represents about 60 percent of the total unit demand. Within that subject area, there are believed to be three major retrofit opportunities:

- Reduction of heat loss or gain through added insulation;
- Reduction of heating or cooling loads through reduction of air infiltration; and
- Reduction of heat loss or gain through windows via terminal blanketing and solar shading.

The reinsulation program is simple and of low cost. Its most significant problem lies in establishing how much insulation is cost effective and what variations of retrofit techniques are desirable.

Air infiltration (leaks through the envelope) is subject to much misunderstanding about its presence and how much is desired. Some must be present to support combustion, life, etc., but it simultaneously results in the loss of heat. The techniques for optimally retrofitting to decrease infiltration are not yet fully developed and require further study. For example, the need for recaulking, weather stripping or other closure techniques is presently determined by direct observation of an apparent crack or hole and many possibilities are overlooked. The real need should be established dynamically by imposing pressure or sound tests for actual infiltration.

The windows of a housing unit generally represent about 10 percent of the total envelope and account for approximately 50 percent of the heat loss or gain. An emerging project line provides insulating blinds over windows when those windows are not actually required for visual or illumination reasons. The major areas for investigation of this technique are mainly related to the occupants' voluntary acceptance of participation in the use of thermal barriers, i.e., will they, can they, be taught to use them to advantage?

There are numerous other techniques for ECIP projects. The opportunities they represent generally focus on the balance of the unit energy load, which includes domestic water heating, cooking and food preservation, and lighting.

Other energy conservation technology supports the development of alternative (new) energy sources, rather than concentrating on the reduction of the present energy consumption envelope. To avoid unacceptable long-range impact on the quality of life within our housing units a balance must be struck. At present these energy alternatives, including solar energy, have an N on the order of 10 to 15; therefore, direct comparison on a cost basis is not possible; however, a balanced energy conservation program must support both technologies.

The DoD ECIP has been structured to maximize energy savings while minimizing payback time on investment. It has compared all energy conservation initiatives on this common basis regardless of whether the energy is being conserved, or new energy sources are being created, as in the case of solar energy. Approximately $100,000,000 in solar domestic hot water projects are possible at this time in warmer latitudes where paybacks average less than 15 years. These projects would involve approximately 50,000 units and would save approximately 874,000 MBtu (150,000 equivalent barrels of oil (EBO)) per year.

Replacement of equipment and appliances with more energy-efficient ones is another avenue available to the military landlord. The advent of more efficient refrigerators, heat pumps, and fluorescent lighting offers good potential for improvements as a result of individual studies.

D. Conclusions.

What has been presented in the foregoing paragraphs represents an alternative policy to overall metering which may be implemented more easily in investment steps rather than the "all-or-nothing" approach of a metering program. The number of steps can be chosen or timed to fit national policies, with a potential for energy savings comparable to or better than metering, at a cost equal to or less than metering, and largely devoid of the massive and unquantifiable personnel impacts. The potential savings from a given improvement is estimable far more accurately than potential savings of an alternative involving human occupant behavior modification because the facility status quo is easily determined while the mind-set of the occupant and his personal receptivity or resistance to further change is predicated on many things, including the changes he has (or thinks he has) already made.

IV. Energy Conservation Advocacy Program.

The Science Applications, Inc., work on norm development (see Chapter 2 of this report) noted that the behavior of occupants varies widely, so widely in fact that it has been difficult to establish a norm to represent good conservation practice. If this behavior can be made more efficient and energy conserving, a significant reduction in the consumption of energy in family housing can be achieved.

In Chapter 4, "Occupants Response," section II.C.2.b, reference is made to a program which demonstrated its effectiveness in getting military housing residents to reduce their consumption of energy.

This is a model program designed to achieve reduced immediate and long-term utility consumption by residents of military family housing without installation of individual utility meters. The model program is designed to cover one complete cycle (year), with the program being repeated in the same general format in succeeding years (see Table 5-1). Thus, over a period of 1 year every resident would be exposed to a complete conservation education program for their climatic zone. If the family moved to a new area, the program would immediately cue them to the key factors affecting their utility consumption in the new climatic zone.

The elements in this model program were tested in a short-term field trial conducted at the Navy's Corry Station family housing in Pensacola, Florida. That effort achieved a 5 to 6 percent savings in electricity consumption during the summer air conditioning season. Improvements and additional program development may raise the savings up to 10 percent.

The model program is based on the following major principles and methods:

- Face-to-face coaching regarding energy saving methods and practices
- Conservation advocacy by a person seen as expert and concerned about the quality of the tenants' lives
- Active participation in the learning and change process by all family members from school age up
- Identification with neighborhood and community
- Communication of community social norms regarding energy consumption
- Group (neighborhood and community) energy consumption feedback on a regular basis

Table 5-1
Model Long Term Energy Conservation Advocacy Program
for Navy Family Housing

	TRANSITIONAL SEASONS (Minimal heating or cooling)	HEATING/COOLING SEASONS
Program Objectives	Develop plan, schedules, and materials for upcoming heating/cooling season; perform repairs, rehabilitation, self-help improvements; train assistant advocates	Reduce utility consumption by behavioral changes of residents.
Housing Management	Perform structural energy audit, repairs, and rehabilitation; update instructions and directives; set conservation goals for station.	Publicize conservation goals and achievements; implement non-housing energy conservation programs.
Conservation Advocates	Planning: Obtain information; pamphlets, etc.; locate resource persons; schedule people and activities; develop activities, materials and training programs; administer training; conduct check-in indoctrinations. Publicize self-help for upcoming season.	Implement conservation advocacy program: Involve resident families in educational process; obtain their commitment to adopt conserving practices; deliver feedb[illegible] edit newsletter with conservation t[illegible], feedback and recognition of achievements; conduct check-in indoctrinations.
Resident Families	Self-help improvement of housing unit.	Participate in conservation program activities and events (children and adults); commit all family members to adopt conserving practices.
Program Evaluation	Set up and test procedures for data gathering, handling.	Perform data gathering, analysis, summary.
Conservation Emphasis	Lighting, food preparation, water heating.	Space heating/cooling.

The overall structure of the program is to have energy conservation advocates conduct intensive resident contacts at the beginning of the high-energy-use periods (heating season and cooling season) to involve residents in establishment of good practices and setting family goals. The beginning of the heating and cooling seasons were chosen for heavy emphasis, because space heating and cooling are the largest users of energy (60 percent overall, according to the FEA in 1974). Because the majority of this usage would be concentrated in two well-defined time periods, the greatest impact with the maximum efficiency can be achieved by focusing on these two periods. There would be regular monitoring, feedback, and information presented during the remainder of the season. There would be less intensive monitoring and reminders during the intermediate seasons. The intermittent high-intensity program is necessary to have significant impact on residents' behavior while avoiding satiating residents to the point where they ignore conservation education and appeals.

The energy conservation advocate positions would be filled by college graduates, preferably with experience living in military family housing, who are highly gregarious and possess some administrative and planning ability. One such person would be required on a full-time basis throughout the year for each housing management office. During the first 2 months of the high-use period the supervisory energy conservation advocate would be supplemented by additional temporary persons of similar qualifications in the ratio of one person per 100 dwelling units.

During the transitional seasons, when residents have less extensive heating and cooling requirements, the supervisory energy conservation advocate would plan the next season's program and develop materials (e.g., poster contests, children's in-home activities, speaker series) to be used during the high-intensity periods. Each program would be designed by the energy conservation advocate to suit the local community and its resources. There would be flexibility to coordinate with community governmental agencies, schools, and utility companies to put together the strongest possible local program using the combined efforts, resources, and capabilities of all concerned parties.

In support of the energy conservation advocacy program, housing management could use the transitional seasons for repairs and rehabilitation of housing units, updating their instructions and directives dealing with energy conservation, and establishing conservation goals for the entire command. Where self-help programs are to be coordinated with the energy conservation advocacy program (e.g., changing furnace filters or installing door and window seals), materials and supplies would have to be ordered and made ready for distribution to housing residents in timely fashion during the high intensity period of the program.

Also of crucial importance during the inital planning season is setting up and testing procedures for data gathering and data handling. The model requires regular weekly or biweekly feedback of group utility consumption, i.e., the housing complex must possess a master meter for each energy source, distinct from nonhousing consumers on the base. Given such metering, some additional development is required to provide a simple, straightforward means of comparison of current consumption with historical records of the previous year's consumption in the same housing complex. This requires that some simple method of adjustment be developed to correct for differences in climatic conditions between periods.

Any required training of personnel in structural modifications (meter installation or repair) and software development must be accomplished prior to initiating the high-intensity period.

At the beginning of each heating and cooling season an intensive 2-month education/advocacy program would be mounted. Active involvement of residents would be obtained by means of a series of personal contacts with each family by the conservation advocates during which residents would be given energy conservation information and encouraged to commit themselves to adoption of new conservation practices. Programs and activities for all family members would offer interesting ways of motivating conservation consciousness and learning and applying good practices. For example, children could role-play "energy detectives" who spot "energy thieves" or bad practices operating in their household. They could work toward good practices for which they would obtain incentives, such as energy conservation stickers.

The energy conservation advocates would monitor consumption during the heating and cooling seasons and report consumption levels back to residents through a local energy conservation newsletter (e.g., "The Kil-A-Watt"), and would interpret the results in terms of relative usage by various groups or housing complexes in relation to earliest periods. (See Appendix M.)

Housing management could support the energy conservation advocacy program by use of a check-in indoctrination procedure for new residents which would stress the importance of utility conservation and would provide advice on how this might be most effectively accomplished in the particular climate region given structural characteristics and appliance inventory of the family housing units. This check-in process could be administered by the energy conservation advocates.

V. Summary and Conclusions.

This chapter has addressed some diverse factors and possible considerations implicit in or likely to arise from the application of metering to family housing as directed by Congress. The substance of the following paragraphs is that from the aspect of the considerations reviewed, the metering program is possible although workability and potential for saving is greatly impaired by the lack of accuracy of norm predictions, and the improbability that the required billing accuracy of ± 1 percent can ever be obtained without unacceptable regimentation of all aspects of the day-to-day lifestyle of the occupant. However, there appears to be another possible alternative.

The legality of submetering of utilities in military housing, whereby the energy used by an occupant above the norm would be essentially sold to him at Government purchase unit cost, was reviewed. Although 31 states now have laws essentially prohibiting submetering in the private sector, the principle of "Federal supremacy" is considered to facilitate such submetering as is directed by Public Law 95-82, although this interpretation could be challenged in the courts by a State government, a utility company, or by housing occupants under a class action suit. If for any reason the proposed submetering were abandoned in favor of individual unit billing directly by the utility companies, the residential billing structure as now applied would cause the overall cost of utilities per unit to escalate from 20 to 40 percent above present unit costs incurred at commercial rates. In some cases, the segregation of the housing utility consumption segment from an activities total utility bill could also result in a slight increase in overall energy unit costs due to stepped rate structures.

Potential theft and vandalism experience of the private sector was reviewed as an indicator of probable incidence in military housing. Vandalism is not considered to be a major problem; however, available information did not cover several types of meters that would be included in the military housing system. On the other hand, theft of energy is growing as a problem in the civilian sector and probably would be equaled in the military community. Incidences of theft by various means could exceed 10 percent with responsibility for such action very difficult to establish.

Energy conservation-oriented improvements for housing facilities and appliances have been underway for some time as dictated by good management practices, and within funding limitations. As projected energy costs continue to escalate, and outright energy shortages, which defy simple economic model tradeoffs become more likely, actual conservation of energy objectives become more critical than specific payback or cost/benefit criteria. There is a relatively small projected

savings of energy from the metering as directed by Congress (6 percent); however, the annual costs exceed the estimated value of energy saved. Some other metering alternatives offer slightly higher energy savings estimates, but with consistently negative annual payoffs.

On the other hand, greatly expanded energy conservation facility improvements offer energy savings of equal or greater magnitude, without the adverse morale and personnel retention aspects of any metering program involving payment of utilities bills by military quarters' occupants. Although the exact scope, cost, and parameters of such a program are beyond the scope of this study, conceptual studies strongly suggest that energy savings equal to or greater than those available through any metering program may be achieved through a vigorous program combining facility improvements and occupant education and motivation. The costs to achieve this saving would be less than the costs of metering, considering first cost and annual cost, and the payback on initial cost would be 15 years or less. This program could be done on an incremented basis while metering requires total commitment. Savings from metering begin only after the system is complete (5 to 6 years), while benefits from each increment of facility improvement begin as soon as that increment is in place. The potential adverse morale and retention impact of metering, though difficult to quantify in dollars, are indisputably real and will greatly increase the direct costs associated with those alternatives, making the improvements alternative clearly more attractive.

VI. Recommendations.

It is strongly recommended that the potential for energy conservation through facilities improvement and occupant education and motivation be further studied and quantified before embarking on an extremely expensive universal metering program. The potential for this alternative and its scope and funding limitations should be evaluated on the basis of potential for actual energy conservation or new energy source development using realistic energy cost projection and considering the impact of further scarcity of energy at any price.

Chapter 6. PERSONNEL IMPACTS

I. Introduction

Previous chapters have dealt primarily with the technical problems associated with a utility metering and excess-consumption billing system. Of equal, and potentially even greater, significance are the effects that such a program would have on military people--on their morale, on their personal financial situation, and on their propensity to continue in their military careers.

Certain aspects of these human considerations have been touched upon in preceding chapters during discussions of norm development, meter installation problems, and particularly in the discussions of military versus civilian consumption patterns and the consumption changes that might be expected with a move to a metered environment. However, it will be important to avoid focusing on isolated issues or to view potential problem areas solely from a managerial, as distinguished from a leadership, point of view. To reasonably assess the potential effects of the program on the members themselves, it will be necessary to view the program from their perspective and to review the cumulative effects of the various problems on their lifestyles and attitudes.

In addition, any metering initiative must be considered in the context of members' past experiences and in light of the unique environment of the military on-post community. Potential changes in behavior patterns that may result from this proposal should then be scrutinized, with an appropriate determination of the institutional desirability of those changes, as well as their effects on other operational or policy issues. For example, if a metering program were actually implemented, it would almost certainly necessitate significant changes in existing housing assignment policy.

At first glance, the metering and excess-consumption billing proposal might appear to be a worthwhile project based on the prospect of curtailing energy waste in military family housing; however, the associated personal and institutional costs cannot be ignored. Ultimately, a decision whether or not to proceed with a metering program must depend on an overall assessment of the relative magnitudes of the energy savings actually realizable versus the cost of the proposal--not only in monetary terms, but also in terms of human and readiness costs.

While the prospect of substantial energy savings at small or moderate cost may be quite attractive, that of a small reduction in energy consumption at a substantial cost would be

highly undesirable. Between these extremes, some assessment must be made concerning the location of the point of diminishing returns at which the energy savings would not be worth the cost. Beyond this point, other alternatives should be pursued to achieve the desired result without the negative side effects.

II. Equity Considerations.

A major factor in determining the kind and intensity of reaction by family housing occupants to a metering program would be on the degree of fairness, both actual and perceived, entailed in establishing norms for utility consumption. Because the norm would determine whether a bill would be issued to a given occupant as well as the amount of the bill, a large number of queries could be expected from occupants concerning the number and validity of factors used in developing the norms for their particular units.

For example, to the extent that the norm development did not assess all variables having a bearing on determining reasonable consumption, it would be seen as (and would in fact be) an inequitable basis for assessing financial penalties for excess usage. Further, other questions invariably would be raised concerning the accuracy of the measurements taken or the validity of the factors used in compiling the normative data, whether for an individual family unit, a certain geographic location, or for the whole of the family housing inventory. These types of considerations are discussed below.

A. Unmeasured Variables.

As described in Chapter 2, a large number of data items were used in development of the consumption norms for the purposes of the metering test. The algorithm to calculate one norm for one housing unit, for a 30-day period, for a single energy supply, involves 289 pieces of data and entails 21 calculations.

Even so, the list of variables incorporated in the norm development process is far from exhaustive. Numerous structural, environmental, and human factors were not considered--primarily for reasons of simplicity--although these factors in the aggregate could have a significant impact on a true calculation of what would be considered normal consumption patterns.

For example, equipment efficiencies are considered on a blanket annual, average basis for the purpose of norm calculation. In fact, they will vary from house to house as a function of load. Heat pumps, as well as mechanical air conditioners, will also vary hourly as a function of ambient operating temperatures. Variations in ceiling heights will affect heating efficiency. Certain weather conditions that could affect both the thermal performance of the structure and the performance of installed equipment were not evaluated or tracked. These include the unit's orientation to the prevailing wind, the wind velocity, and relative humidity. The actual number and ages of the dependents in the household were not used in the norm equation except for the purpose of calculating hot water usage. In fact, these variables materially affect the number and types of appliances in the household, heating or cooling requirements

(for aged dependents), as well as the average number of entries into and exits from the residence during the course of a normal day.

The inclusion of these factors could greatly magnify the complexities of the system only to reveal new unevaluated performance variables. Even the color and composition of exterior paint could be an influencing factor. So could the duty hours of the military sponsor, because energy consumption patterns for shift workers can vary considerably from the patterns of those with normal duty hours.

Thus, the list of potentially significant variables for a given household could be virtually endless, generating legitimate cause for complaint from occupants who would feel that the norm did not adequately model their unique usage conditions, and making it nearly impossible for the responsible agency (housing officers, engineers, etc.) to explain the norms satisfactorily to the occupants.

B. Repair and Service Requirements.

Another consideration is that the occupant's usage may be determined in part by the state of repair of the structural facility itself as well as that of its major equipment components. On military installations, the Government is responsible for service in these areas. This is not an occupant responsibility and is, in fact, beyond the control of the occupant. To the extent that consumption-related service requirements are not performed in a timely manner, occupants receiving bills could be expected to express legitimate grievances to the effect that the excess use was not due to personal overconsumption.

C. Meter Accuracy and Reading.

As pointed out in Chapter 1, accurate calibration of metering devices would be essential to any billing system. Because of compressed installation schedules, meters were not recalibrated by contractors prior to installation on the test units. Under actual billing conditions, recalibration would be essential prior to installation and at least every 5 years thereafter.

Meter reading accuracy would also pose a potentially serious problem for on-base occupants. Applying a 5 percent error rate to the 538,000 monthly readings--which Table 1-10 indicates would be required under a full metering system--would yield over 26,000 erroneous readings each month. To the extent that such errors yielded consumption readings above the applicable norms, they would generate unwarranted bills.

Potential error rates must be of significant concern under such a program because these errors would not be self-correcting, as they are in the civilian community. That is, if a

civilian consumer is erroneously overcharged one month, a presumably correct meter reading the next month will yield an offsetting undercharge. However, military members under the proposed system would be "starting with a clean slate" each month, because their consumption would be measured against an absolute usage norm for each given month. Without cash credits for consumption below the monthly norm, an undetected erroneous overcharge would be irretrievably forfeited.

The metering test showed that certain types of metering systems exhibit persistent accuracy problems. At present, there is no method of adequately measuring steam as an energy source for residential billing purposes. Similarly, inaccuracies in the indirect measurements of elapsed time meters for the purpose of determining fuel oil or natural gas consumption render such systems highly questionable. The test results showed that master/slave meters are unacceptable measurement systems because each particular housing unit's consumption is in part dependent on the consumption of the other units in the energy network, and because of the rapid compounding of even small errors in such interdependent networks.

If a metering system is directed, no charges should be implemented until adequate systems have been developed to replace all existing steam condensate, elapsed time, and master/slave metering systems. Otherwise, obvious and quite serious equity concerns would be generated by the practice of charging only the occupants of units with accurately measurable energy sources.

D. Residential Computer Analysis.

For the purposes of the metering test, individual computer analysis of each unique residence was not undertaken, primarily for reasons of time and complexity. This means that measurements of a particular resident's consumption were not based on analysis of that housing unit's unique dwelling configuration and construction features, but upon models developed from samples of various configurations and structural types. Thus, the sample norms may not be completely representative of actual individual dwellings and living conditions.

Such sampling techniques would obviously form an inappropriate basis for measuring energy consumption for actual billing purposes. Any structural, configurational, or orientational feature of a particular unit which made that unit unique from others on the installation would require an individual computer analysis of the unit for the purpose of determining a similarly unique norm for the occupants of that unit.

E. Occupant Understanding and Perceptions.

The preceding paragraphs have discussed the potential problems of imprecisely defining a norm or failing to develop a

unique norm for each residence and occupant's consumption. These problems would be compounded by difficulties in accurately communicating the system methodology to the family housing occupants.

A major determinant of the degree of tenant acceptance achieved under an excess consumption billing program would be the occupant's level of understanding of the system. To a certain extent, this presents a paradoxical credibility problem. A relatively simple system is easy for the occupant to understand, but is also susceptible to occupant criticism for omission or oversimplification of significant consumption-related factors. On the other hand, the more variables that are added to decrease the margin of norm error, the more complex and confusing the system becomes. This, in itself, could contribute to a lack of understanding and a lack of acceptance of the norm by the occupant. Add the probability of at least one meter reading error per month among a given occupant's circle of acquaintances, and it is not difficult to foresee potentially serious credibility problems from the occupant's perspective concerning the validity of the norm and billing system calculations.

Perceptions of errors or inaccuracies may easily arise even in circumstances where the data are valid. For example, acquaintances who occupy similar housing, but who have different family compositions, different appliances, or differences in other less visible norm-covered variables may have totally different billing experiences in a given month without being able to identify to their satisfaction the reason for the apparent discrepancy. Such misunderstandings, as well as the inevitable reading errors and norm deficiencies, would all contribute to occupant resentment of what they would view as an unfair billing system. Even those not personally affected would probably be able to commiserate with one or more friends whose seemingly legitimate complaints could generate concerns about their own potential receipt of an apparently arbitrary bill on some future occasion.

Over time, such concerns could multiply to a very serious level, particularly when real or perceived system errors resulted in repeated financial penalties.

