

AD-A159 740

FORT ERWIN CALIFORNIA FAMILY HOUSING COMPARISON TEST:
OPERATION AND MAINT. (U) CONSTRUCTION ENGINEERING
RESEARCH LAB (ARMY) CHAMPAIGN IL R D NEATHAMMER AUG 85
CERL-IR-P-85/14

1/1

UNCLASSIFIED

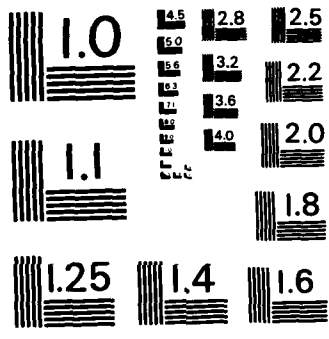
F/G 5/11

ML

END

FALMED

STC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



**US Army Corps
of Engineers**
Construction Engineering
Research Laboratory

USA-CERL

INTERIM REPORT P-85/14
August 1985

AD-A159 740

Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units

by
Robert D. Neathammer

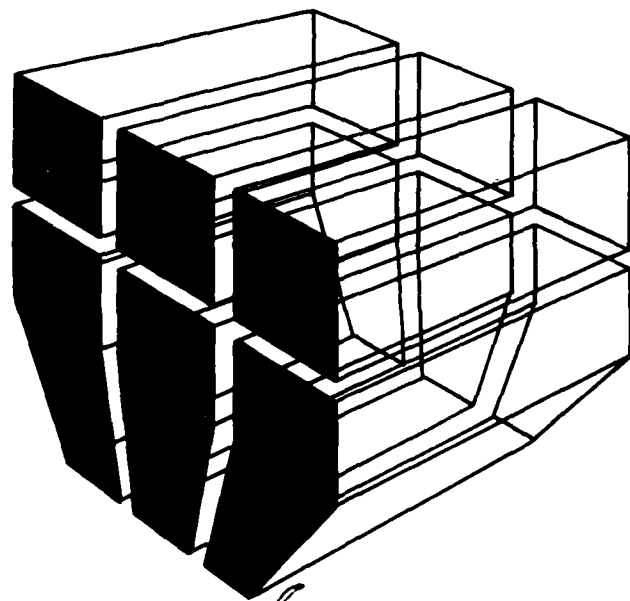
Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress directed the Department of Defense (DOD) to conduct a study to compare the operation and maintenance (O&M) costs of manufactured housing and conventional housing. DOD will report to Congressional committees on the conditions and parameters under which this test was conducted and the results of the test after it is completed in FY88.

To compare these two types of construction properly, DOD must be able to identify O&M costs and user satisfaction reliably. In addition, it must be able to identify differences in O&M costs and the reasons for those differences.

This report is the first of four interim reports on the progress of the study. A yearly summary will be provided by USA-CERL for each of FY84-FY87. A final report covering the first 5 years of O&M costs will be written at the end of FY88.

No conclusions or inferences should be made as to which type of construction was lowest cost until the final 5-year summary is complete.



DTIC FILE COPY

DTIC
ELECTE
OCT 8 1985

B

Approved for public release; distribution unlimited.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official indorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

***DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED
DO NOT RETURN IT TO THE ORIGINATOR***

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER IR P-85/14	2. GOVT ACCESSION NO. AD-A159 740	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FORT IRWIN, CA, FAMILY HOUSING COMPARISON TEST: OPERATION AND MAINTENANCE COSTS OF MANUFACTURED VS. CONVENTIONALLY BUILT UNITS	5. TYPE OF REPORT & PERIOD COVERED Interim	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) Robert D. Neathammer	8. CONTRACT OR GRANT NUMBER(s) IAOs R039 FHAA022-83	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Construction Engr Research Laboratory P.O. Box 4005 Champaign, IL 61820-1305	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE August 1985	
	13. NUMBER OF PAGES 25	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service Springfield, VA 22161		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Fort Irwin, CA housing projects operation and maintenance cost analysis prefabricated buildings		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards. Congress directed the Department of Defense (DOD) to conduct a study to compare the operation and maintenance (O&M) costs of manufactured housing and conventional housing. DOD will report to Congressional committees on the conditions and parameters		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

BLOCK 20 (Continued)

under which this test was conducted and the results of the test after it is completed in FY88.

To compare these two types of construction properly, DOD must be able to identify O&M costs and user satisfaction reliably. In addition, it must be able to identify differences in O&M costs and the reasons for those differences.