F. Norm Validity Deficiencies.

As indicated in Chapter 2 of this report, the energy consumption norms developed during the metering test achieved a statistical reliability of only approximately 85 percent. Any proposal to use a norm of this statistical quality for billing purposes would be highly questionable and should be expected to generate numerous strong complaints from family housing occupants.

If metering and an excess-consumptior billing system are directed to be implemented, to provide some degree of equity, the system must allow an appropriate margin for error to help offset the validity deficiency. For example, if norm validity remained at 85 percent, no bills should be rendered except for those households whose consumption exceeded 115 percent of the norm.

III. Unique Environmental Considerations.

To a large extent, past discussions of metering and energy conservation proposals for military family housing have been based on an assumption that the on-base housing environment is comparable in many respects to that of the local community--that is, that on-base occupants would behave in the same manner as civilian tenants or that private sector energy consumption experience would be readily transferable to on-base military communities.

In truth, such is almost certainly not the case. The military family housing area represents a unique community concept that is unduplicated in the private sector. In this regard, its occupants must abide by certain rules and regulations that would not be tolerated in civilian communities. Any analysis of expected changes in behavior patterns as a result of changing family housing rules or entitlements should not be based on assumptions culled from civilian experience, but rather must be conducted with proper consideration for the pressures and limitations inherent in the unique on-base environment. The following is a discussion of some of these factors.

A. Institutional Influences on Military Family Housing Occupants.

The services exercise a degree of control over the lifestyles of family housing occupants that is rarely encountered in the private sector. The on-base resident is an integral part of the military institution on a 24-hour-per-day basis. In this regard, the occupant's home is as much a part of the installation as his or her workplace. Uniquely, the member's conduct in the home environment may in some ways affect his or her career progression and serve as the basis for administrative sanctions of even disciplinary action.

Family housing occupants are subject to strict rules concerning grounds appearance and interior and exterior decor. Units must pass cleanliness inspections approaching "white-glove" meticulousness upon exit. Any failure to comply with such rules may be reported directly to the installation commander, who may take any of a variety of actions.

This institutional control also extends to cover the occupant's use of the various environmental amenities for which the civilian tenant usually has to answer to no one but himself or herself. Thermostat settings, lighting, water consumption, and actual control over the major appliances are all within the domain of the installation commander, who may direct and enforce limitations on any or all such services.

B. Existing On-Base Energy Conservation Environment.

In fact, military commanders have exercised these controls to varying degrees since the early 1970's, when rapidly rising utility costs began to impose severe constraints on commanders' operations and maintenance budgets. Voluntary curtailment of occupants' energy consumption has been urged at every military installation as part of base-wide efforts to reduce utility usage. Emphasis is added by commanders' repeated personal urgings during staff meetings, commanders' calls, and other official functions. Frequently, these exhortations have been accompanied by specific formal reduction goals, such as a 10 percent reduction from the previous year's consumption.

At many installations, these directions have gone beyond voluntary measures to mandatory limitations on use of the various utilities. For example, thermostats on all hot water heaters have been set back to 140° F. Outdoor decorative lighting has been eliminated during holiday seasons. Limitations have been placed on the number and type of window air conditioners in family housing. Space conditioning thermostat settings have been mandated at no higher than 72° F in winter and no lower than 78° F in summer at all installations. Electric demand deferral units have been installed on space conditioning units at many bases to electronically curtail usage during peak electricity loading periods. Outdoor use of water has been eliminated on occasion during dry summer months.

At some installations, controls have extended to physical disconnection of all family housing air conditioners (unless required for legitimate health reasons) except for peak summer months (e.g., mid-July to early September). Even then, directives have been issued that air conditioners not be operated at night. In some cases, enforcement has been carried to the extent of employing "energy monitors" to drive through housing areas at night to identify sponsors violating such directives. Spot checks of space conditioning and hot-water thermostat settings are also commonplace at many installations.

These examples serve to convey the sense of urgency and priority that has been placed on energy conservation efforts in military family housing. Even where enforcement efforts have been less vigorous, commanders have conveyed repeatedly and very strongly their firm expectations that all family housing occupants will do their utmost to conserve valuable energy resources. This need has been understood and accepted by the large majority of occupants.

C. Public Service Considerations.

An important consideration in an analysis of behavior patterns in the on-base community as opposed to civilian communities is an appreciation of the role of the military occupant as a public servant. There is a singular expectation from the

public, from the Government, and from the military leadership that service members must be particularly responsive to national problems, whether these problems affect economic, environmental, or other key areas. In this regard, a unique sense of duty is expected from and displayed by military people in addressing such problems. As energy costs have risen, this sense of duty has been extended to apply to conservation efforts among those occupying Government housing, just as it has been applied to conservation efforts in the Federal workplace. Thus, family housing occupants are under singular institutional pressures to conserve--pressures from the public, from the Government, from their immediate commanders, from their neighbors, and from the internalized sense of duty.

This unique expectation--the concept of serving as an example to the national public--is not new to military people. In three of the last four years, their annual pay raises (and those of Federal civilian personnel) have been capped below statutory comparability levels as an example of fiscal restraint for private industry. In the recent energy crisis years, it has been seen as reasonable to set an example by imposing mandatory energy conservation controls in Federal buildings and military working environments. However, military members actually experience extension of such controls to their home lives through such means as mandatory thermostat settings.

On the whole, these controls have been accepted and willingly observed by on-base residents. This was borne out by the survey results discussed in Chapter 4. These findings showed that family housing occupants are aware of the energy situation and its implications for their daily lives. They regard themselves as energy conservers and most have taken specific conservation-oriented actions or changed some of their behaviors to adapt to these new situational demands. They do not condone energy waste among their neighbors.

All of these considerations tend to indicate that family housing occupants would be less inclined to waste energy than civilian tenants in master-metered (i.e., no utility payment) environments, because the latter tenants are under less direct pressure to conserve. This means that energy savings realized in the civilian sector by moving from master meters to individual meters would probably not be applicable to the military situation. That is, the energy savings potential in the military environment would be less because the on-base families would be starting from a lower per capita consumption baseline.

Likewise, existing conservation pressures in on-base communities raise substantial doubts concerning one of the underlying assumptions of the military metering proposal--that "energy consumption by the occupants of military family housing might exceed consumption of occupants of similar housing in the private sector by greater than 30 percent and in some cases by

as much as 50 percent." In fact, the study analyses discussed in Chapter 4 show that many studies indicating greater consumption by family housing occupants failed to correct consumption data for certain key differentials such as family size (military members tend to have more and older dependents), appliance similarity (civilians may not have had air conditioning), or unit structural differences. In the one study where such corrections were accomplished, military consumption was shown to be less than that of the civilian sector.

D. Impact of Funding Limitations.

In addition to the direct and social controls over energy usage by family housing occupants, the Government's capability to respond to occupant needs will have a significant bearing on occupant energy usage.

For example, judgments concerning the necessity for repair or replacement of major appliances, the availability of replacement parts or appliances, and even the manpower required to effect repair or replacement are all subject to budget constraints. There is an already existing backlog of repair and improvement requirements, and commanders even now must prioritize the apportionment of limited operations and maintenance funds. As previously indicated, implementing a metering and excess-consumption billing system would be expected to generate significant additional demands for repairs and improvements. These would have to compete with existing backlogs for limited funds, and there is no assurance that all legitimate requirements could be met. Hence, an occupant might have to pay for excessive energy usage due to equipment or structural inefficiencies, a situation he could eliminate by repair or replacement if the decision were left to him. If such maintenance needs were given highest budget priority, it could be at the expense of other needed projects (e.g., playgrounds, sidewalk or driveway repairs, etc.) directly affecting the quality of life experienced in the on-base community.

IV. Financial Considerations.

Any proposal to bill family housing occupants for energy consumption, excess or otherwise, must consider the potential financial impact on military people, not only in absolute monetary terms, but also in terms of the incremental impact when such charges are added to existing pay deficiencies. An additional concern will be the occupants' perceptions of the intent and policy implications of the charges.

A. Existing Military Pay Deficiencies.

A recent joint study conducted by the Office of the Secretary of Defense and the military services identified substantial deficiencies in the military compensation package. Specifically, the study disclosed that, because military pay raises have lagged significantly behind inflation, the real purchasing power of military pay, in terms of constant dollars, declined by 7.4 percent between 1972 and 1978--6-1/2 percentage points worse than private sector white collar workers, 14-1/2 percentage points behind manufacturing production workers, and 19-1/2 percentage points behind Federal wage systems workers over the same period. During 1975 through 1978, military members experienced two pay-raise caps and two pay-raise reallocations, all of which served to depress their present and future compensation values. The situation was further exacerbated in 1979 by an additional pay-raise cap of 7 percent as opposed to the 10.4 percent increase the President's Pay Agent determined would be needed for comparability.

The study also identified serious shortfalls in other compensation elements. For example, it concluded that military members annually absorb $600 million in excess housing costs above their quarters allowances, and $800 million annually in excess moving expenses above and beyond their Government relocation reimbursements. Overall, the study identified current military pay deficiencies of up to $5.5 billion.

Military people have clearly felt the impact of their declining pay value. Recent survey results show that they have increasingly had to take second jobs, that their spouses have had to seek employment, and that a substantial percentage have had to withdraw from savings or go into debt just to meet normal monthly expenses. The vast majority report that personal finances are a significant daily concern.

Under such circumstances, imposition of any type of additional charges on military people would be expected to be viewed with considerable concern.

B. Impact of Family Housing as Compensation.

During the recent years of declining pay value and rising off-base housing costs, military family housing has played a

vital role in helping to maximize the utility of military members' limited budgets.

Although only about 30 percent of eligible military families occupy Government quarters at any given time, a substantially larger percentage may hope to use these quarters at some point during their military careers. In this regard, families stationed in areas where military housing is not available may obtain occupancy during a future assignment and gain a period of respite from the high housing costs of the private sector.

Thus, a change in housing entitlements such as the proposed metering and billing system would have a potential impact on a substantial percentage of the military population, and would be of concern to virtually all military families rather than only the 30 percent occupying the quarters at any given time.

C. Occupant Perceptions.

Although the test program showed that only a relatively small percentage of families would actually be assessed charges during any given month under an excess consumption billing program, a much larger percentage of families would be concerned with the threat of receiving a bill of unknown magnitude at some time in the future. As previously discussed, these concerns would be exacerbated by any misunderstanding of consumption or norm computations, by real and perceived inequities in those computations, and by mutual reinforcement through discussions with neighbors and coworkers.

A particularly responsive complaint system would have to be devised to identify and correct errors promptly in order to allow reasonable redress of unwarranted financial penalties, with the benefit of the doubt going to the occupant.

Another major determinant of occupants' views regarding the billing process would be the consistency of effort placed on conservation initiatives other than metering and billing of occupants. Any metering and billing initiative would have to be accompanied by simultaneous pursuit of other obviously important energy-saving initiatives, such as increasing wall insulation, installation of storm windows, and insulation of hot-water heaters. Otherwise, occupants could perceive that they were being asked to bear a disproportionate share of the conservation burden. In this regard, it might appear to some occupants that the Government would rather transfer charges for excess consumption to military members rather than undertake the initiatives required to effect real efficiency improvements. This argument would be difficult to refute if improvement and repair backlogs continued to exist, for the opportunity costs of the metering program would be readily apparent. This would be particularly chafing to mil tary people, because it could be demonstrated rather easily that an excess-consumption billing system is considerably less cost-effective

in terms of actual energy savings than an equal expenditure on direct conservation measures such as insulation and storm windows.

Finally, military members could be expected to question the equity of an approach that relied on negative or punitive actions without according due recognition to the conscientious, energy-saving families. In this regard, families that consumed well below the norm for 11 months but exceeded it in the 12th would still receive a bill for the 12th month, without regard to their prior savings. Psychologically, there would appear to be little encouragement or expectation for families to take extra steps to save energy; staying below the norm would appear sufficient to meet the criterion of acceptable energy-conserving behavior. As mentioned in Chapter 4, the standard established by the norm could become not only the minimum accountable performance, but also the maximum. Thus, imposing a norm without also implementing rewards for consumption below the norm could actually lead to increased consumption among the most zealous current energy savers, who might perceive that they had been imposing greater sacrifices upon themselves than was expected by the Government.

V. Impact on Housing Desirability and Occupancy.

Implementation of a metering and excess-consumption billing system, by altering the perceived desirability of on-base family housing, could significantly affect occupancy rates on military installations. Such changes could generate certain secondary effects or necessitate adjustment of certain long-standing policies.

A. Occupancy Decision Factors.

At present, the relative desirability of living on or off base may be affected by several considerations. One such is personal financial standing. Many relocating families find that they cannot afford the extraordinary housing expenses that may be encountered by new arrivals in the civilian community, particularly if the family is reassigned to one of the growing number of recognized high-cost metropolitan areas. To these families, on-base quarters may appear quite attractive, depending on availability and condition. Others, particularly those with past homeowner experience, believe that purchase of a private residence is an essential investment that represents their only opportunity to keep pace with inflation.

For many, the security of the on-base environment and the convenient access to the sponsor's workplace and various on-base shopping or recreation activities are significant influencing factors. Others prefer to avoid what they see as an excessive regimentation that places unwanted restrictions on their lifestyle, and they prefer to keep their work and home environments separate to as great a degree as possible.

Although there is a need for additional Government family housing assets at certain high-cost locations, and while some members are mandatorily assigned to family housing at certain locations, individual preferences concerning on- or off-base residence now can be accommodated to a great extent. However, implementation of a metering and billing system could significantly change occupancy behavior by reducing the desirability of on-base quarters.

The most obvious decision factor alteration would be the reduced price increment between on- and off-base residence due to the potential imposition of an unknown utility charge. The relative weight accorded this factor would vary from member to member, but their estimates of the financial savings to be realized from on-base residence would be reduced--substantially so for those who would overestimate their potential billing liability.

Another decision factor would be the potential esthetic or convenience deficiencies imposed by the metering program. Time constraints on meter installation did not allow appropriate consideration of these issues during the metering test, and

resulted in unsightly alterations to housing units. Similarly, some meter locations imposed interference with proper opening of doors, while the interior locations made it necessary for residents to be home for meter readings, interrupted their privacy for these readings, and caused other inconveniences that gave rise to considerable occupant resentment. Such factors would have to be given much more consideration in a DoD-wide program to avoid a significant decline in the desirability of the units thus affected.

Lack of control over home improvements would also be of increased importance in occupancy decisions. Particularly at those locations experiencing chronic operations and maintenance shortfalls and large repair and improvement backlogs, the energy-efficient condition of the housing units or major appliances would doubtless be a major deterrent to on-base residence.

B. Management Policy Impacts.

If a metering proposal were implemented, it would be necessary to reexamine the continued feasibility of the current policy requiring mandatory assignment to military family quarters under certain circumstances. At present, commanders may direct particular members to reside on-base for reasons of military necessity (i.e., to ensure availability of key personnel) or to ensure that family housing units do not stand vacant due to lack of voluntary occupants. Previous sections have discussed the variety of circumstances that could result in excess consumption charges despite reasonable conservation efforts by a particular occupant. Under such circumstances, it would appear highly inequitable to force a member to occupy military family quarters against his will and still threaten imposition of charges for consumption above an established norm.

In addition, a prospective occupant would probably have to be afforded somewhat more latitude in the choice of a housing unit. At present, a member may decline to occupy a unit offered to him; however, if he does so, his name may be dropped to the bottom of the housing waiting list. Because a single base may possess several different types of housing assets, with varying energy efficiencies, a member who declined an inefficient unit under a metered environment should be given the opportunity to accept the first available unit of the more efficient category.

Any projections of the secondary budget impacts of a metering program would be highly speculative. However, to the extent that occupancy rates in family quarters might drop, BAQ funding requirements would experience a corresponding increase. Similarly, station housing allowance (HA) requirements in Alaska, Hawaii, and U.S. possessions would also increase. As noted previously, increased service calls and major repair and improvements requests under a metering system would generate increased operations and maintenance funding requirements. Lack of response to these requests because of funding limitations would increase occupant frustration.

VI. Erosion of Benefits.

A major attitudinal problem that a metering and billing proposal would encounter would be the charge that it would constitute a further erosion of military entitlements. There would be a strong managerial tendency to respond to that charge by asserting that no one should have an entitlement to waste valuable energy resources.

The inherent truth of this rebuttal cannot be denied. However, in its simplicity, it fails to address the crux of the problem from the military occupant's standpoint--what determines the level of usage that constitutes waste, and to what extent does the occupant have control over that waste? The military member's concern is that an imperfect norm system may well set standards that will either deny his or her family a reasonably comfortable lifestyle or impose an unwarranted financial penalty for efforts to accommodate that lifestyle.

To the extent that a metering and billing system yielded either of these results, it would in fact impose a reduction in the member's current entitlements.

A. Background on Military Compensation and Entitlements Changes.

As the Services moved toward an all-volunteer concept at the beginning of the last decade, it was readily apparent that the attractiveness of the military compensation system would have to be enhanced and then maintained if the Services were to be able to meet and sustain their manpower requirements in a draft-free environment. Following a major restructuring of the pay and allowances tables and three pay raises between November 1971 and October 1972, it was generally accepted that reasonably competitive compensation had been achieved. For this reason, 1972 compensation levels serve as an important benchmark against which subsequent gains and losses in pay and entitlements may be measured. Further, a substantial majority of the current force entered service since 1972, and their sole experience spans only this 7- to 8-year period.

Since 1972, increases in Regular Military Compensation (RMC) have lagged significantly behind inflation, with the result that a military member's real purchasing power at the present time is substantially lower than was that of a member with equal rank and longevity in 1972. This decline in real pay value amounts to 10 to 15 percent, depending on grade, between October 1972 and the present.

There are certain facts that indicate that military members have suffered a greater decline in real pay value than their private sector cohorts. For example, a 5 percent cap was placed on the October 1975 pay raise, although the President's Pay Agent advised that an 8.75 percent increase would have been

necessary to maintain comparability with private sector pay. In 1978, the President's Pay Agent indicated that an 8.4 percent increase would be necessary to maintain this comparability. However, national economic considerations necessitated a 5.5 percent cap on Federal civilian and military increases. Federal and military pay raises were again capped in October 1979, this time at 7 percent, despite the Pay Agent's indication that a 10.4 percent raise would be required to regain statutory comparability levels.

In addition, the reallocation of portions of the 1976 and 1977 military basic pay increases into the BAQ further reduced current income for many military members. For example, this action substantially raised the BAQ forfeiture of family housing occupants above that forfeiture which they would have experienced without reallocation. It also resulted in dollar-for-dollar offsetting reductions in the separately appropriated station housing allowances received by members stationed in high-cost oversea areas. Because these members would otherwise have received the reallocated amounts in their basic pay, reallocation served to further reduce the real value of the 1976 and 1977 raises.

In direct contrast to the decline in real purchasing power experienced by military members, the January 1979 Economic Report of the President indicated that wages for union-represented employees kept pace with inflation between December 1972 and September 1978, rising 59.7 percent while the consumer price index rose 59.9 percent. Because of the media attention that normally accompanies negotiated increases in union contracts, such increases (which frequently have exceeded 10 percent) often form the basis of comparison for military members' perceptions of their own increases. Such comparisons have led many members to conclude that they are being asked to assume financial sacrifices in excess of those expected of other segments of society.

Military people are also very concerned about alterations in other elements of their entitlements package. While it is generally recognized that there have been gains in the entitlements, particularly in the areas of travel and transportation entitlements and survivor benefits, these have been more than offset in the eyes of most members by many other actual and threatened reductions. Although most of these were intended as management efficiencies, their financial impact on military people has been no less real.

A brief listing of these actions will serve to illustrate this perspective. In 1973, reduction of military obstetric/gynecological services necessitated increased reliance on the cost-sharing Civilian Health and Medical Program of the Uniformed Services (CHAMPUS) and increased out-of-pocket medical costs. In 1974, the general Regular Reenlistment Bonus was phased out and replaced by the Selective Reenlistment Bonus,

which was authorized only for members in critical skills. In 1975, the authorization to grant travel pay to the member's home of record was deleted for members who immediately reenlisted. In addition, Superior Performance Proficiency Pay was deleted.

In 1976, authorization to "sell back" unused leave was limited to 60 days of leave over a member's entire career, as opposed to 60 days upon each reenlistment. Payment of the Basic Allowance for Subsistence (BAS) and Basic Allowance for Quarters (BAQ) was also eliminated from terminal leave payments. Physician reimbursements under CHAMPUS were reduced from the 90th percentile of local physicians' fees to the 75th percentile (later partially corrected--to the 80th percentile--in FY 1979), substantially increasing out-of-pocket medical expenses for many members. The 1 percent add-on to retired pay adjustments was deleted, although this action was ameliorated by institution of a semiannual adjustment process. The fully funded Vietnam Era GI Bill educational program was replaced by the contributory Veterans Educational Assistance Program (VEAP). Many special and incentive pay rates, established one to two decades ago, have not been adjusted with the passage of time, so that inflation has substantially reduced their real value. Funding for morale, welfare, and recreational activities has been reduced, with corresponding reductions in services and increases in charges to members using these facilities.

Equally important from military members' perspective have been the omnidirectional proposals for reductions in other areas. Perhaps the single most significant concern among military members in recent years has been the continued uncertainty over the implications of a succession of proposed changes to the military retirement system. The last decade has witnessed at least seven different proposals to modify this system, all of which recommended substantial reductions in retired pay levels for 20-year careerists, and many of which would have provided only limited protection, or "grandfathering," for those already on active duty. The lack of full grandfathering was viewed as a serious breach of faith on the part of the Government and has led most military members to view subsequent retirement reform proposals with trepidation, even though the Uniformed Services Retirement Benefits Act recently submitted to the Congress by the Department of Defense would fully recognize the obligation to grandfather existing retirement entitlements for the current force.

In addition, the services have experienced persistent attacks on traditional institutional entitlements during the past several years. An example is the repeated proposals to phase out appropriate fund support for military commissaries. It has been generally recognized that the savings (20 to 22 percent) that military people realize from these facilities greatly exceed the appropriated funds spent in their support, and military families are extremely sensitive to the commissary's value

in this time of rapidly rising food prices. Just as important, commissaries, health care, and other institutional entitlements add a degree of "psychic value" to the military compensation package as symbols of the Government's commitment to provide for the fundamental needs of military members and their families. Thus, they assume an importance and a value in the minds of military people that far exceeds the cost to the Government. Conversely, benefits--particularly when proposed by influential Government or congressional leaders--arouse strong emotional reactions from military people because they generate perceptions of declining Government concern for their welfare. Although the full commissary subsidy ultimately has been appropriated in each of the past 3 years, the repeated efforts to eliminate this funding have generated considerable concern regarding the future status of this key entitlement.

Even some legitimate gains have not been achieved without anxiety. Funding for long-sought oversea travel entitlements for junior enlisted personnel, first approved in FY 1979, appeared threatened during FY 1980 congressional hearings and was sustained only when additional restrictions were placed on the number of military dependents overseas--raising the prospect of increased family separation. Other increases in travel entitlements have tended to lag well behind the increases in expenses actually being incurred by relocating members.

To summarize, the erosion of benefits issue has not arisen overnight. It has resulted from the experience of several years of entitlements changes as well as the anticipation of additional changes, such as utility metering, in the future. Undeniably, many elements of the military compensation system have been substantially improved in recent years. However, there have been many actual reductions, many others have been proposed, and many others are still being contemplated. By way of comparison, these changes have occurred during a time when reductions in <u>any</u> private sector benefits, for whatever reason, have been virtually unheard of. Thus, it should come as no surprise that military personnel have begun to question the degree of value placed on their services by public representatives or that they now view any potential changes in their compensation and entitlements package with considerable concern.

B. Unique Conditions of Military Service.

In considering such proposals for change, it is important to view the various entitlements in the light of the significant adverse conditions of service that they are intended to help offset--frequent moves, family separation, overseas service, exposure to combat, long hours of overtime without pay, and the loss of many personal freedoms associated with civilian life. Yet all of this must be done in the light of--and in comparison to--a civilian sector that is considerably different. Military people are asked to be highly disciplined when society places a heavy premium on individual freedom, to

maintain a steady and acute sense of purpose when some in society question the value of our institutions and debate our national goals. In short, they are asked to surrender elements of their freedom in order to serve and defend a society that has the highest degree of liberty and independence in the world--a society with the highest standard of living and an unmatched quality of life.

Implicit in this concept of military service must be long-term security and a system of institutional supports for service people and their families which, to offset the adverse conditions of service, should differ from those commonly offered in the private, industrial sector.

During deliberations concerning possible adjustments in military compensation levels, these important distinctions must be given due consideration, and military members must continue to be provided with pay and benefit levels commensurate with the extraordinary demands and sacrifices imposed upon them.

C. Potential Billing System Evolution.

Significant reservations are already being expressed in many quarters of the military community concerning the potential long-range evolution of the metering system and the ultimate impact of imposing charged over and above occupants' BAQ forfeiture for various environmental services.

It is recognized that it was the stated intent of the Congress in directing the metering test not to dilute or eliminate occupants' entitlement to both shelter and reasonable utility usage in return for their BAQ forfeiture. However, increasing fiscal constraints on future leaders could prompt proposals for use of an existing metering system to bill occupants for all energy consumption. This would effectively constitute a significant real cut in occupants' take-home pay, with obvious attendant morale and retention impacts. Some opponents have indicated their belief that installation of meters, with or without excess consumption charges, would be the first step in an inexorable transition to a full billing mode.

Others have expressed concerns that the acceptable quality of life standard used in the initial development of reasonable consumption norms could be skewed in the future to effect management efficiencies at occupant expense. For example, the standards for winter thermostat settings could be reduced, normative levels of water usage could be reduced, or other technical modifications could be applied to the algorithm to reduce normative living standards below those originally envisioned by this Congress.

Another reservation is that any utility billing system could set a precedent for charges for other services, such as water, sewer, garbage collection, etc.

The common thread through all of these apprehensions is that a metering system could generate a fundamental, undesirable, and unforeseen change in how the intent of the BAQ is viewed, as well as a change in the Government's inherent obligation to provide either adequate housing or the BAQ to each of its members. In this regard, the BAQ has been interpreted as being intended to recognize members' total housing expense requirements, and not merely the shelter portion of those requirements.

Because family housing occupants are required to forfeit their BAQ, imposing additional charges for part or all of their energy consumption could generate questions concerning whether they were in fact being provided adequate quarters. This could be especially problematical if it could be demonstrated that the excess consumption was due at least in part to inherent deficiencies of the quarters' or Government appliances.

VII. Retention Impacts.

The preceding sections have discussed the numerous ways that an energy metering and billing system could affect military members' lifestyles and attitudes. From this discussion, it can be seen that the impact of such a program would be clearly negative from the members' viewpoint. The vital question that remains concerns how implementation of a metering initiative would affect their retention patterns. While it can be assumed that any resultant alteration in these patterns would be negative, we can only guess at the likely magnitude of the change.

A. Recent Retention Trends.

Retention trends among all services have been increasingly unfavorable over the last several years. Of greatest concern has been a relatively precipitous decline in the reenlistment propensity of midcareer enlisted personnel and in retention rates among midcareer officers. The concern over these trends is two-fold. First, these categories of people compose the services' vital middle management personnel--the first and second level supervisors whose training and experience are essential to ensuring the efficient and effective function of the national defense organization. Second, the increasing loss of high-quality midcareer personnel significantly reduces the services' margin of selectivity in choosing and developing the senior leaders and managers of the forces of the future.

The magnitude of the current problem is reflected in the last 5 years' retention statistics. Marine Corps overall career reenlistments (i.e., personnel completing their second or subsequent terms of service) declined from 73.1 to 51.9 percent over a similar period. Navy rates dropped from 80.5 to 62.2 percent, and Army rates declined from 75.4 to 66.4 percent. Retention among second-term Navy enlisted personnel alone declined from 59.1 percent in FY 1975 to 45.3 percent in FY 1979. The Air Force experienced a similar decline from 75.4 to 60.1 percent.

Serious problems also are being experienced in the career officer force, particularly in highly technical and combat skills. For example, the percentage of Air Force line officers remaining after their initial period of obligated service, who complete at least 12 years of service (i.e., retention from the 6- to the 12-year point), has declined from 72.3 percent in FY 1975 to 45.4 percent in FY 1979. Among unobligated Air Force pilots, the percent remaining to the 12-year point declined from 75.5 percent in FY 1975 to 44.7 percent in FY 1979. The Navy is also experiencing serious officer retention problems, with overall retention rates in the 30 to 40 percent range. Nuclear-trained submarine officer retention is projected to decline below 40 percent this year. Pilot retention was down from 62 percent in FY 1977 to 31 percent in FY 1979, with a

projection of 28 percent for FY 1980. Surface warfare officer retention dropped from 42 to 31 percent in the past year alone.

In view of these statistics, service leaders are expressing increasing concern over the serious readiness impacts of allowing such trends to continue and are devoting more and more of their attentions to the development of policy and legislative alternatives that will help reverse them.

B. Replacement Costs.

Declining retention rates entail a variety of costs to the Government associated with recruiting, training, and maturing replacements for exiting personnel. These costs can be expressed in a variety of ways, but in the final analysis they require considerable subjective interpretation.

The Department of Defense maintains some data on the cost of accessing personnel and completing initial entry and skill training. These include the cost of recruiting, pay and allowances, training overhead, and certain other processing and administrative support costs. A 1976 report estimated this initial accession and training cost at $55,000 for officers. Multiplying this figure by subsequent pay raise percentages would yield a figure of approximately $65,000 for FY 1980. An FY 1978 study of enlisted accession and training costs cited an average DoD figure of $7,700. Multiplying this figure by the two subsequent pay raise percentages would yield an FY 1980 approximation of $8,700. Of course, the cost for individual skills would vary widely.

However, these figures reflect only the <u>initial</u> accession and training costs required to bring a junior officer or enlisted member to the first permanent duty station. Such an individual could not be considered a replacement for a fully trained and experienced member--particularly not for a supervisor separating with 8 to 12 years of service.

While assessments of the relative value and the true cost of replacing those years of training, expertise, and experience may vary, they are obviously substantial. For example, there has been a general acceptance of the Air Force's estimate of $600,000 to $800,000 as the replacement cost of a midcareer pilot. The Navy, using a new and relatively sophisticated computer modeling system, has estimated the average replacement cost of a midcareer petty officer at approximately $100,000. Using the Navy costing, it can be seen that a change of even 1/4 percent in the DoD career reenlistment rate would generate an incremental replacement cost of $43 million for career enlisted personnel alone.

First-term reenlistments and officer retention must also be considered. Using the Navy model as a base, one could conservatively extrapolate replacement costs of roughly $30,000 for

enlisted members completing their initial term of service and $125,000 for an average unobligated officer. At these values, the incremental replacement cost of a 1/4 percent change in FY 1979 retention rates would be $13 and $62 million, respectively, for first-term enlisted members and officers. Summing up all of these values yields a total personnel replacement cost of $118 million associated with any initiative that would reduce existing retention rates even by an amount as small as 1/4 percent. Any alternative having greater economic impact on the occupants can be expected to result in greater attrition.

Even these costs are somewhat misleading, because it is not possible to purchase years of experience and maturity. Once retention has dropped below the level of acceptability, replacement costs must be measured in terms of time as well as money. Replacing a 10-year veteran may take up to 10 years, depending on the manpower profiles in the younger year groups. The cost in terms of readiness is incalculable, because it is a function of policy, changing force requirements, and risk analysis.

C. Retention Impact of Compensation Changes.

Various explanations may be offered concerning the reasons for the recent downturns in retention rates, but it generally has been recognized by DoD and service officials that dissatisfaction with the military compensation package has been a significant causative factor.

In this regard, it does not appear to be a coincidence that the decline in retention has occurred simultaneously with the rising erosion of benefits concerns and a succession of pay raise caps. A recent memorandum from the Joint Chiefs of Staff to the Secretary of Defense summarized the views of the service leaders:

> "The results of the (joint OSD/Service pay) study show clearly why many dedicated members are leaving the military profession. A recent Air Force survey confirms that many believe their pay is inadequate when compared to the demands placed on them and that they can no longer financially afford to remain in the military. Further, they can see no evidence that gives them hope for timely relief. It is important that the military and civilian leadership show a determination to provide a solution to this problem. Current recruiting shortfalls and inadequate retention levels provide ample evidence that military compensation is not competitive with the civil sector."

Thus, it appears that a threshold of pay dissatisfaction has been achieved among military people that may be exacerbated by new proposals that would be perceived as imposing

additional reductions in their take-home pay. Such initiatives could be expected to have a particular morale-depressing effect in the current emotional environment, because recent public expressions of concern by Defense and congressional leaders have generated growing recognition of military pay inadequacies. In this regard, initiatives such as the metering proposal would appear to work at cross-purposes with ongoing efforts to enhance military career incentives.

For the most part, the members who would potentially be affected by the metering proposal are the same careerists whose retention has now become a matter of major concern to the services.

The potential impact of the metering proposal on these members' retention decisions is highly speculative. However, during a period when existing retention trends are already being described as unacceptable, it would be highly desirable to avoid any apparent further dilution of career incentives.

VIII. Summary.

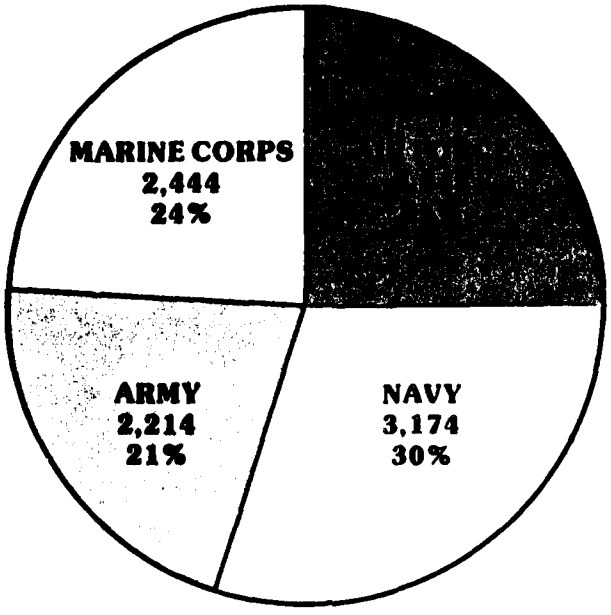
A utility metering and excess-consumption billing program could be expected to generate a considerable degree of resentment among military people, whose unfavorable experiences with pay caps and other compensation changes in recent years have resulted in an extreme sensitivity to additional proposed cutbacks or limitations on their compensation package. It is widely recognized that this experience has been a significant factor in the disconcerting decline in retention that all of the services have experienced.

A utility metering initiative would be particularly galling from their perspective for several reasons. First, family housing occupants are already under strong institutional pressures to conserve energy, and experience at many installations demonstrates that their positive response has generated substantial savings. Deficiencies in the consumption norms, the housing units, and the Government appliances--both actual and suspected--as well as extensive potential uncorrected meter-reading errors would give rise to widespread and often justifiable complaints of unwarranted and inequitable financial penalties to the occupants. In addition, such a program would constitute a fundamental change in the existing interpretation of the equivalence of military family housing and the BAQ, especially if carried to the extreme of billing for full utility consumption.

Service, Department of Defense, and some congressional leaders have expressed strong views that reversing the unfavorable retention trends will require <u>enhancement</u> of the military compensation package. A metering program, with its inherent actual and perceived negative financial aspects, would work at cross-purposes with these retention efforts, directly affecting the midcareer officer and enlisted personnel whose changing continuation rates have been of such major concern.

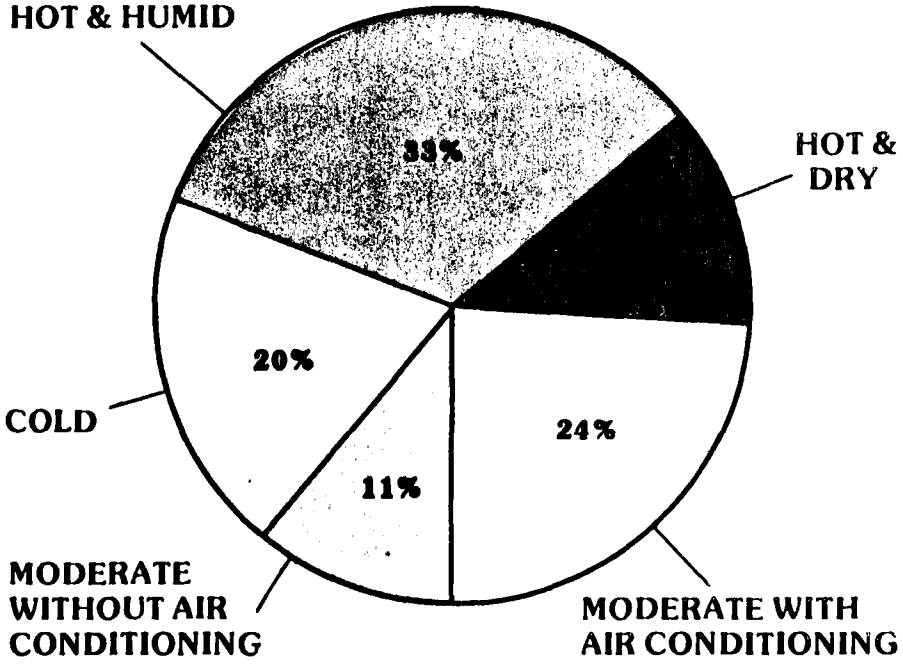
Thus, it would appear that the very modest reduction in energy consumption to be gained from an excess consumption billing system (as shown in previous chapters) would be more than offset by the potential adverse effects on morale, retention, and readiness.

Under such circumstances, it would be much preferable to explore other conservation alternatives that promise greater energy savings without the attendant adverse personnel impacts.



UNITS PROVIDED FOR TEST METERING

TOTAL 10,379 UNITS



TEST METERING UNITS BY CLIMATE

TOTAL 10,379 UNITS

FIGURE 7-1

Chapter 7. REPORT SUMMARY

I. Introduction.

House Armed Services Committee Report 95-290 indicated that energy consumption by occupants of military family housing might exceed consumption by occupants of similar housing in the private sector by greater than 30 percent and in some cases as much as 50 percent. On this fundamental presumption Public Law 95-82 was passed which included direction to the Department of Defense to (1) install meters on all family housing units, (2) establish reasonable energy ceilings, and (3) bill occupants for energy used above the ceiling. However, charges were not to be made until a test had been conducted on the feasibility of the overall program, until the Secretary of Defense had provided a written report to the Committees of Congress, and until 90 days had passed. A total of $8,500,000 was provided for the test, the report of results of which were to be submitted to Congress not later than 1 March 1980.

II. Meter Installation.

A. Test Preparations.

Prior to the actual passage of Public Law 95-82, a Department of Defense Metering Task Force had been established to conduct preliminary planning, should this provision be included in the law. Representatives of all services as well as the Office of the Secretary of Defense (OSD) met and established the basic concepts and ground rules for the conduct of the test, selected 10 test locations, and established certain basic energy consumption criteria for the test. Selected test units were drawn from the active inventories of the four services, with a view towards representing all types of climates, as shown in Figure 7-1. The actual test sites are shown in Figure 7-2. Harry Diamond Laboratory, White Oak, Maryland, was the central computer service location for the test.

B. Meter Installation Costs.

A total of 19,279 meters were installed at a total cost for design and installation of $5,407,575, for an average installation cost of $521 per unit metered or $280 per meter installed. There was, however, considerable variation in the cost of metering individual units from a low of $129 to a high of $5,536 per unit. 1226 units estimated to be extremely expensive to meter were dropped from the test program, leaving 10,379 units metered. It was estimated that in certain cases costs to install necessary meters would have exceeded $35,000 per unit. These very high-cost estimates resulted from a number of problems which will be addressed in the following paragraphs.

METERING TEST SITES

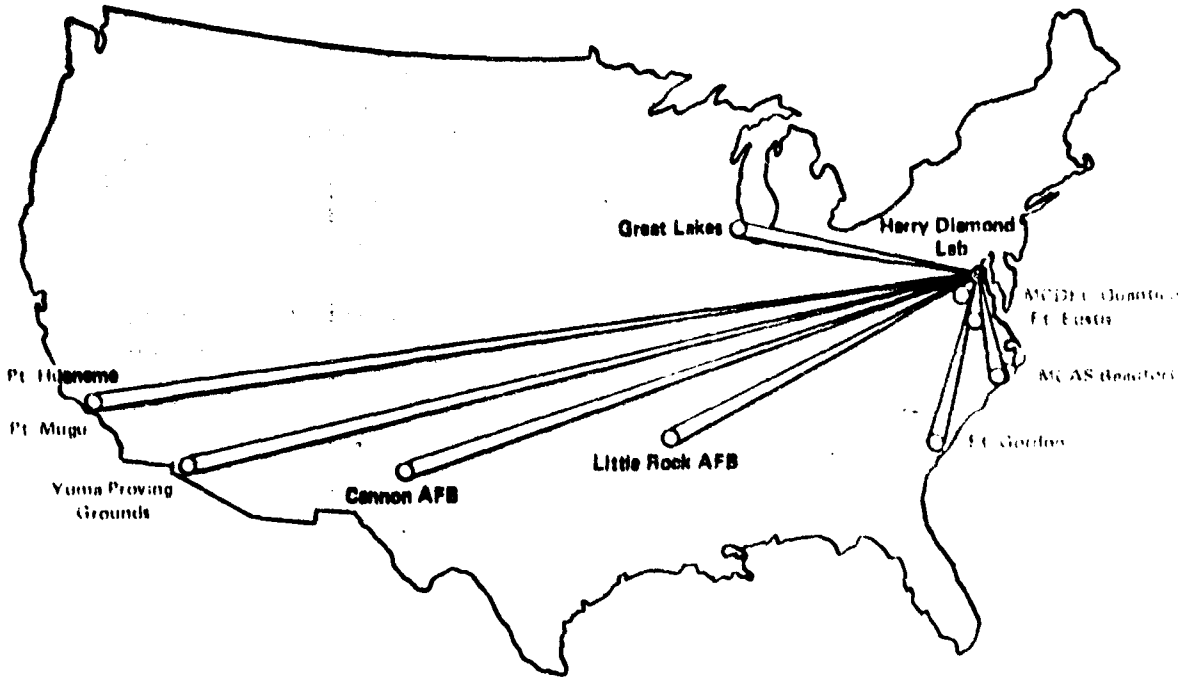


FIGURE 7 2

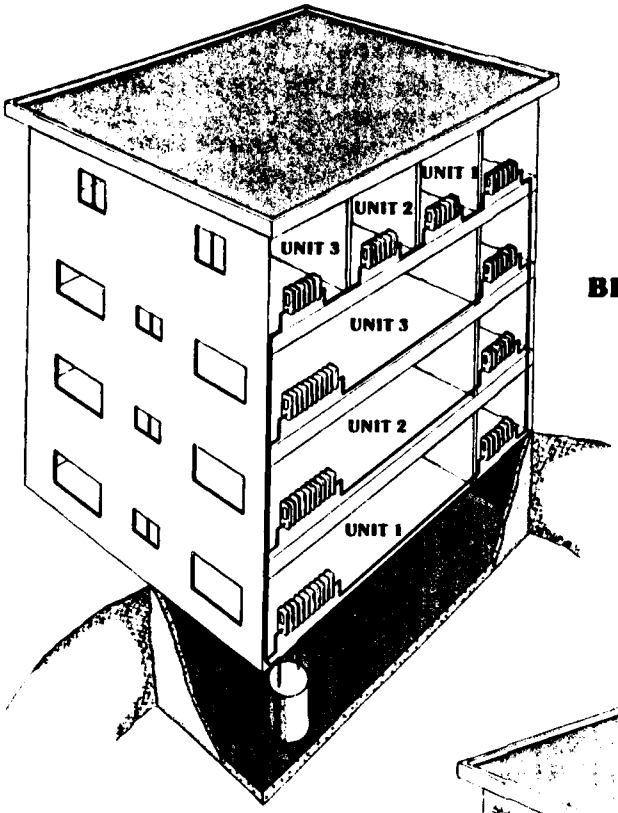
C. Meter Installation Problems.