This report is the first of four interim reports on the progress of the study. A yearly summary will be provided by USA-CERL for each of FY84-FY87. A final report covering the first 5 years of O&M costs will be written at the end of FY88.

No conclusions or inferences should be made as to which type of construction was lowest cost until the final 5-year summary is complete.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

	Page
DD FORM 1473	2
FOREWORD	3
1 INTRODUCTION	5
Background	
Objective	
Scope	
Approach	
2 DESCRIPTION OF THE FAMILY HOUSING UNITS	5
Manufactured Housing Units (MHU)	
Conventionally Built Units (CBU)	
3 DATA COLLECTION PROCEDURES	6
Data Collection	
Data Verification	
Data Analysis	
4 WHOLE HOUSE ENERGY TESTS	7
House Tightness	
Furnace Efficiency	
Wall Heat Transfer Characteristics	
5 O&M COSTS	7
Overall Costs	
Frequencies of Maintenance Per Housing Unit	
Frequencies of Maintenance Per Component	
6 ENERGY COSTS	7
Electricity Consumption	
Gas Consumption	
7 OCCUPANT SATISFACTION	9
8 CONCLUSION	10
METRIC CONVERSION TABLE	10
APPENDIX A: List of Housing Units	11
APPENDIX B: Data Collection Forms	12
APPENDIX C: Energy Efficiency Tests of 15 Conventionally Built Housing Units at Fort Irwin, CA	16
APPENDIX D: Energy Efficiency Tests of 16 Manufactured Housing Units at Fort Irwin, CA	18
APPENDIX E: Building Components/Subcomponents	20
APPENDIX F: User Satisfaction Questionnaire	22

FORT IRWIN, CA, FAMILY HOUSING COMPARISON TEST: OPERATION AND MAINTENANCE COSTS OF MANUFACTURED VS. CONVENTIONALLY BUILT UNITS

1 INTRODUCTION

Background

Congress believes that use of manufactured (factory built) military housing, rather than conventionally built units, may result in lower overall costs, but still provide durable housing that meets contemporary housing standards. To verify this belief, Congress directed the Department of Defense (DOD) to construct 200 units of manufactured housing at Fort Irwin, CA, for comparison with conventionally built housing.¹

The manufactured units were to be constructed to meet DOD standards and criteria for essential space, structural durability, energy efficiency, material quality, and life safety. These standards and criteria are compatible with, and complementary to, the Federal Manufactured Housing Construction and Safety Standards (FMHCSS). The Fort Irwin study will compare the impact of the FMHCSS versus standard DOD criteria, except for the essential criteria listed above.

The study will be conducted during the first 5 years the housing units are occupied; initial occupancy on some units began in December 1983. The study will compare 200 two-bedroom manufactured housing units (MHU) to 144 two-bedroom, conventionally built units (CBU). DOD will present the conditions and parameters of this test to Congress and will report the study results at the end of each year of the test.

To properly compare manufactured versus conventional housing, the study must address operation and maintenance (O&M) costs and user satisfaction for both types of housing. The study should not only identify the differences, if any, in O&M costs, but also identify the reason for the differences and their importance for future construction criteria, construction methods, and occupant satisfaction.

¹Report No. 97-44, *Military Construction Authorization Act* (House of Representatives Committee on Armed Services, 1982), pp 8-9.

Objective

The objective of this report is to present results of the O&M analysis, of whole house energy tests, and of occupant satisfaction through September 1984.

Scope

This report addresses O&M costs and occupant satisfaction for both conventionally built and manufactured housing from construction through September 1984.

Approach

The first step in the project was to develop data collection and data analysis procedures. The cost comparisons and analyses which will be done in this study were established in USA-CERL Special Report P-140, *Fort Irwin Housing Comparison Test*.² The data will be collected, summarized, and reported on a yearly basis.

2 DESCRIPTION OF THE FAMILY HOUSING UNITS

Manufactured Housing Units (MHU)

These 200 units consist of 50 two-story fourplexes. Each upper unit has a balcony-porch and each lower one has a patio with privacy fencing. Each unit has a refrigerator, range, garbage disposal, and central air conditioning. Each unit has two bedrooms, a kitchen, living-dining area, one bathroom, and a one-car garage. There are two units on each level.