Many DoD family housing units are in multifamily structures. At the time of construction no consideration was given to layout of internal utility systems to facilitate isolation of one unit from another. On the contrary, utilities were run in the most economical way. Figure 7-3 is representative of typical "before" and "after" hot-water heat service connections. In the "before" cases electric, gas, steam, chilled- and heated-water and domestic hot-water lines were usually run within the building in the most effective manner possible from a construction and first-cost view. Metering of a building such as this required that all systems for each unit be isolated. Figure 7-4 shows the work required in separating gas service in a quadruplex, originally in the concrete slab, to individual metered service; this procedure would also cause considerable occupant inconvenience. In some cases, there were as many as three different energy sources involved for a given unit and as many as five noncontiguous locations (laundry, garage, storage, study room) all of which would have to be metered in order to determine the aggregate energy consumption for that unit. Such work would have severely impacted on the livability of the unit, and in some cases, a vacancy of 6 weeks was judged to be necessary. System isolation was one of the most prevalent and difficult problems to overcome in terms of time and expense.

Three percent of the DoD housing inventory (10,000) use steam, the metering of which was a problem because small steam meters designed for family housing consumption levels were not readily available commercially. Meters actually installed for the test were condensate meters which were adversely affected whenever a steam trap malfunctioned. The result either was severe damage to the meter or, at a minimum, inaccurate readings. As a result of these problems, actual testing of our ability to adequately meter residential steam service was not completed nor was the feasibility of accurately metering domestic steam service proven during this test period.

The third major problem in metering installation was the extremely limited time allowed to install meters at the ten test sites. Public Law 95-82 enacted on 1 August 1977, specified that meters should be in place by 1 January 1978. At all locations installation of meters was performed by construction contract. At most locations design of metering system was performed by A&E contract. The various steps of contract procurement are rigidly prescribed by law and time required for these operations drastically impacted the total time required for meter installation. The earliest installation was April 1978, the latest took until November 1978. As may be seen from Figure 7-5, a frequent result of the short time frame allowed for meter installation, coupled with the limited funds available for installation, was that meter installation ignored and consequently severely detracted from the esthetics of the house. Some of the minor problems encountered and which may be expected to continue during meter readings are shown in Figure 7-6.

SIMPLIFIED CUTAWAY DRAWING OF BEFORE-AND-AFTER PIPING FOR HOT WATER HEATING ONLY



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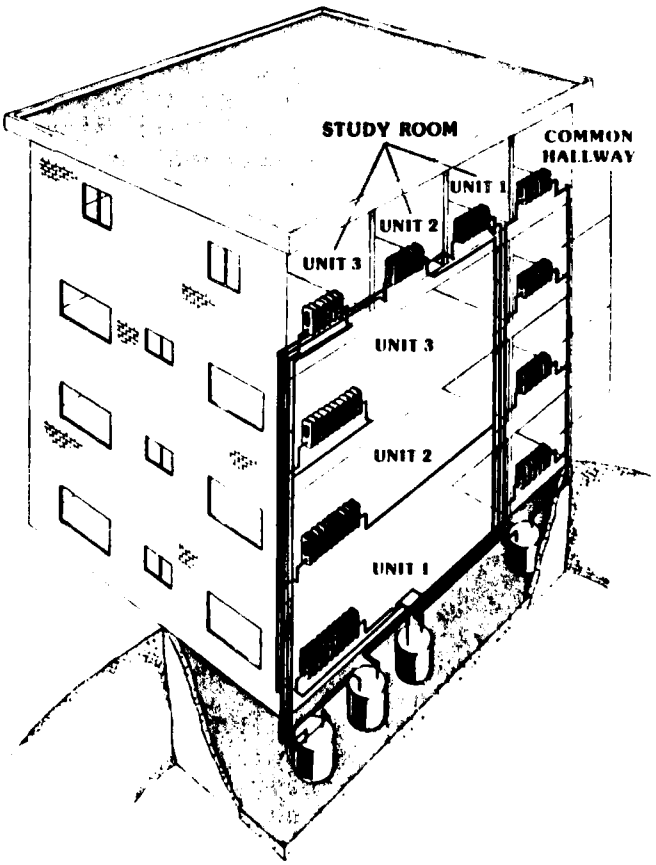


FIGURE 7-3

SIMPLIFIED CUTAWAY DRAWING OF BEFORE-AND-AFTER PIPING FOR NATURAL GAS

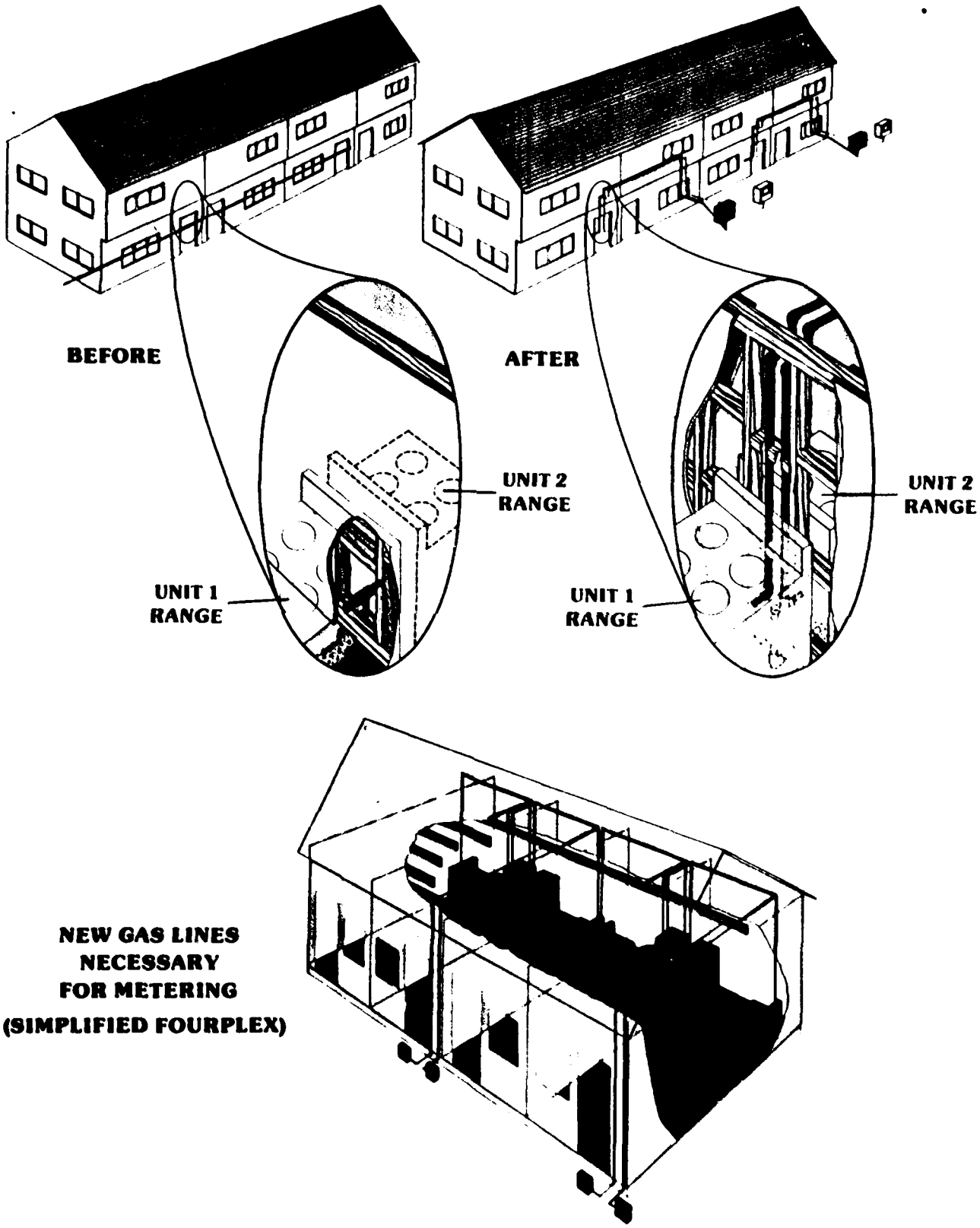
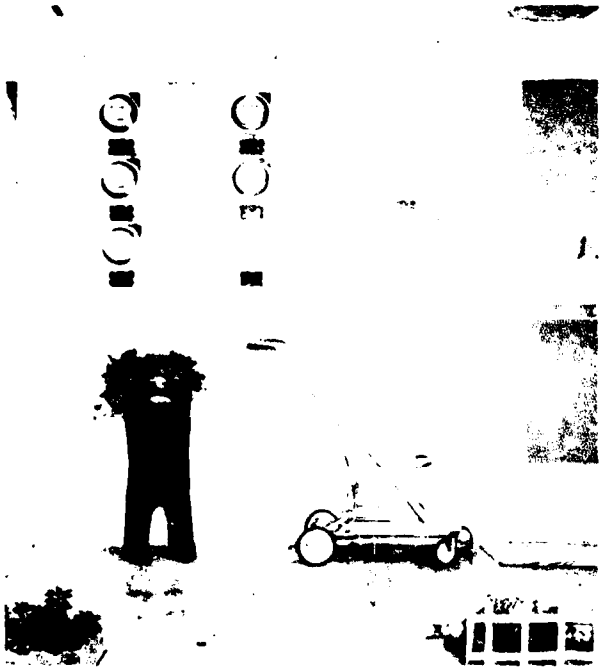
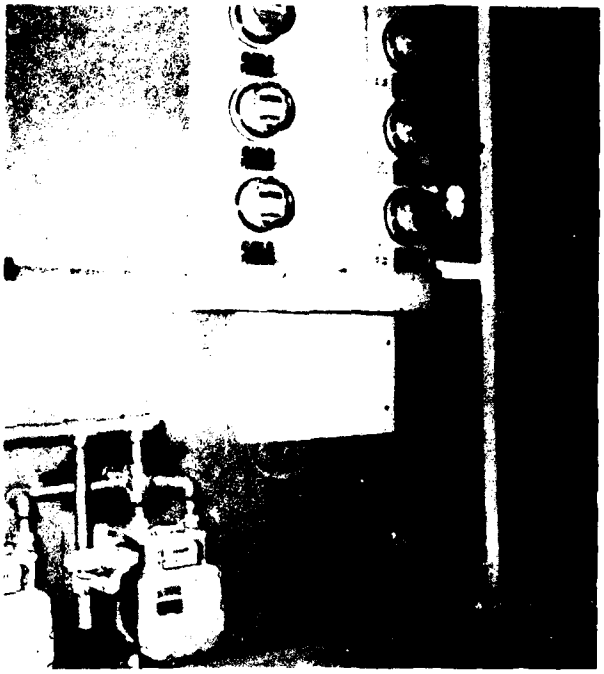


FIGURE 7-4

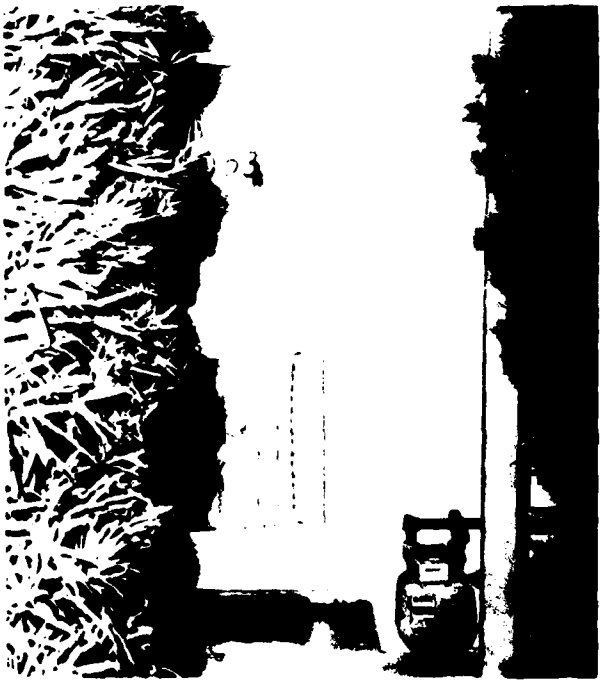
TYPICAL METER INSTALLATIONS



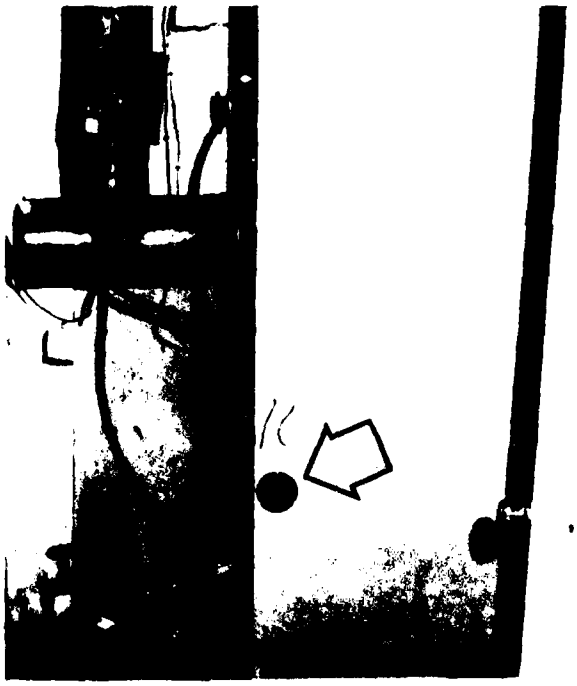
METERS FREQUENTLY AT FRONT DOOR BECAUSE SERVICE ENTRANCE IS IN FRONT



SEVERE DETRACTION FROM FRONT ENTRANCE



POOR GAS METER LOCATION



FUEL OIL METER INSIDE HOUSE

FIGURE 7-5

D. Full Service Meter Installation Cost.

IN VIEW OF THESE PROBLEMS, RETROFIT INSTALLATION OF METERS, IF DIRECTED, WILL REQUIRE A SIGNIFICANT PERIOD OF TIME. THE TOTAL IMPLEMENTATION OF A DOD-WIDE METERING PROGRAM IS ESTIMATED TO REQUIRE BETWEEN 5 AND 6 YEARS. THE ESTIMATED COST OF METERING THE REMAINING 300,000-ODD UNITS OF DOD HOUSING IN THE 50 STATES AND U.S. POSSESSIONS IS $415,177,000 IN 1981 DOLLARS, ALTHOUGH ACTUAL EXPENDITURE WILL BE SPREAD OVER SEVERAL YEARS.

III. Norm Development.

Establishing a reasonable ceiling (norm) for household energy consumption turned out to be the most difficult task faced in the family housing metering test program. Setting the criteria for good energy consumption practices in military family housing is basically an executive decision. Implementing the criteria in the form of a norm can be done empirically. A DoD task force set the criteria and established that the norm should represent each unique combination of residents, housing unit, and the immediate environment. The criteria were determined so that the norm would be fair to the family housing residents and provide them with a quality of life comparable to their civilian counterparts.

The development of the energy ceiling - or norm - proceeded concurrently with the design and installation of the meters and billing system. Specifically, a norm must accurately predict the energy requirements for a given household, including space heating and cooling, domestic hot water, cooking and miscellaneous appliances, and lighting. These energy requirements are heavily dependent on weather conditions, thermostat set points, size and construction of the house, and number and habits of occupants. It was initially determined that due to the complexity, number, and interaction of the variables to be considered, the norm would have to be driven by a computer-based model. CERL's BLAST system was selected for the metering test because it appeared to model as well as any system available. During the course of the test, studies were also made of other systems and the potential for refining the BLAST system, which was originally designed to model commercial and industrial facilities, to better model family housing. The consumption criteria originally established by the metering task force for such energy requirements as cooking, lighting, and appliances predicated on the number of bedrooms in the house and number of gallons of domestic hot water allowed per occupant per day were also subjected to a closer review for refinement purposes, although the initial values were determined as accurately as time permitted.

A. Norm Calculations.

The norm calculation as used in the metering test contains many variables and accounts for a great number of factors which impact upon the energy requirement of the house. It was, however,

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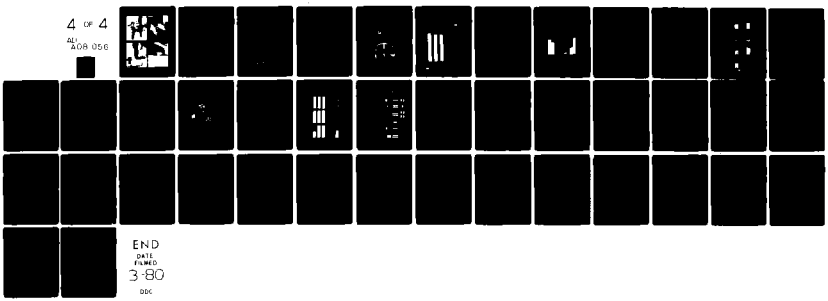

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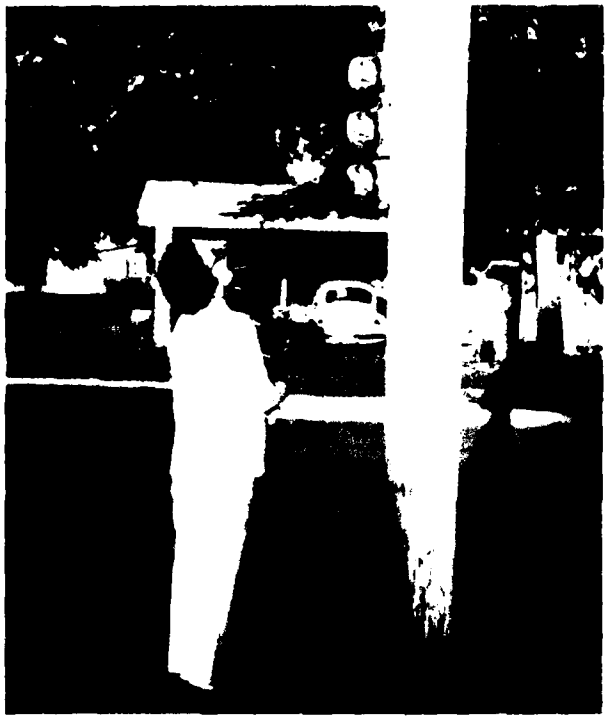
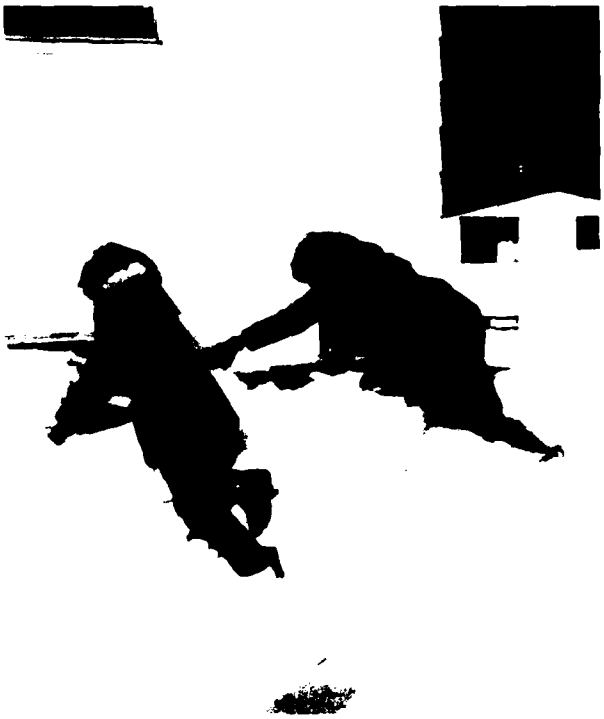
METER READING PROBLEMS



HIGH LOCATION



WHERE IS IT?

HAZARDOUS STEAM
METER LOCATION

SELF EXPLANATORY

FIGURE 7-6

recognized that there were many other variables which have an effect on energy requirements which are not modeled in the present norm formula. These include wind velocity and direction, relative humidity, and building orientation. The norm formula used contains almost 300 variables for one house for a 1-month billing cycle; however, it still does not quantify or model the complex aspects of human behavior, nor does it provide of itself a means of comparing military family life with the life in the civilian sector. For instance the computer model was constructed by OSD so that heating would be only to 68° F and cooling would be only down to 78° F; however, there is nothing to indicate that these parameters are really comparable with what the average civilian household chooses for its quality of life.

B. Test Results.

The actual test data for the ten locations displayed a very large degree of data scatter, and large deviations were experienced between the norm and the average of unit consumptions. These deviations were not consistent or even in the same direction from month to month. (See Figure 7-7 for representative data plots.) The norm itself appears to be of questionable accuracy because the norm and average consumption data for a given group of houses neither coincide nor display a constant difference which could be corrected by simple formula adjustment. If a simple formula adjustment could be made, the question of what is the appropriate adjustment would remain, thus rendering the process subjective, not objective. This would result in major credibility problems from the standpoint of military occupants' ability to understand and believe the norm.

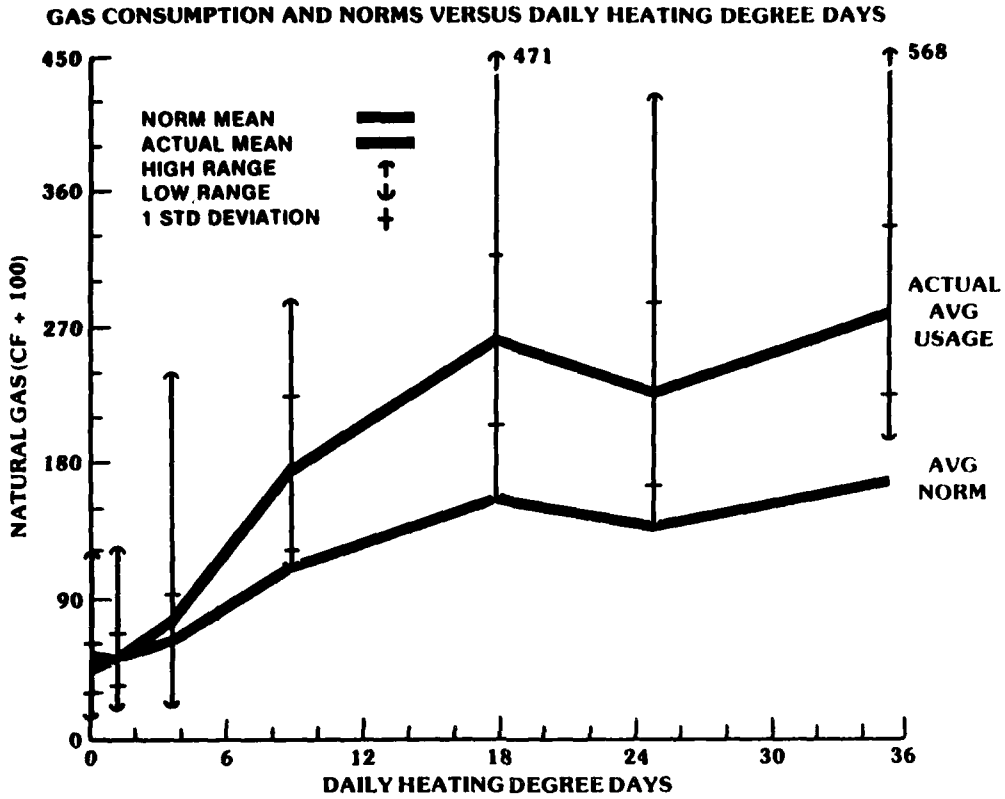
The results in most cases were that the actual consumption was below the norm. While it might be suggested that this is the result of the norm being set too high, other test results strongly suggest that military consumption is considerably lower than previously anticipated on a comparative basis. In any case, there is no specific information to say that either the norm or the actual consumption more nearly represent the American quality of life which should be the goal.

Studies of potential refinement of the norm indicate that while the norm may be refineable to include other functions or variables of lifestyle previously not modeled, the reliability and dependability of the norm is expected to remain no better than 85 percent. In essence the norm is not considered to be of billing quality and the feasibility of future refinement to an acceptable quality is highly doubtful. A billing system based on such a norm could be grossly unfair to housing occupants unless a significant confidence factor adjustment was added.

IV. Billing System.

The computer billing system was designed to take data regarding the house, appliances, occupants, the weather, and the actual meter readings, and produce from this information a

TYPICAL TEST RESULTS



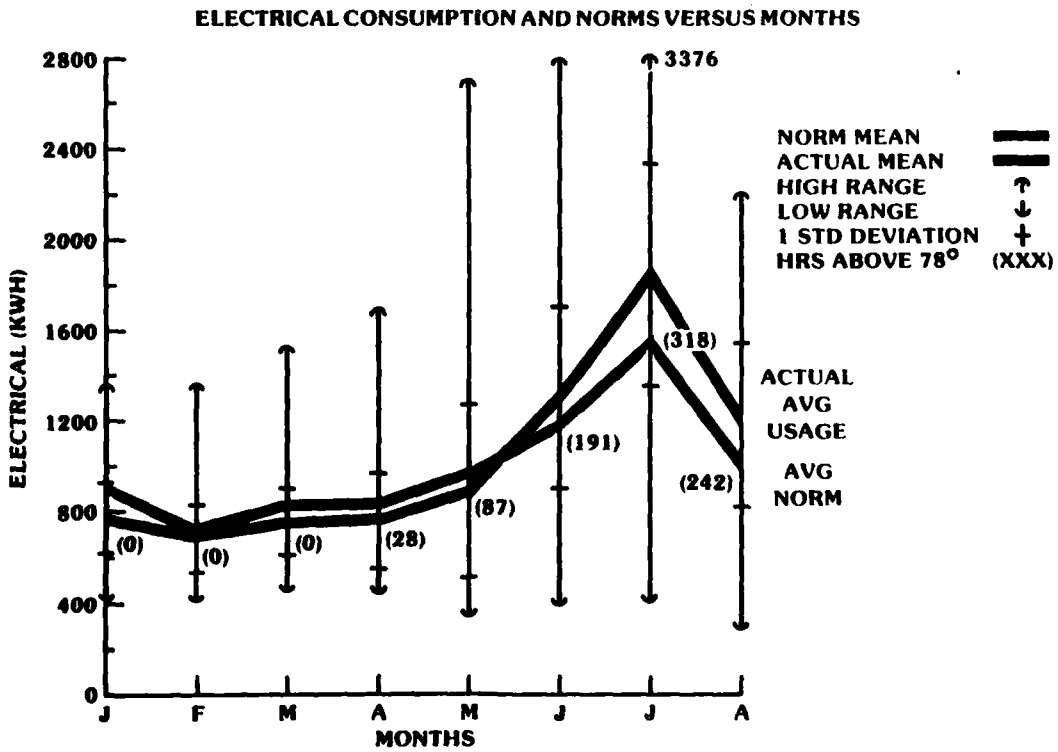


FIGURE 7-7

mock bill indicating whether the specific occupant consumption is above or below the norm. This computer system worked well. Several alternatives for an actual billing system were considered: a DoD central computer, a central computer for each of the four services, and lastly the use of a number of minicomputers located at activities with more than 500 housing units. The concept of a DoD central computer system was eliminated because of the very poor responsiveness, limited hardware flexibility, and poor data reliability associated with this alternative. The minicomputer approach was found most feasible in terms of providing the best degree of service at the activity level and quick response time for occupant questions and corrections to bills. The operation of such a billing system would be as depicted in Figure 7-8.

The estimated cost for procurement of necessary minicomputers and software to perform the calculation and produce the bills is $24,797,000 in 1981 dollars.

V. Energy Consumption Studies.

While the meter installation and metering test were ongoing, literature researches were made and a number of studies were undertaken to attempt to determine probable occupant reaction to various metering and billing strategies as well as to quantify comparable military and civilian consumption rates.

A. Literature Search.

In essence all studies previously done either compared different groups at the same point in time or the same group at different times. The difficulty in either approach was the need to identify and quantify all variables which impacted on the comparison. (The norm which was being tested during this study was the type of common parameter needed to have a scientific comparison between different groups of occupants of houses.)

Most studies available, including the recent Department of Energy (DOE) study done by Booz, Allen and Hamilton (1979), generally compared the same group at different times, before and after metering. This study reviewed a number of cases of conversions done not only in the U.S. but in Europe over a rather long period of time, some dating back as far as the 1950's when the cost and awareness of energy problems were totally different than in 1980. All incidents relating to the installation of meters were in situations where apartments were being converted from a master-metered situation (where utilities were included in the rent) to a situation where individual meters were installed and the occupants made fully financially responsible.

Electricity was the source of energy most often studied. The results reported (Figure 7-9) contained a very wide variance from a case of 50 percent savings to a case of an increase of 18 percent in energy consumption. Attempts to correlate the before and after conditions in these studies

FAMILY HOUSING MINICOMPUTER BILLING SYSTEM

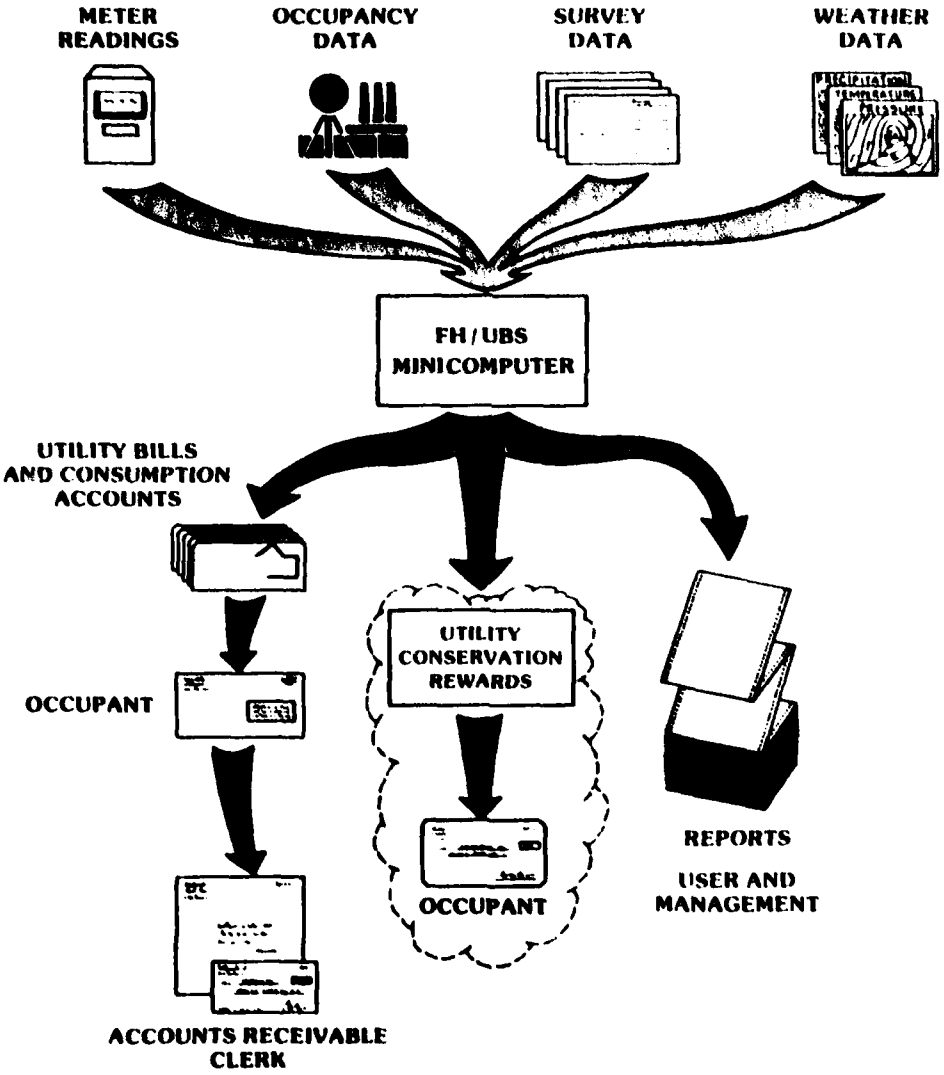


FIGURE 7-8

COMPARISON OF CIVILIAN UTILITY CONSUMPTION

MASTER METERING CONVERTED TO INDIVIDUAL METERING

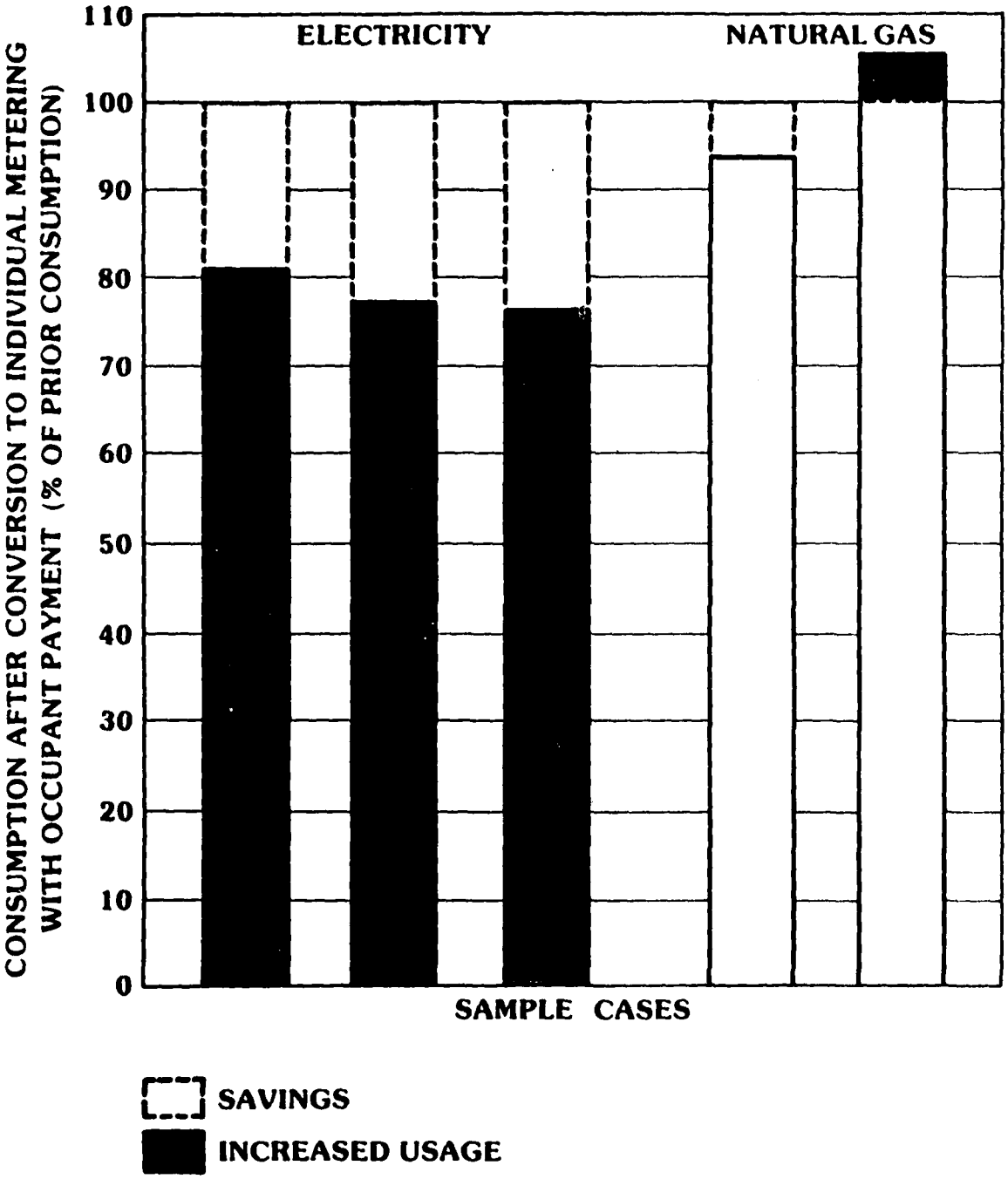


FIGURE 7-9

varied considerably; however, the net result was the projection that conversion from master metering to individual metering and full billing would probably result in a savings of electric energy of between 15 and 20 percent. No cases were studied where the conversion was from master metering to a norm and penalty system as prescribed in Public Law 95-82.

Natural gas was studied in only few cases. The savings for natural gas were much smaller and in a far narrower range, ranging from a savings of 7 percent to an increase in consumption of 8 percent, with the conclusion that conversion of unmetered to metered natural gas would result in very little consumption change. The DOE study contained no information on other energy sources such as fuel oil, steam, central hot water, chilled water, or propane, all of which are present to varying degrees within the DoD inventory. There was no suggestion that master-metered military households would consume energy at any higher rate than comparable master-metered civilian households.

B. Military Energy Conservation.

Occupants of DoD family housing, while not paying directly for energy consumed, have been subjected for some time to energy conservation pressures which are not found in the civilian sector. Such pressures for energy reduction or conservation programs have been ongoing for a number of years; however, since the 1973 energy crisis, these have been stepped up considerably, and have yielded significant results. According to available data, between 1975 and 1979 there was an actual 7.7 percent energy consumption reduction in military family housing. Therefore, the question arises as to how present military consumption really compares with present civilian consumption when all aspects of occupancy and house construction are taken into consideration.

C. Comparative Studies.

To gain a better insight into military versus civilian consumption, available consumption data were gathered and a scientific test was conducted at Port Hueneme involving a number of military housing units and a number of civilian houses where the occupants agreed to have their energy consumption monitored over a period of 6 months. Unlike previous studies the actual requirements of the two different groups of houses were leveled using a norm formula similar to BLAST, whereby the number of occupants in the house as well as the actual characteristics of the house and appliances could be accurately taken into consideration. It was found that there was considerable variation between the different military and civilian houses with respect to various characteristics of both house and occupancy which would have a great effect on energy requirements to support a similar quality of life. While actual energy consumption varied considerably house to house, the net result of this 6-month study as shown in Figure 7-10 was that while the mean of military occupants' consumption

MILITARY VS CIVILIAN CONSUMPTION

AVERAGE ACTUAL ENERGY CONSUMPTIONS

PERCENT OF NORM VALUES

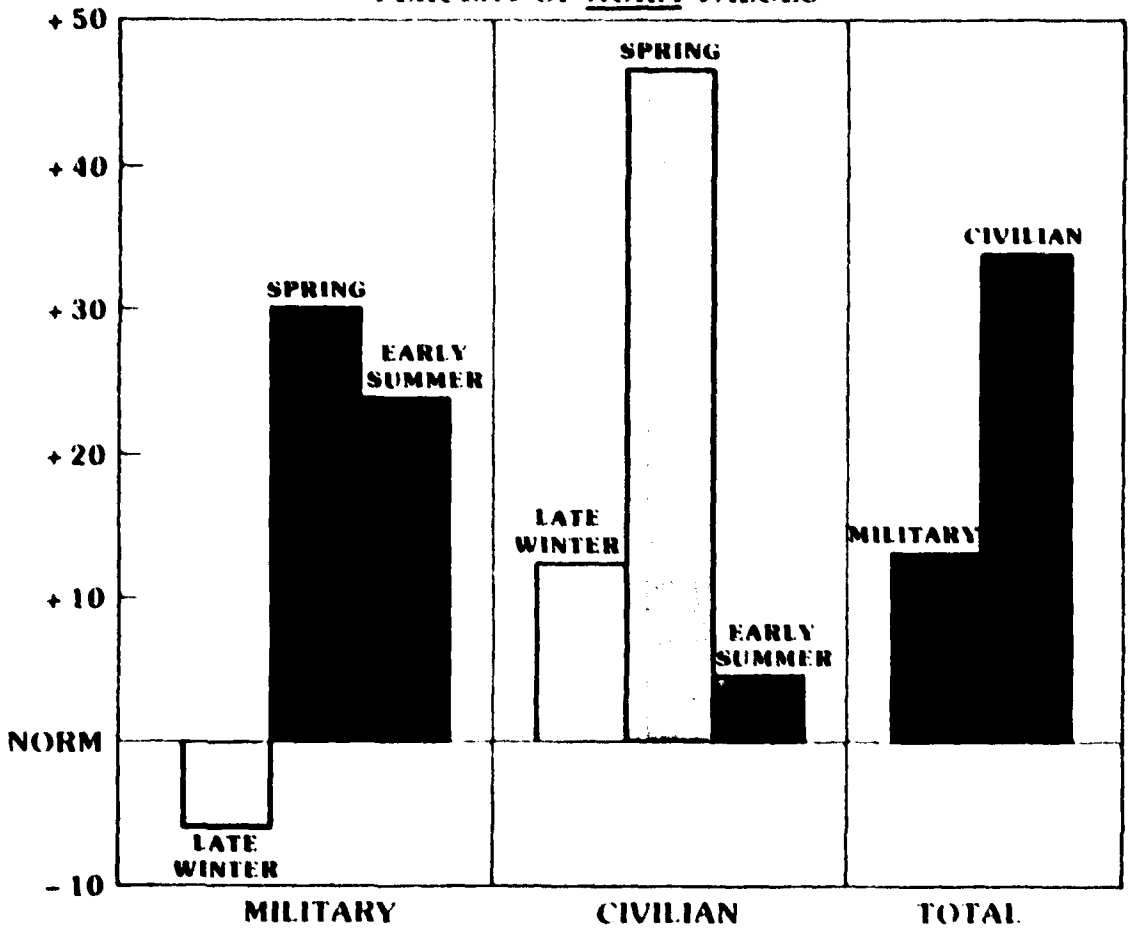


FIGURE 7 10

exceeded the norm by 13 percent, the mean of consumption of the civilian units in the test exceeded the norm by 34 percent. Contrary to the initial assumption, it was found that military households actually used less energy by a significant amount, after all variables were considered. On a per capita basis, actual military consumption was 12 percent less than civilian consumption.

On a less scientific basis, the average consumption of the 1,535 units at Little Rock Air Force Base was compared with a number of generally similar civilian all-electric homes served by Arkansas Power and Light. This particular study indicated that housing units on base, which had received considerable energy efficiency improvement, used an average of 15 percent less energy than the civilian units in the surrounding area. Similar information from Charleston, South Carolina, shows that over a period of 2 years, the average Navy family housing unit consumption on base derived from master meters showed consumption per unit comparable to that reported for all electric civilian houses in the Charleston surrounding area.

THESE DATA STRONGLY SUGGEST THAT MILITARY FAMILY HOUSING OCCUPANTS ARE, ON THE AVERAGE, AHEAD OF THEIR CIVILIAN COUNTERPARTS IN REDUCING ENERGY CONSUMPTION, RAISE SERIOUS QUESTIONS AS TO THE ADDITIONAL ACTUAL ENERGY SAVINGS RESULTS TO BE EXPECTED FROM THE INSTALLATION OF METERS ON ALL DOD HOUSING UNITS, AND BRING INTO QUESTION THE REAL NEED TO SPEND TAX DOLLARS INSTALLING METERS WITH EXPECTATION OF ONLY LIMITED ENERGY SAVINGS.