Initial occupancy was:

61 units	Dec 83
7 units	Jan 84
64 units	Feb 84
57 units	Apr 84
9 units	May 84
2 units	Jun 84

Conventionally Built Units (CBU)

The 144 units consist of 13 sixplexes, 6 fiveplexes, and 9 fourplexes, all two-story buildings. Each unit has two bedrooms. The fourplexes have two units on each level. There are two units on the second story in

²M. J. O'Connor, *Fort Irwin Housing Comparison Test*, Special Report P-140/ADA130349 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], February 1983).

the five- and sixplexes with the additional unit(s) on the first level. The CBU also have a one-car garage, refrigerator, range, garbage disposal, and central air conditioning.

A detailed description of all units can be found in the Los Angeles District Office report.³

Initial occupancy was:

8 units	Feb 83
28 units	Mar 83
38 units	Apr 83
31 units	May 83
23 units	Jun 83
14 units	Jul 83
2 units	Aug 83

3 DATA COLLECTION PROCEDURES

Data that should be collected in this study and their level of detail were discussed in USA-CERL SR P-140. That report emphasized that data be collected at such a level of detail that any differences found between the two types of construction could be explained. Appendix A lists the housing units and their identification numbers used in the data collection.

Data Collection

Discussions were held with the technical monitor, Facilities Engineering Support Agency (FESA) representatives, the FORSCOM HQ representative, Fort Irwin Personnel, and the base operations contractor, Boeing Services Inc. (BSI) representatives to determine best methods of collecting the data. For O&M data, USA-CERL designed report forms (Appendix B). BSI was contracted to segregate all service orders for maintenance for the test units and report cost data to USA-CERL through the Fort Irwin Directorate of Engineering and Housing (DEH) on a monthly basis.

BSI was contracted to read gas and electric meters at the end of each month and report similarly.

Self-help data reports* and occupancy data were to be forwarded quarterly.

An occupant satisfaction questionnaire (Appendix F) is given to each vacating family with a mail-back envelope to USA-CERL.

Data Verification

USA-CERL is verifying the reported data several ways. Each service order is checked against the reported data forwarded by BSI. Discrepancies are resolved on verification visits to Fort Irwin. Additionally, BSI has set up separate accounting codes for the two groups of units and the total billed is compared to the total obtained from summing over all the individual service order data.

On meter readings, USA-CERL developed a computer program to compare monthly readings. When apparently erroneous data occurs, BSI is notified and corrections are made.

Data Analysis

Maintenance Costs

These costs are reported on a unit-month basis and yearly basis. In future reports they will be on a unit-year basis. The data will also be summarized by building component to determine if one or more components for one of the types of units is the cause of large maintenance costs. If so, an effort will be made to determine why these costs occur, i.e., what criteria or design features should be reviewed/changed.

Cost differences will probably be caused by material quality and/or installation, differences inherent to manufactured or conventional construction, and possible errors in specifications for the two projects.

Warranty work referred to the construction contractor will not be included in the cost comparison since no cost data are available or applicable, as it is not a cost to the government.

Energy Consumption

Gas and electricity consumption will be reported on a unit-month basis and a yearly basis. Since most of the MHU were not completed until April 1984, prior energy consumption data for the CBU will not be used in comparisons. Energy consumption comparisons

³Fort Irwin Family Housing Study. A Report on Manufactured/Factory-Built Housing and Site-Built Housing. Fort Irwin, CA (U.S. Army Corps of Engineers, Los Angeles District, September 1984).

*Self-help is a program whereby occupants obtain supplies and materials from a central warehouse to make minor repairs themselves.

are only valid for the same time frame because of varying weather conditions.

Occupancy Effects

Occupancy data are also being collected. These data will be analyzed to ensure that both types of units have a similar distribution of occupants during the 5 years (ages, numbers). If required, these data will be correlated with O&M costs to help explain differences in costs.

Self-Help Data

These data will be summarized to see if maintenance costs are affected.

Occupant Satisfaction

Questionnaires are given to vacating occupants. Additionally, special surveys will be done periodically on occupants who have resided in the units for 1 to 2 years. Comparisons will be made to determine if satisfaction differs for the two housing types.

4 WHOLE HOUSE ENERGY TESTS

Three whole house energy tests were performed on a sample of units from each type of construction. Appendices C and D give details.

House Tightness

The number of air changes per hour were measured with the following results:

Type	No. Units	Average	Standard Deviation
CBU	15	13.0	1.06
MHU	12	10.9	2.67

There is a statistically significant difference between the two types of construction, with the MHU being more airtight on the average.

Furnace Efficiency

The furnace efficiency results were as follows:

Type	No. Units	Average	Standard Deviation
CBU	13	66.2%	6.24%
MHU	16	79.3%	3.36%

The furnace efficiencies of the MHU were significantly higher than those of the CBU.