D. Occupant Response Field Studies.

Because the entire metering concept would derive its benefits from modification of occupant behavior, tests were conducted to attempt to determine potential occupant response to initiatives for conservation, including actual installation of meters and penalty billing for excess consumption and alternative programs. In view of the extremely high cost of installation and operation of a metering system and the potential adverse personnel reaction to billing, attempts were made to ascertain the potential for savings with or without individual metering and billing by using individual or master (group) consumption feedback and occupant education at various levels of intensity. Also reviewed was the possibility of monetary rewards for energy conservation, which of course would be the complement of the penalty system prescribed by Congress.

At the Navy's Corry Field, Florida, an electrical energy saving of between 5 and 6 percent was achieved in a group of 100 houses by the use of an energy advocate's making frequent personal contact with occupants of these houses, including the children, and by feedback of overall consumption information for the test group. Involvement of the children appeared

especially beneficial in such roles as junior energy detective. A control group of 100 similar units was used as a means of determining the amount of savings achieved. Indications are that this particular magnitude of savings could be sustained and possibly increased by a more intensive level of effort. Figure 7-11 shows the overall results as well as the spread of sub group attitudes and behaviors identified.

A study was conducted at Port Hueneme to attempt to determine maximum possible savings from individual metering and feedback but with no bill rendered. Out of approximately 120 families requested to participate, 60 families volunteered for this study. A control group of 60 other families was utilized. Maximum levels of education, group meetings, peer pressure, biweekly feedback of actual consumption unit by unit, and rewards for good conservation were utilized. In this very intensive short-term program, a savings of 24 percent was achieved compared with the control group. However, in view of the nature of the test and the fact that the selected participants were volunteers this level of this saving is considered very unlikely to be duplicated on a broader nonvolunteer base or sustainable for a long period of time.

E. Projected Occupant Response to Metering.

The bell-shaped curves (Figure 7-12) indicate the expected reaction by housing occupants in the civilian sector upon conversion from master-metered utilities included in rent to a full billing system, Curve A (DOE study). However, a system providing only penalty bills would impact only on those occupants who exceed a norm, and would be of considerably different shape as shown by Curve B because occupants below the norm would have no reason to alter consumption habits. The potential savings are reduced from the estimated 20 percent to about 12 percent because those people below the billing threshold are not affected in any way. (Actually, use of the norm may psychologically cause low consumers to raise their consumption and result in a greater clustering near the norm.) Even this curve, however, is not considered to portray accurately the present military family housing consumption situation. The average military occupant has already cut his consumption considerably (7.7 percent since 1975) because of past administrative actions, so an appreciable percentage of occupants already lie below a reasonable norm. Therefore, unless the norm is artificially lowered (below average civilian consumption), few, perhaps 15 percent, of military personnel would actually receive a bill. Therefore, the actual savings via a penalty billing system would be on the order of only about 6 percent, as shown on Curve C. The requirement for a confidence factor of ± 15 percent to insure fairness to the occupant because of the lack of accuracy of the basic norm formula would further reduce the impact of the norm in achieving energy consumption reduction by metering. Curve D depicts what might be expected if a system of rewards for low consumption in addition to

FIELD TEST

MASTER METERING WITH FEEDBACK AND ENERGY ADVOCATE

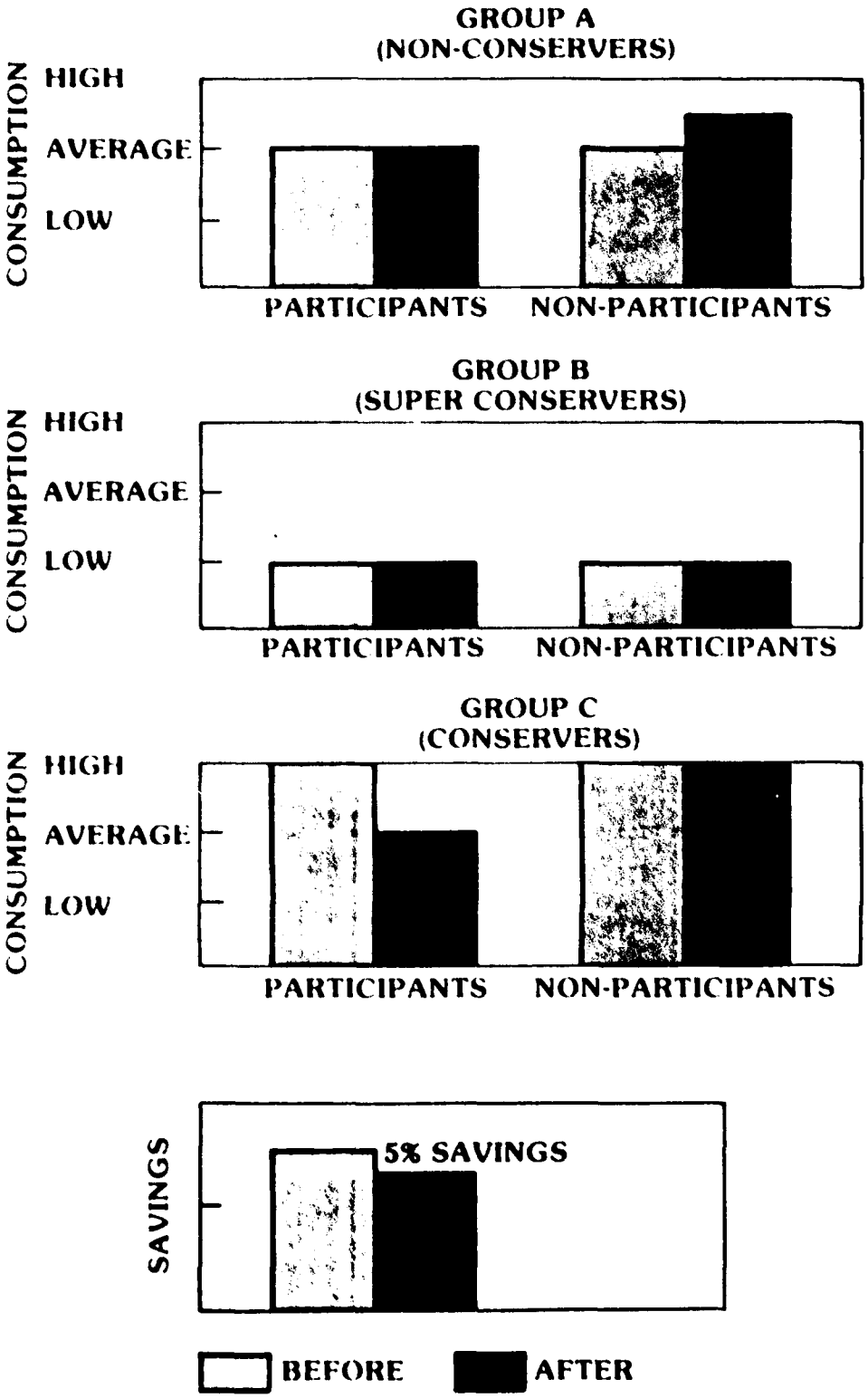


FIGURE 7-11

PROJECTED OCCUPANT RESPONSE TO METERING

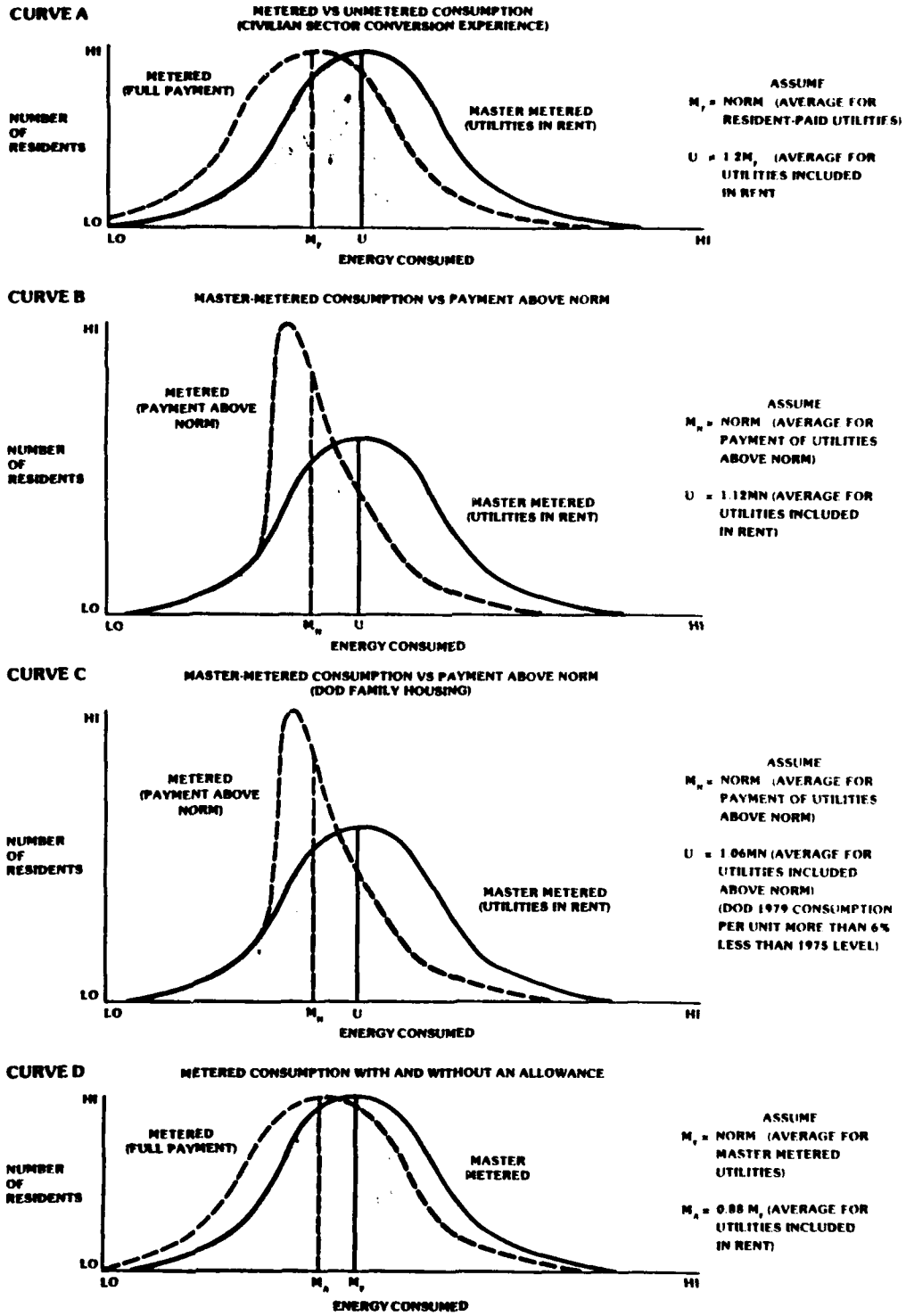


FIGURE 7-12

penalties was instituted, possibly using a utility allowance payment in addition to BAQ, from which the occupant would pay a full utility bill.

VI. Adverse Occupant Reaction.

Any charge or penalty for military occupants for whom all energy was previously included in the rent will have definite morale impact with accompanying personnel retention considerations. These were evaluated to some extent late in the study; however, many of the projections are very subjective and depend on the conditioned perception of impact held by the individual military member.

Because of the complexity of the norm computation itself and the level of confidence of only approximately 85 percent there would be a definite credibility problem with respect to the norm for virtually any housing occupant who receives a bill, especially if that individual feels that his family and house are very similar to another occupant's, maybe next door, who receives no bill even though consumption may be relatively similar. In addition, the threat of an occupant's receiving a bill of unknown proportions under a system which is not understood or easily explained could have a devastating impact on both the real and the perceived compensation structure.

Occupant reaction could take a number of directions from a genuine concern for the energy efficiency of the house, resulting in a major increase in requests for landlord maintenance service to class action suits in the Federal courts to prevent a change in previously implied employment contract terms. The presently declining DoD military personnel retention rates, especially for career-designated personnel, are of growing concern, and attrition in this hard-to-replace group is rising dramatically. A family housing metering program would especially impact this group and would be perceived as being a further negative compensation or a reduction of benefits.

The long-range effects on the morale and retention aspects of metering are of course indeterminate; however, a variety of actions could be expected. Some prospective occupants of military housing, unless involuntarily assigned, could find military housing sufficiently less attractive and decide to occupy civilian housing. Others could simply decide to leave the service. The negative retention and morale aspects could lead to reduced retention and recruiting and ultimately to a reduced force readiness, because personnel who leave as a result of this program would be difficult if not impossible to replace except on a longer term basis. As a measure of the possible cost impact, an attrition of 1/4 of one percent of career military personnel as a result of a metering program would cost $118,000,000 for replacement of these experienced midrange management personnel.

VII. Other Considerations.

Other factors impacting on or relating to the metering proposal were also studied. Thirty-one states presently prohibit submetering and resale of energy by anyone other than a designated public utility. Charging of a penalty related to the cost of the energy purchased by the Government might be viewed as a form of submetering; however, it is believed that the concept of Federal supremacy would allow DoD to submeter in this case because the direction is contained in public laws.

As in the case of the private sector, incidents of vandalism and theft could be expected as meters are installed and penalties charged for overconsumption. Vandalism is not viewed as any more significant a problem than it is in the private sector; however, it would result in some annual cost. Theft of energy, on the other hand, has been increasing dramatically in the civilian community, essentially in proportion to increases in energy cost. Similar theft aboard military bases could be expected not only out of resentment on the part of individuals of the fact that they are being charged for what previously was provided as a benefit, but secondly, because of the relative technical sophistication of many occupants of family housing and their greater potential ability to execute the theft successfully.

Several serious questions on fairness of metering with a penalty system arose and were considered. First, the law as interpreted provides no credit for underutilization. Under this concept a given occupant could underutilize for many months, receive no credit for it, and then receive a bill for a slight utilization above norm during the following month.

With the onset of a billing system in any form, a great increase in occupant interest in the Government landlord maintenance responsibility is anticipated. The manifestation of this would be an increase in the number of maintenance service calls received by the housing maintenance authority. If these service calls were responded to there would be an increase in maintenance costs. If the service calls were not responded to in a manner expected by the occupants, a negative occupant attitude could be expected because the Government could be viewed as not doing its part to maintain the facility, while the occupant is being penalized for energy utilization.

VIII. Alternative for Energy Consumption Reduction.

Energy savings from further facility improvement was studied because this saving is much more easily estimated and predicted than energy savings which depend upon occupant attitude and performance. Significant work has been done in improving the energy efficiency of DoD family houses within program constraints; however, there is much that remains to be done in this area, especially as the cost of energy continues

to rise, making economically attractive many other types of improvements. These potential improvements take the form of either reducing existing energy consumption or creating new energy sources such as solar energy. Figure 7-13 suggests a few types of improvements likely to be executed. Based on the approximately 310,000 units in the DoD/US family housing inventory, it has been estimated that a 1 percent savings in energy per year (810 billion Btu per year or 139,000 equivalent barrels of oil) would cost approximately $27,000,000. While this relationship is not linear over an unlimited range of investment, it is believed to be linear to a saving of 12 percent or more and therefore offers the opportunity for considerable energy savings at a predictable and incrementable cost. Further, it is not dependent upon the amount of energy previously saved or being saved by occupants as a result of energy conservation efforts.

Solar energy retrofits for domestic hot water in warmer climates are somewhat less efficient in terms of direct energy savings per dollar of investment; however, generating new energy instead of conserving present consumption makes these very attractive. It is anticipated that approximately 50,000 units of housing in the southern part of the country could be beneficially retrofitted at the cost of approximately $100,000,000, generating a savings on the order of 1 percent of the total DoD energy requirements. The potential for both the solar and facility improvement has been calculated theoretically; however, the potential is real and can be predictably achieved.

IX. Implementation.

Paramount to any initiative, such as meter installation, is the length of time to commence reaping the expected benefits of the program. The installation part of the test program was especially troublesome because of the time constraints. The time required to implement any metering program must be closely considered. If metering is directed, studies of energy source trade offs, planning and design, contracting and meter installation would require between 4 and 5 years to complete. In some cases houses must be actually vacated for a number of weeks in order to allow meter installation. These installations should be programmed for accomplishment during normal change of occupancy. Similarly, procurement of the necessary ADP hardware and software would require approximately 50 months. Finally, it would be necessary for such a system to be run in and tested for not less than 1 year subsequent to the completion of all meter installation and ADP procurement. This is necessary to validate the accuracy of the meters, the norm, and the billing system, as well as to generate credibility with the occupants. There would be a total of between 5 and 6 years before benefit accrued from meter installation because, from a fairness point of view, no occupant should be liable for bills until all occupants of housing are involved. In contrast,

FACILITY ENERGY IMPROVEMENTS

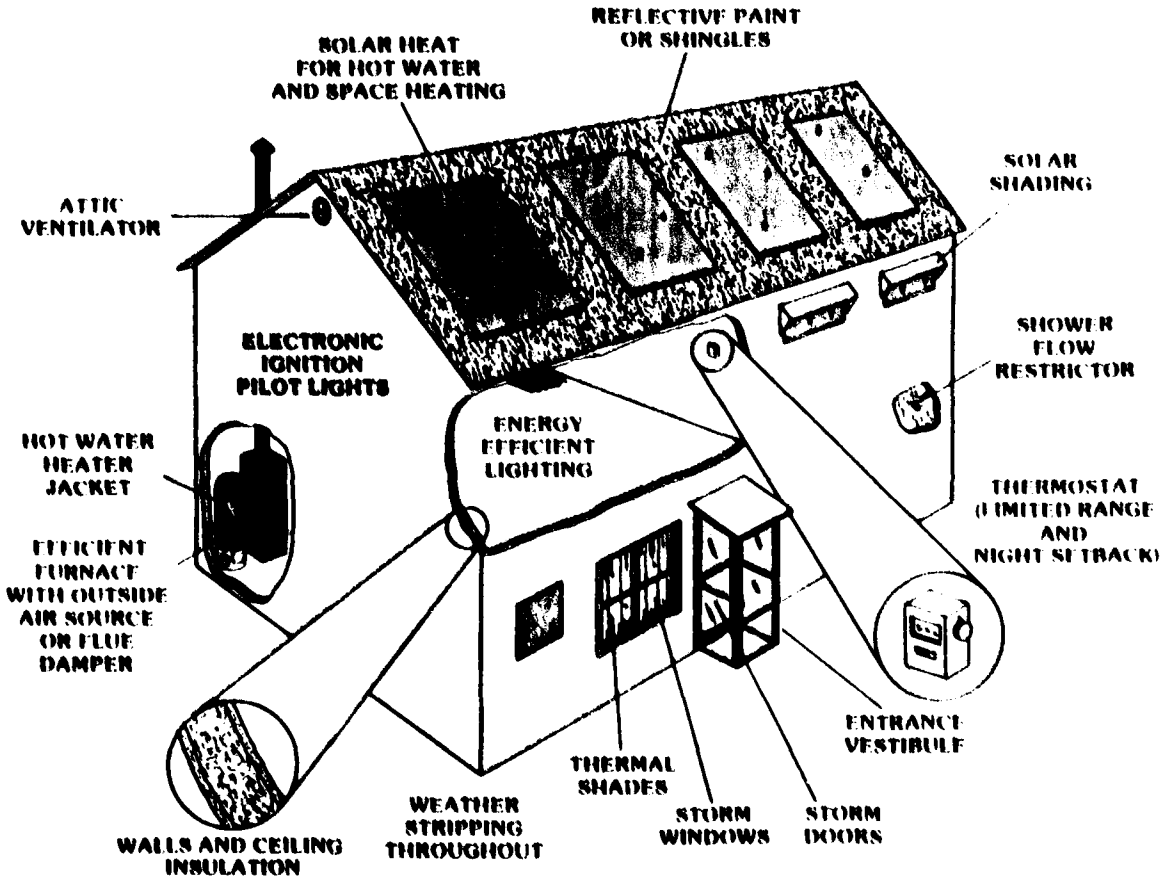


FIGURE 7-13

savings from facility improvements begin to accrue as soon as any increment of improvement is in place.

A. Annual Operation and Maintenance Costs.

Costs of operating and maintaining a metering system and billing occupants are significant and must include meter maintenance, norm data base maintenance, meter reading and consumption data input, and collection and accounting for funds. These functions are estimated to have an annual cost of over $32,000,000 in FY 1987 dollars and to require a minimum of 487 additional employees for meter reading alone. Related costs of occupant education and response to increased occupant-generated maintenance service calls would raise this annual cost to over $55,000,000.

B. Estimated Energy Savings.

It is estimated that a norm and penalty billing system as included in the public law, if they can be made technologically feasible, might result in a 6 percent energy consumption reduction in DoD family housing, or a saving of approximately 4,860,000 MBtu. The estimated 1987 value of this energy saved would be about $31,867,000. Because of the high annual system operating cost of $55,000,000, there would be a $23,712,000 annual operating loss. Additionally if amortization of the initial costs was over 25 years, the total annual loss would be $42,320,000.

C. Alternatives.

In addition to the directed alternative of overall metering with norm and penalty charges, several other alternatives and options have appeared during the course of the study. The overall costs and benefits of each are compared in Figure 7-14 while Figure 7-15 adds the possible impact of projected adverse personnel reaction.