Wall Heat Transfer Characteristics

This parameter was not measured for the CBU because of unfavorable weather. This parameter was *calculated* for both types of construction using the designed wall construction. These data are given in Appendices C and D and are summarized below:

Type	No. Units	Average (Btu/hr-°F)	Standard Deviation (Btu/hr-°F)
CBU	16	310	51
MHU	15	237	58

5 O&M COSTS

Overall Costs

The total housing unit-months and maintenance costs through September 1984 are shown below:

Type	No. Months	Total Cost (\$)	Cost/ Month (\$)	Cost/ Year (\$)
MHU	1420	11874	8.36	100
CBU	2527	35100	13.89	167

The MHU have not been through a complete heating season yet, and their costs may increase over the coming winter season.

Frequencies of Maintenance Per Housing Unit

For the MHU the number of service orders for a housing unit ranges from 0 to 21. For the CBU the range is 0 to 32. Table 1 lists the frequencies.

Frequencies of Maintenance Per Component

Table 2 lists the frequencies of service orders per building component, where the frequency is at least 2 percent of the total number of service orders.

6 ENERGY COSTS

Comparisons of gas and electricity consumption began in April 1984, since most MHU were not occupied before then.

Table 1
Frequency of Repair
(CBU vs. MHU)

Conventionally Built Units		Manufactured Housing Units	
No. of Service Calls	No. of Units With These Totals	No. of Service Calls	No. of Units With These Totals
32	1	21	1
25	1	15	3
23	1	14	1
22	1	13	1
21	1	12	2
19	2	11	3
18	3	10	5
17	3	9	8
16	6	8	8
15	2	7	11
14	4	6	16
13	5	5	23
12	7	4	18
11	8	3	26
10	6	2	29
9	7	1	24
8	14	0	23
7	16		
6	9		
5	15		
4	13		
3	12		
2	5		
1	5		
0	1		

Electricity Consumption

The average usage (kWh) per housing unit is shown below:

	MHU	CBU
Apr	417	418
May	780	704
Jun	1007	966
Jul	1220	1170
Aug	1272	1139
Sep	1015	1004

For the 6-month period, an MHU used an average total of 5942 kWh while a CBU used an average of 5405 kWh.

Gas Consumption

The average usage (100 cu ft) per housing unit is shown below:

	MHU	CBU
Apr	174	145
May	90	71
Jun	68	64
Jul	57	53
Aug	62	60
Sep	58	55

For the 6-month period, an MHU used an average total of 475 cu ft while a CBU used an average of 450 cu ft.

Table 2
Maintenance Per Component
(Percent of Service Calls by Component)

Component No.	Description	Conventional Housing Units (N=1264)*	Manufactured Housing Units (N=856)
0104	Gutters and Downspouts	29 (2%)	.. **
0206	Exterior Doors and Frames	91 (7%)	48 (6%)
0207	Storm and Screen Doors	27 (2%)	--
0208	Windows and Frames	--	20 (2%)
0212	Interior Drywall	19 (2%)	13 (2%)
0214	Interior Doors	70 (6%)	39 (5%)
0215	Interior Casework	--	21 (2%)
0220	Garage Door	38 (3%)	--
0301	Resilient Flooring	--	26 (3%)
0601	Heating Plant	66 (5%)	--
0607	Heating Controls	44 (3%)	--
0608	Other Heating	25 (2%)	--
0701	Cooling Coils	--	17 (2%)
0702	A/C Motors, Blowers, Pumps	21 (2%)	14 (2%)
0704	A/C Refrigerant	74 (6%)	20 (2%)
0706	A/C Controls	24 (2%)	17 (2%)
0707	A/C Other Cooling	41 (3%)	48 (6%)
0801	Water Heater	28 (2%)	25 (3%)
0803	Piping, Supply	35 (3%)	41 (5%)
0804	Faucets and Shower Heads	31 (2%)	42 (5%)
0805	Lavatories	25 (2%)	--
0806	Water Closets	52 (4%)	33 (4%)
0807	Bathtub/Shower Unit	--	19 (2%)
0902	Panel Box	--	17 (2%)
0904	Wall Receptacles	19 (2%)	25 (3%)
0906	Light Fixtures	50 (4%)	--
1001	Garbage Disposal	49 (4%)	31 (4%)
1002	Dishwasher	40 (3%)	44 (5%)
1003	Range	92 (7%)	83 (10%)
1201	Water Supply	35 (3%)	35 (4%)

*N = Number of Service Orders

** = Less than 2%

7 OCCUPANT SATISFACTION

One part of the study assesses occupants' satisfaction with their housing. Use of lower cost housing would be questionable if it created morale problems with Army personnel. A questionnaire developed at USA-CERL and approved by FORSCOM, FESA, and OCE is given in Appendix F.

A copy of the questionnaire with a mail-back envelope (to USA-CERL) is given to each vacating family by BSI approximately 2 weeks before vacating.

BSI is also to check with the family when they are vacating to encourage completion and mail-back.

Through September 1984, the return rate on the questionnaires was 35 percent. This response rate is considered low. A special survey was done of all 78 families who have lived in their CBU quarters at least 1 year. Of these, 25 (32.1 percent) returned questionnaires. A similar survey on MHU will be done in 1985.

Because of the small number of responses to date (49 for CBU and 15 for MHU), no summary was made at this time.

3 CONCLUSION

Data collection procedures were set up to collect all maintenance and energy use costs for the test units. The procedures are working well. Data were validated and summarized through September 1984.

Whole house energy tests were performed on a sample of each type construction.

Maintenance costs were collected, and gas and electricity consumption data were also collected.

Response rate of the vacating occupants to questionnaires about their satisfaction with the units is low and these personnel will be encouraged to return the completed questionnaire.

METRIC CONVERSION TABLE

$^{\circ}\text{F}$	$= 9/5^{\circ}\text{C} + 32$
therm	$= 100.000 \text{ Btu}$
1 in. water (60°F)	$= .07355 \text{ cm of mercury } (60^{\circ}\text{F})$
Btu/hr	$= 1.055 \times 10^3 \text{ joule/hr}$
ft^2	$= 9.290 \times 10^{-2} \text{ m}^2$

8. Did any of the items listed in question 7 require repair?

Yes No 22

If No, skip to question 9.

If Yes, were repairs accomplished by Occupant FE/Contractor 23

Briefly describe occurrences (if self help, was it easy in comparison to other gov't quarters?, etc.) _____

9. Is there another set of quarters above you? Yes No 24

If No, skip to question 10.

If Yes:

has noise from it ever annoyed you and/or your family? Yes No 25

have odors from it ever annoyed you and/or your family? Yes No 26

10. Is there another set of quarters below or adjoining yours? Yes No 27

If No, skip to question 11.

If Yes:

has noise from it ever annoyed you and/or your family? Yes No 28

have odors from it ever annoyed you and/or your family? Yes No 29

11. Is the floor plan of your quarters satisfactory? Yes No 30

If No, please explain _____

12. Has your air conditioning been satisfactory? Yes No 31

If No, please explain _____

13. Has your heating been satisfactory? Yes No 32 sk 33

If No, please explain _____

7. For each item below, please check the appropriate answer for the questions.

	In general, are you satisfied with the item?			Is the item		
	Satisfied	Not Satisfied	No Opinion	Hard to Clean	Easy To Clean	No Opinion
a. Bathroom floor	_____	_____	49	_____	_____	50
b. Bathroom tubs and showers	_____	_____	51	_____	_____	52
c. Bathroom sink and faucets	_____	_____	53	_____	_____	54
d. Kitchen floor	_____	_____	55	_____	_____	56
e. Kitchen cabinets	_____	_____	57	_____	_____	58
f. Kitchen sink and faucets	_____	_____	60	_____	_____	sk59 61
g. Range/oven	_____	_____	62	_____	_____	63
h. Refrigerator	_____	_____	64	_____	_____	65
i. Dishwasher	_____	_____	66	_____	_____	67
j. Living/Dining room floors	_____	_____	68	_____	_____	69
k. Bedroom floors	_____	_____	71	_____	_____	sk70 72
l. Doorknobs and locks	_____	_____	73	_____	_____	74
m. Interior walls	_____	_____	75	_____	_____	76
n. Electric outlets/switches	_____	_____	77	_____	_____	78sk79
o. Light fixtures	_____	_____	7	_____	_____	80cd1 dup1-5 8 sk6
p. Windows	_____	_____	9	_____	_____	10
q. Doors	_____	_____	11	_____	_____	12
r. Garage	_____	_____	13	_____	_____	14
s. Closet/interior storage space	_____	_____	15	_____	_____	16
t. Exterior storage space	_____	_____	17	_____	_____	18
u. Kitchen and bath exhausts	_____	_____	19	_____	_____	20
						sk21

Any comments on above? _____

**APPENDIX F:
USER SATISFACTION QUESTIONNAIRE**

Quarters No: _____ 1-5 sk 6
Date: _____ 7-12 sk 13

HOUSING SATISFACTION QUESTIONNAIRE FOR RESIDENTS OF NEW HOUSING

This questionnaire is designed to assist the Director of Engineering and Housing in evaluating the new housing you are occupying. Your careful completion of this questionnaire will help us to continue to improve new Army family housing. Please mail the questionnaire in the attached envelope.