On a more quantitative basis, Table 8-1 (page 8-14) arrays estimated norm and penalty system (alternative I.A) costs for comparison with costs of some other alternatives. The first cost of the metering and norm alternative is highest because of the requirement not only to install meters on all houses but to develop a norm. The prospective benefits of the metering are viewed as rather lower because of the fact that military consumption has already been reduced by administration action. Alternative I.A only impacts upon those who are above the norm and does nothing to decrease consumption of those below the norm. The provision for rewards in addition to penalty charges (alternative I.B) would encourage people below the norm also to save and shows potential for savings up to approximately 12 percent. The basic problem with alternative I, however, is the fact that the norm itself is of questionable accuracy. It is doubtful that a norm that models well for facility and

COSTS AND ENERGY SAVINGS

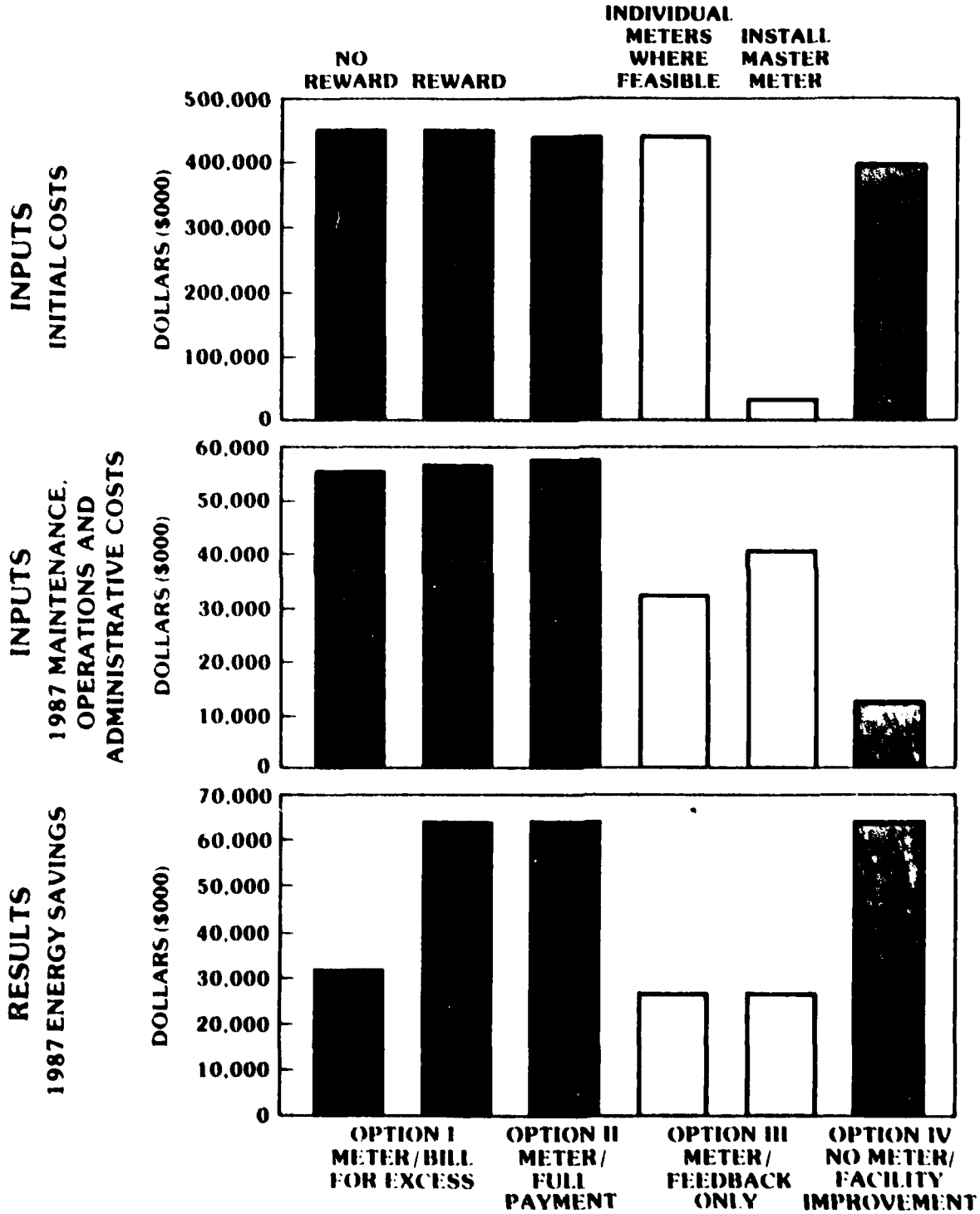


FIGURE 7-14

THE BIG PICTURE

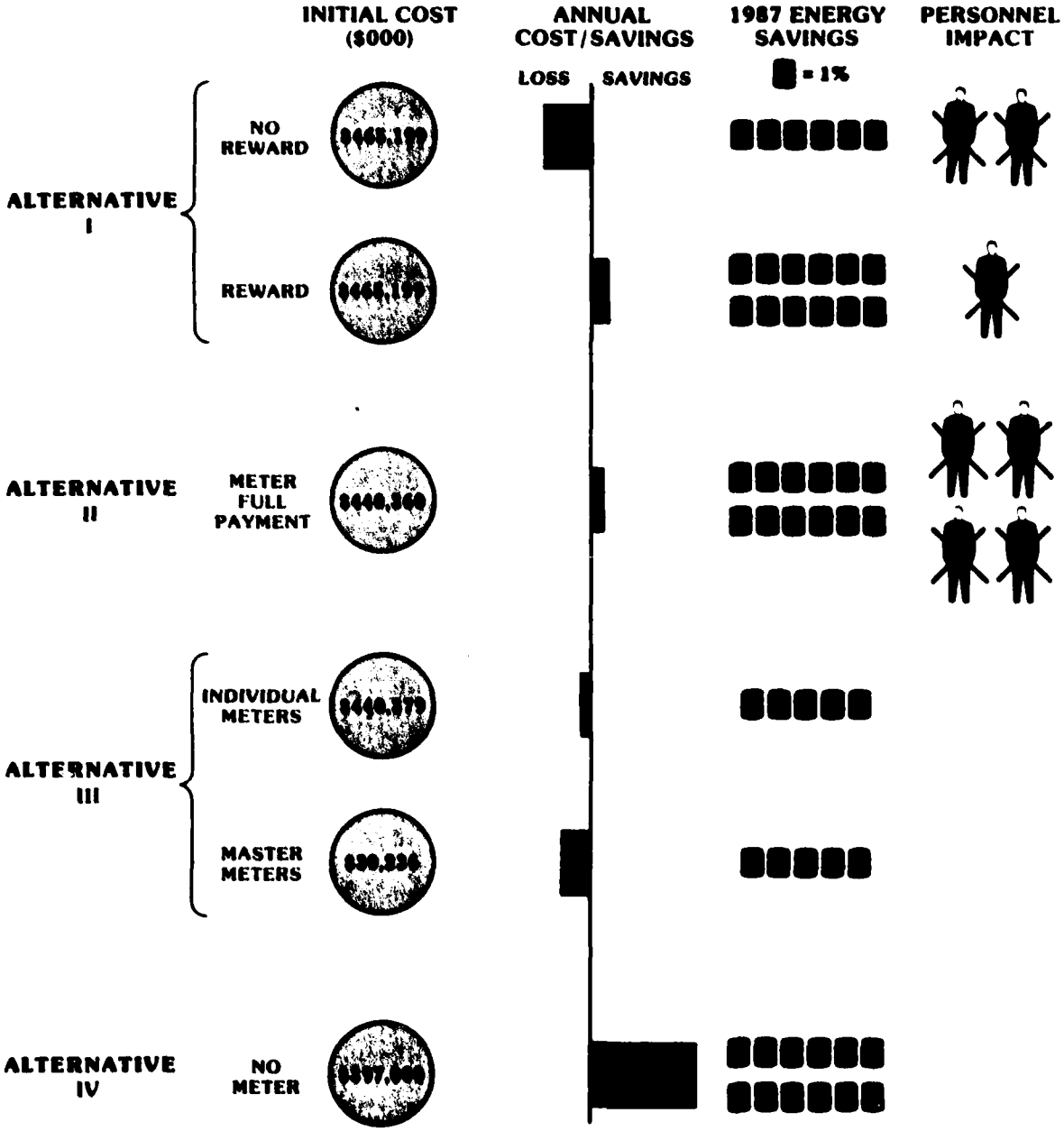


FIGURE 7-16

occupants, fairly and adequately reflecting the average American quality of life, can be developed. Any norm computation must be used in conjunction with a confidence factor which will greatly decrease the incidence of billing and possible savings, especially if bills are rendered as based on the low commercial energy rate paid by the Government.

Alternative II, an obvious possible use of meters without a norm, would impose a requirement for full payment by the housing occupant. Obviously, to impose this requirement without providing some type of monetary energy allowance would amount to a substantial change in take-home pay and the implied contract of employment of military personnel and could be expected to have massive personnel and retention impacts. However, it would be projected to save at least 12 percent of all energy now being consumed.

Alternative III, involving metering data feedback in conjunction with occupant education, is viewed as having a lesser potential of between 2-1/2 and 5 percent savings depending upon the specific structuring of the program. Installation of individual meters, where economically and technologically feasible, and feedback of individual consumption data could be expected to have a better savings (at higher cost) than the use of group consumption data from master meters, either existing or planned. This alternative, however, would involve little or no adverse personnel reaction unless the installation of individual meters, albeit for feedback purposes, were viewed by individual occupants as the first step toward the ultimate commencement of charging for all utilities.

Alternative IV involves installation of no new meters but rather concentrates on improving the facility efficiency and on developing new solar energy. This alternative is seen as having no adverse personnel impact while having potential for savings of 12 percent or more depending on the level of investment in facility improvement and solar energy and possible utilization of occupant education also. The investment in facilities improvements may be incremented to suit national and budgetary considerations whereas any type of meter installation cannot be reasonably incremented, thereby making it an all-or-nothing situation.

D. Summary.

While the program of metering with norm and penalties will doubtlessly produce energy savings, they will be rather small and the direct cost of achieving those savings would be very high. Additionally, accompanying adverse personnel reaction would make that cost even higher, as suggested in Table 8-1. On the other hand, other programs based on education and facility improvements can guarantee a greater potential energy savings with no negative personnel reaction or adverse morale impact. Based on this study these alternatives appear to offer very attractive means of conserving energy within DoD family housing.

Chapter 8. ALTERNATIVES

As described in the previous chapters, many alternative strategies are available to pursue the goal of conserving energy in military family housing. Several of these approaches are within the congressional guidelines for the metering test while others consider other possible methods to accomplish the same objective. The major alternatives are outlined in this chapter. The effort and cost which goes into each is described. Then the various results are projected. It is critical that each alternative be considered not only on the basis of energy savings, initial investment, and annual costs but also the impact it has on the effectiveness with which DoD can achieve its primary mission, national defense. All four alternatives require a major commitment by DoD to prompt, effective maintenance servicing of the family housing and GFE. Without such a commitment, the credibility of an energy conservation program of any type would be questioned by the housing residents. A summary of the alternatives is provided in Table 8-1.

I. Alternative I--Metering and Billing of Excess Consumption.

A. General Description.

This alternative is the most literal interpretation of the congressional direction provided in 1977. Each housing unit would be individually metered and consumption data collected monthly. DOD would develop a norm (ceiling) which would serve as a standard describing its interpretation of the maximum amount of energy a given family should utilize considering the type of house, weather, etc. The consumption data would then be compared to the norm and the occupant would be billed monthly for any energy consumed above the norm.

To reflect the inaccuracies represented in a norm, to be fair in situations where more than one energy source is used and to respond to the residents' feelings of fairness, the bills should be based upon total energy consumed in the residence. Thus, if the resident is below the norm by $5.00 on one source of energy, such as electricity, and $5.00 above on another, such as natural gas, no bill would be received. These allowances are, in addition to the 15 percent allowance factor, considered necessary with the norm computation.

This alternative can be split into two options depending upon the use of the funds which are collected from residents. In one instance, option A, the funds could be retained in the service's Family Housing Management Account, Defense (FHMA(D)), and used to offset the cost of energy, to administer the billing system, etc., an income maximization approach. In the second case, option B, the funds could be redistributed as a reward to the

best conservers of energy, an energy conservation maximization approach.

As shown in Table 8-1, most initial and annual costs are the same; meter installation and maintenance as well as the norm development expenses are identical; and the cost to service buildings and GFE should be similar for both options. Although the content of the educational programs for each case would vary somewhat, the differences should not be large enough to require different funding.

B. Option A--No Reward for Good Conservation.

1. Description. Option A requires charging for consumption above a norm, with all of the receipts retained within FHMA(D), and the incorporation of a norm into a traditional public utility billing system, which would increase the cost considerably. In addition, the use of a norm makes it important that actual, rather than estimated, bills be issued each month. The payment collection costs for such a system should be lower than in a traditional system because payments would be received from only a few, up to about 15 percent of the residents.

2. Costs and results. If the funds received from those billed as excess consumers are retained in the FHMA(D), the program serves as a punitive one for the estimated 15 percent of the consumers who are over the norm. The remainder of the residents would not be influenced at all unless they receive statements of consumption. It is projected that the feedback received by 85 percent of the residents would reduce that group's consumption by 4 percent. The consumption attributed to excess usage by the 15 percent above the norm is projected to drop far enough that an additional 2 percent of the total family housing energy would be saved. Not all excessive users would drop below the norm because of the lack of sufficient incentive to change their lifestyle. Therefore, option A is projected to produce a savings of 6 percent in the amount of energy consumed in military family housing. The projected reduction is only 6 percent because overall DoD family housing per unit energy consumption is already down 7.7 percent since 1975. If the 1978 level of energy consumed does not change and the cost of energy increases at the rate of 10 percent per year, 4.86×10^6 MBtu, worth $31,867,000, will be saved in 1987. If the initial costs for this alternative are amortized over 25 years, the energy savings achieved will be at a net annual cost of $42,320,000 in 1987. Because of the relatively small projected savings and high operating costs, there is a net operating deficit (annual) and no projected payback on initial costs.

Option A will directly affect about 15 percent of the military family housing residents and indirectly a much larger portion. Because it is a punitive approach, it can be expected to influence morale negatively because many personnel will see the program as a further erosion of benefits. The residents can

respond by stealing energy so that they do not exceed the norm, by filing a class action suit to bring attention to the issue, by moving out of family housing, or by leaving the service. The incidence of each would be expected to increase.

C. Option B--Reward for Good Conservation.

1. Description. Option B is identical to option A except that the funds received from excess consumers of energy are not necessarily retained in the FHMA(D). These funds as well as funds originally budgeted for utilities are available for redistribution to the residents who conserve the most energy.

2. Costs and Results. As in Option A, a norm is required which increases the cost of the billing system far beyond a traditional one. Although the collection costs would be the same as in option A, an additional disbursement cost would be required to cover the redistribution of receipts to good conservers.

If the funds received from those billed for excess consumption are redistributed to the best conservers, the program is punitive for about 15 percent of the residents who are above the norm and rewards approximately 15 percent who are furthest below the norm. It is projected that such a system would provide not only feedback but also an incentive for all residents to save. If it is assumed that military housing residents already consume the same amount of energy as civilian in individually metered and billed housing, the savings under option B are projected to be about 20 percent. However, previous reductions are believed to have already lowered military consumption. If military family housing residents actually consume more than civilians in individually metered and billed housing, the savings under option B may be materially greater. If the 1978 level of energy consumed does not change and the cost of energy increases at the rate of 10 percent per year, 9.72×10^6 MBtu, worth $63,734,000, will be saved in 1987. If the initial costs of this option are amortized over 25 years, the energy savings achieved will be at a net annual cost of $11,571,000 in 1987. Because of the high projected operating costs, this rate of energy saving results in a small net annual dollar saving of $7,037,000; however, the payback period on initial investment is 66 years.

Because Option B combines both reward and punishment, there should be limited effect on morale. Although some residents may see the program as an erosion of benefits, others would identify it as actually enhancing their quality of life because it provides a reward for a positive action they take. It is possible that some individuals will try to increase their chance of obtaining a reward payment by stealing energy. Because the reward payments are not very large and the punishment for the theft of Government or another individual's property is quite severe, this should not be a major problem.

D. Problems.

Both options within alternative I require that an accurate, acceptable norm be established. If the residents do not accept the norm as reasonable and accurate, the effect on morale will be catastrophic. At this time the norm is not accurate. Because it does not describe present or desirable energy consumption within realistic boundaries, family housing residents cannot be expected to accept the norm and respond in a positive fashion. As reflected in Chapter 2, "Norm Development," it appears that the norm may be improved with additional work, but the probability that one can be developed which is accurate enough for billing purposes without a very large error factor is rather low.

Both options are quite complex systems compared to any other alternatives. Therefore, an extremely well-designed, long-term educational program may be essential to develop the understanding and acceptance of the residents required to gain maximum results. This is the most difficult alternative described and entails the highest level of risk in effective implementation.

Option B may require new legislation to make it possible to provide incentive payments to the best conservers. Without such the impact of option B is lost. Both options require complete metering. To facilitate collection of overdue charges, a uniform procedure for pay checkage is recommended. At the present time electricity, natural gas, and propane are readily metered although the retrofit of previously unmetered units is expensive. The technology appears to be present for metering fuel oil, kerosene, steam, and hot or chilled water. Nevertheless, it has not been applied to single-family units enough for its adequacy over time to be known, and it is very expensive. There appears to be a good probability that the problem can be solved, but the cost will be high.

II. Alternative II--Meter with Full Payment.

A. Description.

Alternative II is identical to the method used by public utilities to sell energy to individual home residents. Each family unit would be individually metered and the consumption data collected periodically, typically monthly.

Every occupant would then be billed for all of the energy consumed during the billing period. The rates charged for the energy could be the adjusted cost to the base. An added fee based on actual cost could be charged for late or delinquent payment.

B. Costs and Results.

Alternative II requires complete metering, billing, and education but does not need a norm. It may be a little cheaper to design the billing system, but the cost to operate it would be greater. It is necessary to collect payments from every housing unit. Because the system is simpler than those in Alternative I and already familiar to most family housing occupants, the educational program will be the easiest to design of any alternative. The annual administration of the education program should be maintained at a level equivalent to the others.

The full-payment program may reduce 1987 energy consumption as much as 12 percent from that used in 1978 if the projected level of energy consumed in 1987 is similar to that in 1978. If the cost of energy increases 10 percent annually, 9.72×10^6 MBtu, worth $63,734,000, should be saved in 1987. If the initial costs of this alternative are amortized over 25 years, the energy savings achieved will be at a net annual cost of $11,657,000 in 1987, not counting costs due to personnel attrition. (Because of the high projected operating costs, even this rate of energy savings results in a small net annual dollar saving of $5,597,000. The pay back period on initial investment would be 74 years, unless the reduced cost to FHMA(D) for energy paid for by the occupants under this alternative is considered.

The major impact of alternative II would be on the morale of the military personnel. Without an addition to the basic allowance for quarters (BAQ) providing for energy payments, a previous benefit of compensation in the form of energy would be withdrawn. Such an action will be interpreted as a major erosion of benefits even though less than 15 percent of military personnel are in military family housing at any one time. About one-third of the eligible military personnel are housed on base at any one time and the majority are housed there at one time or another. With the tight infrastructure represented in the military social system, the impact of alternative II will be felt almost immediately on nearly every military person with more than 1 year's service. It can be expected that there will be a significant

increase in the attrition of career officers and enlisted personnel and a reduction in the retention rate for younger ineligible personnel. Such a factor would negatively affect the ability of DoD to accomplish its mission. This is discussed in greater detail in Chapter 6.

The immediate response of residents could be increased theft of energy, housing vacancies, and possibly, a class action suit. Over a 5-year period, attrition and retention rates would be negatively affected until new personnel are recruited and reach the stage where they are eligible for family housing. The new personnel will be aware of the new policy and should not feel that an implied contract has been violated, although the history of the change in the implied contract could cause future concern for other aspects of military compensation and benefits.

C. Problems.

Attrition of military personnel as a result of lower morale will be the major problem described. As long as a punitive system is presented without any positive effects, the probability that such a program will increase the military manpower erosion is very great.

Because alternative II requires the same metering as alternative I, the identified problem of metering fuel oil, kerosene, steam, and hot or chilled water is present. There appears to be a good probability that the problem can be solved, but the cost will be high.

III. Alternative III--Meter and Provide Feedback.

A. Description.

This alternative emphasizes the principle of consumption data feedback as a method to promote energy conservation. In this instance the feedback provided to each family is the amount of energy consumed by either the family or a major portion of the family housing complex. In the former instance it will be necessary to meter each housing unit. In the latter case master meters will be installed as required to record the total energy consumed in a contiguous complex which may have anywhere from 2 to 500 units. In either situation, the meters would need to be read periodically and statements sent to each residence. The statement would show consumption for the billing period and possibly a comparison with the previous year's identical billing period. A norm would not be used. The information could be presented not only in energy consumption figures such as kWh and Btu but also in dollars. No bill would be sent for any energy consumed. A supporting educational program would aid the resident in the interpretation of the feedback and establish means to conserve energy.

B. Option A--Metering Individual Units.

1. Description. This option requires that each housing unit be individually metered, where economically feasible, for all of the energy consumed by its residents. The meters would be read each month and the resident provided with a statement which identifies the amount and cost of each type of energy used as well as a total for all sources. The same statement would compare current consumption with some relevant past period such as the same one in the previous year.

To support the program, an educational program similar to the one proposed under alternative II would be designed and conducted on a continuing basis.

2. Costs and Results. This option requires almost the same metering system as described in alternatives I and II. Therefore its costs are considered the same, subject to later determination of economic feasibility standards. Because the proposed feedback process is very similar to the procedures used in the civilian sector, the costs for education should be similar to those proposed for alternative II. The previously described norm development costs would be eliminated. The billing system design costs would be reduced somewhat because a norm would not be involved and arrangements would not need to be made for the receipt of payments. The annual costs to operate the system would be only slightly less than those of alternatives I and II. (See Table 8-1.)

This option could be expected to achieve a 5 to 10 percent reduction in the energy to be consumed by a military family each

year. Because there has already been a 7.7 percent reduction in the use of such energy since 1975, it would be realistic to assume a 5 percent annual reduction using feedback in an individually metered system. Assuming that the level of energy consumed in 1979 would not change without a programmed effort and the cost of energy increases 10 percent annually, 4.05×10^6 MBtu, worth $26,555,000, should be saved in 1987. If the initial costs of this option are amortized over 25 years, the energy savings achieved will be at an annual net cost of $23,200,000 in 1987. Because of high projected operating costs, this rate of energy saving does not result in a net annual dollar saving. There is no projected payback on initial investment.