1. How many total years have you lived in military family housing? _____ years 14-16
2. Please identify the different types of quarters you have lived in during these years.

_____ detached dwelling unit (house)

_____ duplex (two units)

_____ multi-level, three or more families

17

_____ single-level, three or more families

3. How long have you occupied these new quarters?
_____ years _____ months

18-19
sk 20

4. List all family members (include yourself) who occupy these quarters, including sex and ages (do not list by name).

	<u>Relationship</u>	<u>Sex</u>	<u>Age</u>
a.	_____ 21	_____ 22	_____ 23-24 sk 25
b.	_____ 26	_____ 27	_____ 28-29 sk 30
c.	_____ 31	_____ 32	_____ 33-34 sk 35
d.	_____ 36	_____ 37	_____ 38-39 sk 40
e.	_____ 41	_____ 42	_____ 43-44 sk 45

5. How would you rate the condition of your quarters? (Circle one)

- a. Excellent
b. Better than average
c. Average
d. Below average
e. Poor

46

6. In general, how satisfied have you been with these quarters? (Circle one)

- a. Very satisfied
b. Satisfied
c. Dissatisfied
d. Very Dissatisfied

47

sk 48

10 EQUIPMENT

- 1001 Disposal
- 1002 Dishwasher
- 1003 Stove, Range
- 1004 Range Hood
- 1005 Refrigerator
- 1006 Other Equipment

11 UTILITY PLANT EQUIPMENT

Not Applicable

12 UTILITY SERVICE

- 1201 Water Supply
- 1202 Gas Supply
- 1203 Electrical Service
- 1204 Sanitary/Sewer
- 1205 Other Utility Service

13 MISCELLANEOUS

**APPENDIX E:
BUILDING COMPONENTS/
SUBCOMPONENTS**

01 ROOFING

- 0101 Roofing Surface
- 0102 Fasteners
- 0103 Flashing, Vents, Protrusions
- 0104 Gutters and Downspouts
- 0105 Other Roof Repair

02 STRUCTURE

- 0201 Foundation and Anchorage
- 0202 Structure, Incl. Framing and Sheathing, Stairs
- 0203 Insulation and Moisture Protection
- 0204 Masonry
- 0205 Exterior Siding, Incl. Skirting
- 0206 Exterior Doors and Frames, Incl. Hardware and Weatherstripping
- 0207 Storm and Screen Doors
- 0208 Windows and Frames, Incl. Hardware and Weatherstripping
- 0209 Stormwindows and Screens
- 0210 Exterior Trim
- 0211 Porch/Deck Construction
- 0212 Interior Drywall, Incl. Fasteners and Accessories
- 0213 Wall Coverings and Paneling
- 0214 Interior Doors, Frames, and Hardware, Incl. Bi-Fold and Sliding
- 0215 Interior Casework and Finish Carpentry
- 0216 Bathroom Accessories
- 0217 Kitchen Accessories
- 0218 Drapery Hardware
- 0219 Other Exterior/Interior Repair
- 0220 Garage Door

03 FLOOR COVERINGS

- 0301 Resilient Flooring
- 0302 Carpet and Pad
- 0303 Ceramic Flooring
- 0304 Underlayment/Substrate
- 0305 Other Flooring Repairs

04 INTERIOR PAINTING

- 0401 Walls and Ceilings, Incl. Patching
- 0402 Trim
- 0403 Touch-Up
- 0404 Bathtub/Shower Unit Calking
- 0405 Other Interior Painting

05 EXTERIOR PAINTING

- 0501 Walls, Siding, Incl. Skirting
- 0502 Doors, Frames, Trim
- 0503 Exterior Trim, Incl. Window, Fascia, Rake, Soffit, Etc.
- 0504 Calking and Sealing
- 0505 Glazing
- 0506 Other Exterior Painting

06 HEATING

- 0601 Heating Plant
- 0602 Motors, Blowers, Pumps
- 0603 Ducts
- 0604 Piping
- 0605 Diffusers, Grilles
- 0606 Insulation
- 0607 Heating Controls
- 0608 Other Heating Repairs

07 AIR CONDITIONING

- 0701 Cooling Coils, Compressor, Condenser
- 0702 Motors, Blowers, Pumps
- 0703 Piping
- 0704 Refrigerant
- 0705 Insulation
- 0706 Controls
- 0707 Other Cooling Repairs

08 PUMPING

- 0801 Water Heater
- 0802 Water Softener
- 0803 Piping, Supply, Incl. Valves, Arrestors
- 0804 Faucets and Shower Heads
- 0805 Lavatories, Incl. Support and Fasteners
- 0806 Water Closets (i.e., toilets/commodos), Including Supports and Seals
- 0807 Bathtub/Shower Unit
- 0808 None
- 0809 Other Plumbing Repair

09 ELECTRICAL

- 0901 Service Entrance
- 0902 Panel Box, Incl. Circuit Breakers
- 0903 Branch Circuits, Incl. Junctions, Fasteners
- 0904 Wall Receptacles and Switches
- 0905 Doorbells, Chimes
- 0906 Light Fixtures
- 0907 Vents, Fans
- 0908 Other Electrical Repair

Furnace Efficiency

The furnaces in all of the units were propane-fired. Tests were performed using a Fuel Efficiency Monitor (FEM), as described in Appendix C. A carbon monoxide meter similar to the FEM was used to insure that each furnace's burner was completely combusting its fuel and there was no unusual concentration of carbon monoxide.

The testing was performed in the early morning hours so there would be a low outdoor temperature to start the furnace. The safety relief on the front of each furnace was taped over to prevent room air from entering the flue. A 1/8-in. hole was drilled into the flue near the furnace. The furnace was turned on and a sample of the ambient air was taken. The furnace was then left to reach steady state (approximately 15 min) and then the FEM probe was inserted into the hole and a sample of the exhaust gas was taken. The FEM took approximately 2 to 3 min to calculate and display the efficiency. Three samples were taken to insure furnace steady state. The hole in the flue was then taped closed.

The furnace efficiencies are typical for the size and type of furnace installed.

A serious problem was found during the furnace testing for Type I Units 3809, A and D. The gas was burning in the mixing manifold before it got to the burner. This is extremely dangerous and was reported immediately to responsible Fort Irwin personnel.

Wall Heat Transfer Characteristics

A Thermo Flow Energy Meter (TEM), as described in Appendix C, was used to test the heat transfer characteristics of the exterior walls of each unit. It was also used to detect insulation defects.

This testing was done in the early morning hours because a constant temperature difference of at least

20°F must exist between outdoor and indoor temperatures. First the outdoor and indoor temperatures were taken until they appeared steady, then the TEM was aimed at an interior wall and the net heat flow reading was recorded. Then the TEM was aimed at an exterior wall and the heat flow through the wall was recorded. Then the same measurement was made on the outside of the exterior wall (being sure that the area was shaded from sunlight). These results were used in conjunction with a standardized chart to determine the wall's thermal resistance. After these measurements were taken, the TEM was used to detect areas of abnormally high net flow readings, which indicate areas of insulation defects. There appear to be a number of insulation voids in Type I, II, and IV Units.

The UA values were calculated for the units, representing the overall heat transfer for the unit inclusive of walls, windows, doors, and roof (heat transferred from one unit to the next unit was considered negligible). The insulation voids listed in Table D2 were determined when the net heat flow varied by 10 Btu/hr-°F.

Table D2
Insulation Void Locations

Building/Unit	Location of Void
3802A	Void area at upper left corner of window in front bedroom.
3802C	Void area above sliding glass door in dining room.
3802D	Void area at right electrical outlet in dining room.
3806C	Void areas in all wall-to-wall seams (corners).
3806D	Void areas in all wall-to-wall seams (corners).
3809B	Void area at upper right corner of sliding glass door in dining room.

**APPENDIX D:
ENERGY EFFICIENCY TESTS OF
16 MANUFACTURED HOUSING UNITS
AT FORT IRWIN, CA**

The objective of these tests was to provide data on the energy efficiency of manufactured housing units which will be compared to existing energy efficiency data taken on conventionally built housing units. Tests were performed to determine the airtightness of the units (a measure of the resistance to air infiltration), furnace efficiencies, and heat transfer characteristics of the building envelope.

Tests were conducted on three types of fourplexes; Type I (Building 3809), II (Building 3802), and IV (Buildings 3800 and 3806). The tests were conducted over 4 days in April 1984. The weather during the testing was mild for high desert area: medium to strong winds, overcast skies, low humidity, and temperatures ranging from morning lows of 40°F to highs near 80°F.