3. Advantages and Disadvantages. Morale should not be affected by alternative III, option A, if the occupants feel that housing management can be trusted and the educational program is carefully designed and conducted. However, if the residents perceive that this program is the first step in a move toward billing in the form of alternative I, option A, or alternative II, morale may drop markedly. The residents' response could be to disregard the energy conservation program or leave the service as soon as possible.

The effectiveness of feedback is dependent upon the presence of an acceptable reference point to compare with current performance. If the historical information, such as consumption during the same period in the previous year, is collected under drastically different conditions from the present ones, the residents may not consider it to be a legitimate comparison. Therefore, only a minimal reduction in energy consumption would take place.

In addition to producing a possible negative impact on morale, this option is not forecasted to achieve a major reduction in energy consumption even though the initial and continuing costs are high.

C. Option B--Master Meters.

1. Description. This option requires that meters be installed as necessary at each base to record only the energy consumed by family housing. For a few bases very extensive modifications to the distribution system would need to be made if the total family housing energy consumption were recorded on a single meter. Therefore, to minimize installation costs at those sites, as many as ten meters might be installed for a single utility for portions of the housing scattered throughout the facility. The meters would be read each month and statements would be sent to the residents of each housing unit. In contrast to the information provided in previous alternatives, no listing of individual unit consumption would be received. The resident would be provided with an aggregate of the energy consumed by all units serviced by the master meter or set of master meters for his subdivision. The statement would identify the amount and

type of energy used currently and compare it with that used in some previous period. A total for all energy consumed would also be included.

A comprehensive educational program would be instituted to support the billing statement and aid the residents in establishing the best ways to conserve. Individual meters installed for the field test would remain in place for local command use, except that cases of adverse esthetic impact would be corrected.

2. Costs and Results. Many bases already have master meters installed to separate family housing consumption from the rest of the base. It is projected that installing the remaining requirements would take $25,000,000. No norm would be required, and the billing system requirements would not be very demanding as shown in Table 8-1. Because group feedback is not as effective as individual, a comprehensive educational program is required similar to the one described in Chapter 5 and pilot tested at the Navy's Corry Field (see Chapter 4, Section II.C.2.b). It is projected that the design and initial work on such a program would cost $236,000, and it would cost $22,709,000 to operate it each year. Meter maintenance costs would be minimal and the billing system operations would be reduced materially from those described under alternatives I, II, and III.A.

Option III.B could be expected to achieve a 5 to 10 percent reduction in the energy consumed by a military family each year. Like option III.A, it would be realistic to project that a 5 percent annual reduction could be achieved via feedback in a master-metered system with an intensive education program. Assuming that the level of energy consumed in 1979 would not change without a programmed effort and the cost of energy increases 10 percent annually, 4.05×10^6 MBtu, worth $26,555,000, should be saved in 1987. If the initial costs of this option are amortized over 25 years, the savings achieved will be at an annual net cost of $15,062,000 in 1987.

3. Advantages and Disadvantages. The initial cost of option III.B is very low in contrast to any other alternative. Its annual costs of maintenance, operation, and administration are similar to alternatives I and II although larger than alternative IV. The negative impact on morale should not be present because the emphasis is on individual and group family effort rather than the family's financial investment.

The primary disadvantage in such a program is the difficulty in developing and maintaining a high level of participation and interest on the part of the families. Such a program is highly dependent upon the innovative and interpersonal skills of the energy advocates present at each base. The educational program cannot be standardized and just administered by base personnel or it will lose the vitality and local relevance required to develop and maintain the personal commitment of the housing residents. Secondarily, the impact of such a program is

dependent upon the sustained commitment of the service and base personnel responsible for its promulgation. It is often easy to reassess priorities for continuing operating expenses and reduce the effectiveness of an educational program by "cutting costs," a sign to residents that energy conservation has been reduced in its priority. Without a comprehensive educational program of a continuing nature, any savings in energy will disappear under option III.B. Group feedback is too ambiguous and impersonal to produce any effect by itself.

It has been assumed that historical information, such as consumption during the same period in the previous year, will be accepted by residents as an acceptable base for comparing present consumption. If weather, occupant characteristics, or structural improvements change dramatically during the year, the reference point may be questioned and the effectiveness of feedback will be reduced.

IV. Alternative IV--Building and Equipment Improvement.

A. Description.

Alternative IV consists of two parts. One involves altering the characteristics of all DOD family housing buildings and the other provides for the development of a new source of energy. The former program is described in Chapter 5, "Other Considerations" and involves three major retrofit opportunities. The latter provides for the conversion of electric or natural gas DHW to solar heat in 50,000 southern units. It is proposed that the retrofitting concentrate on reducing the requirement for space heating and cooling, which represents 60 percent of the demand in a typical home. Two projects, adding insulation throughout and installing thermal blanketing on windows, would reduce the heat loss or gain through the ceilings, walls, floors, and windows. The third project would concentrate on reducing heating or cooling loads by reducing air infiltration through unsealed windows, doors, etc. Additional projects may include the installation of dual element temperature limiting thermostats and insulation blankets on water heaters, solar shading, duct insulation, etc.*

In addition to the structural improvements, it is proposed that present sources of energy be conserved by developing new, renewable sources of energy for homes. Installing solar DHW projects in about 50,000 suitable southern military family housing units would save approximately 150,000 equivalent barrels of oil each year.

B. Costs and Results.

As shown in Table 8-1, the structural improvements would initially cost $297,000,000, but the annual maintenance, operating, and administration costs would be minimal. The solar conversion program would initially cost $100,000,000, and it is projected that the annual maintenance costs in 1987 would be $2,000,000. The latter cost is not very well-known because little long-term experience is available to establish those requirements.

If the 1978 level of energy consumed does not change, the 1987 savings in energy would be 11 and 1 percent, respectively, from the structural improvements and solar conversions. The total number of MBtu saved in 1987 would be 9.72×10^6. These would be worth $63,734,000 in 1987 if the 1978 price of energy increases by 10 percent per year. If the initial costs are amortized over 25 years, the 1987 energy savings would be achieved with a <u>net annual dollar savings</u> of $35,527,000.

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*Heating DHW is the second largest consumer of energy in the typical home and accounts for over 14 percent of the energy utilized.

C. Advantages.

Besides the reduction in energy consumption at a relatively low annual cost, there is a minimal risk involved in achieving those results. The technology involved in adding ceiling and floor insulation is well-known. The technology for solar conversions on domestic hot water is already known and available. The techniques are available to reduce air infiltration and install dual-element temperature limiting thermostats and insulation blankets on water heaters. This alternative does not generally depend on modifying occupant behavior, as do all other alternatives.

There should be no negative impact on the morale of the military family housing residents. In fact, if the maintenance of the units improves, the impact on morale should be positive.

D. Problems.

Installing thermal blanketing on windows is technically very easy. Because this is essentially a very heavy drapery shade or internal shutter, the problem of getting the occupants to correctly use the equipment at the right time of the day arises. Modifying the present educational programs in the service should aid in alleviating this problem.

The technology is not presently available to install insulation in many styles of walls without a major change in construction, such as adding siding. In other instances the problem of adding a vapor barrier for some types of insulation which are blown in is impossible and other insulating materials are of a questionable nature.

The maintenance requirements of all solar DHW systems are not well-known, but do not appear to be a major factor.

V. Other Considerations.

- Preventive maintenance can be emphasized so that heating systems are kept at optimal efficiency, GFE appliances are maintained in optimal condition, etc.

- A primary criterion for replacing GFE in family housing should be its deterioration in energy consumption efficiency. A primary specification for the purchase of new or replacement GFE in family housing should be its efficiency in energy consumption.

- If one of the first three alternatives is chosen, the criteria for the ECIP program could be liberalized so that a more active program would result. The present military family housing units could be made more structurally energy efficient by establishing a carefully prescribed long-term plan.

- The specifications for new housing should be reviewed and upgraded annually to include the optimum contribution to energy conservation. This way new ideas from a rapidly developing field can be incorporated.

Footnotes to Table 8-1

[1]Includes all startup costs except administrative overhead at the DoD and service levels as well as research.

[2]Meter system design and installation, maintenance program design, meter inventory for maintenance and staffing, and training maintenance personnel.

[3]Includes only those expenditures beyond those expended in a typical year prior to 1981. A goal of 11% savings was used for comparison with other alternatives.

[4]Includes the cost to provide further refinement of the norm, initial collection of norm data for all DoD family housing and training engineering personnel in data collection.

[5]Accounts for system design, purchase of equipment, and the staffing/training of personnel. Includes meter reading bill processing and collection, and the redistribution of receipts where appropriate. Norm processing is included for alternative I only. (Norm data for new housing will be provided as a part of the design and construction.)

[6]Housing occupant education only.

[7]Includes all operating, maintenance and local administration expenses for the first year of full operation, 1987. No cost is included for the value of any energy which may be stolen.

[8]Additional expenses incurred as a result of the increased sensitivity of residents to the effect of the building and GFE condition on energy consumption. The cost varies according to the impact of the program on the residents.

[9]Includes maintenance of new structural improvements and equipment.

[10]Includes meter reading, and data input, computation and issuance of bills, maintenance of the norm data and collection/payment of monthly charges and/or rewards as appropriate.

[11]It was assumed that total energy consumed would not change from 1978 through 1987 without this program. A 10% annual increase in the cost of energy was assumed between 1978 and 1987. 1978 baseline is approximately 81 x 10^6 MBtu per year. Estimated 1978 composite cost per MBtu is $2.781. Estimate 1987 cost as $6.55 for comparison of alternatives.

[12]For conversion to Equivalent Barrels of Oil, (EBO) = 5.8254 MBtu.

[13]Assume initial costs prorated over 25 years with no discount.

[14]Algebraic sum of annual operation and maintenance costs, estimated energy savings.

[15]Personnel attrition as result of negative aspects of metering not precisely determinable. Information shown for attrition of only 1/4% of career personnel. Less impact would be expected for alternative IB but much higher actual experience could be expected for alternative II which would greatly raise costs.Numbers assumed are 496 officers and 857 enlisted personnel in case of 1/4% attrition.

[16]Replacement cost of experienced personnel, not necessarily a one time cost. Attrition could occur over a number of years.

[17]Norm development includes BLAST analysis and data input for each house (6 hrs. x 300,000 units x $12/hr.) plus $500K for refinement studies. Total $22,820K.

[18]Includes following operations: metering reading $13,000K, billing $5,460K, penalty collection and accounting (assuming 15% of occupants are billed) $1,118K, and data base maintenance $9,300K.

[19]Includes all above items plus cost of administering payment of rewards, $1,118K.

[20]No norm is required, but equipment and software for computation of bills for all occupants would be required.

[21]No norm is required but payments would be collected from all occupants. Includes meter reading $13,000K, billing $5,460K and collection and accounting $7,453K.

[22]Retention impact arbitrarily doubled for full billing mode. Actual impact that would result from reducing occupants' take home pay by $100 or more per month is unknown, but could be expected to be severe.

[23]Consumption feedback could take the form of a mock bill, but in any case would require most of the billing system features.

[24]If an extremely intensive program was instituted, the cost could increase to $1,445K and $60,397K for design and annual administration respectively.

[25]Includes following costs: meter reading $5,143K and $2,000K for consumption data feedback to each occupant.

[26]Estimated cost of limited ADP support to provide consumption data to occupants based on master-meter readings.

[27]Intensive initial training of conservation advocates is required.

[28]For data collection and feedback to occupants of average consumption from master-meter readings.

[29]Source of saving: facility improvement 11%, solar energy 1%, total 12%.

Table 8-1

	ALTERNATIVES			
	I		II	
	METER/BILL FOR EXCESS		METER/FULL PAYMENT	M
	A. No Reward	B. Reward		A. Indi Meters W Feasible
INPUTS ($000) (1981 dollars)				
INITIAL COSTS[1]				
Meter Installation[2]	Inst. - $415,177 Inv. - $2,367	Inst. - $415,177 Inv. - $2,367	Inst. - $415,177 Inv. - $2,367	Inst. - $ Inv. - $2
Building Improvements[3]	--	--	--	--
Solar Conversions	--	--	--	--
Norm Development[4]	$22,820[17]	$22,820[17]	--	--
Billing System[5]	$24,797	$24,797	$22,797[20]	$22,797[23]
Develop Educational Program[6]	$38	$38	$19	$38[24]
TOTAL	$465,199	$465,199	$440,360	$440,379
1987 MAINTENANCE, OPERATIONS AND ADMINISTRATIVE COSTS[7]				
Meter Maintenance	$3,465	$3,465	$3,465	$3,465
Building and GFE Maintenance[8]	$20,654	$20,654	$25,817	$15,490
Solar Conversion Maintenance[9]	--	--	--	--
Billing Operations[10]	$28,878[18]	$29,996[19]	$25,913[21]	$7,143[25]
Education Program[6]	$2,582	$2,582	$2,582	$2,582[24]
TOTAL	$55,579	$56,697	$57,777	$32,140
RESULTS				
1987 ENERGY SAVINGS[11]				
Estimated % Savings	6%	12%	12%	5%
Amount (MBtu)(x 10^6)[12]	4.86	9.72	9.72	4.05
VALUE ($000)	$31,867	$63,734	$63,734	$26,555
ANNUAL NET COST/SAVINGS				
First Cost Amortization[13]	($18,608)	($18,608)	($17,614)	($17,615)
Annual Cost/Saving[14]	($23,712)	$7,037	$5,597	($5,585)
NET	($42,320)	($11,571)	($11,657)	($23,200)
PERSONNEL LOSSES				
Number (or %)[15]	1/4%	1/8%	1/2% ++[22]	0
COST[16]	$118,000	$59,000	$236,000 ++	0

	ALTERNATIVES			
	II	III		IV
	METER/FULL PAYMENT	METER/FEEDBACK ONLY		NO METER
ard		A. Individual Meters Where Feasible	B. Install Master Meters	Facility Improvement
415,177 ,367	Inst. - $415,177 Inv. - $2,367	Inst. - $415,177(-) Inv. - $2,367	Inst. - $25,000 --	-- --
	--	--	--	$297,000
	--	--	--	$100,000
)	--	--	--	--
	$22,797[20]	$22,797[23]	$5,000[26]	--
	$19	$38[24]	$236[27]	--
	$440,360	$440,379	$30,236	$397,000
	$3,465	$3,465	$209	--
	$25,817	$15,490	$15,490	$10,327
	--	--	--	$2,000
19	$25,913[21]	$7,143[25]	$2,000[28]	--
	$2,582	$2,582[24]	$22,709	--
	$57,777	$32,140	$40,408	$12,327
	12%	5%	5%	12%[29]
	9.72	4.05	4.05	9.72
)	$63,734	$26,555	$26,555	$63,734
08)	($17,614)	($17,615)	($1,209)	($15,880)
	$5,597	($5,585)	($13,853)	$51,407
71)	($11,657)	($23,200)	($15,062)	$35,527
	1/20 ++[22]	0	0	0
0	$236,000 ++	0	0	0

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Chapter 9. IMPLEMENTING REGULATIONS AND PROPOSED LEGISLATION

I. Implementing Regulations.

When Congress directed DoD to conduct a test of metering of energy for military family housing, one item to be included in the formal report was a draft of the necessary implementing regulations. While there are many specific decisions regarding implementation yet to be made, if so directed, these will of necessity evolve during the installation period. The draft directive on the following page will serve as a framework for more specific DoD and service directives and instructions which would be required to install and operate a system of such large scope as that directed in Public Law 95-82. Implementation of any other alternative would require revised regulations.

DEPARTMENT OF DEFENSE DIRECTIVE

Subj: Department of Defense Energy Consumption Metering Program for Family Housing

Ref: (a) Public Law 82, 95th Congress, Sec. 507
(b) DOD Directive 5000.28, Design to Cost (USDRE), May 23, 1975
(c) DOD Directive 4270.1-M, Department of Defense Construction Criteria (Advance Edition), June 1, 1978
(d) DOD Instruction 7150.6, Financing the DOD Family Housing Program/Administration and Management of Funds, July 25, 1978

I. PURPOSE AND OBJECTIVE

The purpose of this Directive is to establish the basic policy for installing energy consumption metering devices on military family housing, to establish reasonable ceilings for the consumption of energy in military family housing, and to assess occupants a charge for metered energy consumption above the established ceilings as directed by reference (a). The objective is to reduce individual military family excess energy consumption in individual military family housing units.

II. APPLICABILITY AND SCOPE

The provisions of this Directive apply to the Military Department responsible for the management of any military owned family housing facility in any State, the District of Columbia, the Commonwealth of Puerto Rico, and Guam.

III. DEFINITIONS

A. Life cycle costing - Is defined in reference (b) as the total cost to government of acquisition and ownership of development, acquisition, operation, support, and, where applicable, disposal.

B. "Norm" - The total amount of energy required by a unique size family to operate a specific housing unit in an energy efficient manner which provides a quality of life comparable to a similar average American family. Such a norm shall consider daily weather information as well as the physical and thermodynamic properties of the unit and the number of occupants.

C. Excess (consumption) charges - Charges, at rates to be determined by OSD, for consumption beyond the estimated norm. (These charges may contain an increment of Administrative charges associated with the collection of excess charges.)

D. Net bill - The monthly excess consumption charge, calculated and based on the actual consumption of each energy source serving the individual housing unit, and containing off-setting energy source costs credits, if applicable, within each bill.

IV. POLICIES AND RESPONSIBILITIES

A. Before meter installation, each military family housing unit will be reviewed on a case-by-case basis to determine, through life cycle costing, the most energy efficient and cost effective method of energy consumption metering with the primary thrust being energy conservation.

B. Installation of meters in existing single family units and many multiplex units will be expedited, and will be accomplished with minimal occupant inconvenience. Installation in multiplex units requiring extensive renovation may require additional time to complete and should be scheduled on a vacancy basis and coordinated with approved repair and improvement projects where practical. All meter installation will be designed to avoid adverse esthetic impact on the housing unit. Units already metered will be reviewed, and such situations corrected as a part of this program. Dwellings with previously awarded renovation contracts will have meters installed during renovation by contract change order or immediately after each is accepted from the renovation contractor. Meter installation in new construction will be performed in compliance with reference (c). The maintenance of all meters, once installed, will be the full responsibility of each service.

C. Necessary ADP equipment will be procured by each military service and will be capable of computing and implementing a norm for all utilities serving each housing unit, generating bills, and meeting OSD reporting requirements.

1. Each military service will assume responsibility for necessary ADP procurement and developing, implementing, and operating its own billing system. However, the procedure for the development of the "norm", which is an integral part of the billing system, will be developed by OSD and promulgated in a forthcoming DOD Family Housing Support Office manual for the Energy Conservation Metering Program. Each service will be responsible for "norm" data collection, input and maintenance.

Meter data may be collected and utilized for administrative purposes and/or for occupant consumption feedback; however, no charges will be levied until directed by OSD.

2. The billing method selected for full-scale development and implementation will depend upon the requirement of the system and the decisions made by each service based on a thorough evaluation of their needs.

a. The methodology as to the handling of bills and collection, interfacing with existing accounts receivable system, will be the responsibility of each military service.

b. Excess charges, in the form of a net bill, will be assessed by each service and may be deducted from the occupant's pay if not voluntarily paid within a reasonable specified period as determined by each service.

3. Report requirements will appear in the forthcoming metering program manual.

V. FINANCING

A. Procurement, installation, and startup costs of the metering system, including ADP hardware and software, as well as costs for norm data development and load, will be requested of Congress for appropriation as a metering program startup cost. Costs for operation and maintenance of the system, once installed, including meter maintenance, meter reading and reporting, billing and funds collection, should be included in the annual budget of each service. The Administration and Management of all funds for the Energy Consumption Metering Program will be in accordance with reference (d).

B. Any proceeds from excess consumption charges shall be deposited at the activity level in the Department of Defense Family Housing Management Account (Defense), (FHMA,D) established by reference (a).

VI. EFFECTIVE AND IMPLEMENTATION DATES

This Directive is effective _____. All installations and procurements including computer hardware and software and norm data input are to be completed not later than five years from the date of this Directive to be immediately followed by one year of "mock" billing prior to commencing actual billing to allow a total system test under various seasons, and to install occupant confidence.

PROPOSED LEGISLATIVE CHANGES

A. In order to execute the metering program, as directed by Public Law 95-82, it is considered necessary that appropriate provision be made for the collection of the charges for excess consumption in case the occupant refuses to pay. This can be accomplished by including in Title VIII of the MCON Authorization Bill for FY 1981, a new provision reading substantially as follows:

"Sec. 8____, Section 507(a) of Public Law 95-82 is amended by addition thereto of a new paragraph (3), to read as follows:

'(3) Charges assessed for excess utility consumption due the U.S. from a member of the Armed Forces pursuant to paragraph (2) shall be paid promptly and, if not paid by the due date established by the authorized Departments, shall be deducted from the pay due that member.'"

B. Attention is invited to the fact that additional appropriation would be required in the MCON Appropriation Bill for FY 1981, to provide for the required meter installations. Additional appropriation authorization to be provided by adding to appropriation limitation of Title V of the MCON Authorization Bill for FY 1981, a provision identical to Sec. 508(4) of Public Law 95-82, changing the amount therein to the difference between the sum of the amounts specified in Sec. 506(a), as proposed to be amended (below) and $70 million, the total of the present authorization.

The proposed amendment to Section 506(a) should read substantially as follows:

"Sec. 8____, Section 506(a) of Public Law 95-82 is amended by striking amounts '$16,000,000', '$24,000,000' and '$30,000,000' therein and inserting in lieu thereof '$_____', '$_____' and '$_____', respectively."