House Tightness

To measure the tightness of each housing unit a blower door apparatus was used, as described in Appendix C.

Each of the manufactured housing units was tested at 0.1, 0.2, and 0.3 in. of water during pressurization and then tested at 0.1 and 0.2 in. under depressurization. Then some of the obvious leaks were taped (furnace doors and kitchen vents) and the unit was retested at 0.2 in. during pressurization and depressurization. During the final day the winds were gusting so high that no consistent manometer reading could be taken, so Building 3809 has no data for air infiltration.

The results of the USA-CERL testing, as presented in Table D 1, demonstrate that the airtightness of all the units except one is acceptable. Unit 3800-C has a significantly higher value than the other units and should have corrective work done to improve its tightness.

Also during the airtightness testing several leaks were found. In Type II, Unit 3801-C, serious leaks were found in the door to the furnace room. In Type IV, Units 3800 and 3806, leaks were found while depressurizing around the furnace vents and doors (Unit A in both buildings). Also, leaks were found around sliding doors (Unit 3800-C), kitchen window area (Unit 3806-D), utility outlets (Unit 3800-D), and a crack in the dining room wall (Unit 3806-D).

Table D1

MHU Energy Efficiency Data

Building/Unit	UA* (Btu/hr-°F)	Air Changes Per Hour	Furnace Efficiency
3800A	296	9.9	75.5%
3800B	296	11.5	81.8%
3800C	363	18.4	80.5%
3800D	363	11.3	82.6%
3802A	271	9.0	70.1%
3802B	271	10.1	75.1%
3802C	370	12.1	81.8%
3802D	370	11.3	80.3%
3806A	296	8.0	78.2%
3806B	296	9.8	77.4%
3806C	363	8.7	80.7%
3806D	363	10.6	82.2%
3809A	249	**	80.9%
3809B	249	**	82.0%
3809C	336	**	80.7%
3809D	336	**	79.6%

*These are calculated based on the wall construction. U = heat transfer coefficient; A = area.

**Unable to test airtightness due to high winds.

Table C1
CBU Energy Efficiency Data

Building/Unit	UA* Btu/hr-°F	Air Changes** Per Hour	Furnace*** Efficiency
3720 A	213	11.4	52.6%
3720 B	181	12.1	61.3%
3720 C	181	13.1	62.8%
3720 D	213	12.8	67.2%
3720 E	304	12.4	71.7%
3720 F	304	13.2	73.0%
3724 A	181	11.8	61.9%
3724 B	181	13.3	62.6%
3724 C	304	13.0	71.4%
3724 D	304	15.1	72.3%
3725 A	181	11.7	61.6%
3725 B	181	12.8	****
3725 C	213	13.9	69.3%
3725 D	304	13.4	72.7%
3725 E	304	14.8	****

*These are calculated values based on the wall construction. U = heat transfer coefficient; A = area.

**The following rating of air changes per hour at 0.2 in. w.c. is based on work currently being done by Mansville Corp. for the U.S. Navy: 0 to 5, objectionably tight; 5 to 10, excellent; 10 to 15, satisfactory; 15 and above, merits corrective work.

***Most gas fired furnace manufacturers claim 80 percent efficiency.

****Unable to test furnace.

APPENDIX C: ENERGY EFFICIENCY TESTS OF 15 CONVENTIONALLY BUILT HOUSING UNITS AT FORT IRWIN, CA

The objective of these tests was to provide data concerning the energy efficiency of conventionally built housing. Tests were performed to determine the airtightness of the units (a measure of the resistance to air infiltration), furnace efficiencies, and heat transfer characteristics of the building envelope.

Tests were conducted over four days in June 1983 on three types of buildings: a fourplex, a fiveplex, and a sixplex. Weather conditions were typical of the high desert area: light to negligible winds, clear skies, low humidity, and temperatures ranging from lows near 70°F to highs near 110°F.

House Tightness

A blower door apparatus was used to measure each unit's tightness. The blower door consists of a variable-speed fan, a digital tachometer to measure the fan blade rotation speed, and an inclined manometer to measure pressure differences. The fan can be operated to induce a positive or negative pressure difference in the house with respect to the outdoors.

To perform this test, the fan is fitted tightly into an outside door frame. A barbed fitting which penetrates the blower door is fitted with rubber tubing and connected to one side of the manometer. The other side of the manometer is open to the house. When the fan is operated, it can either force air into the house (pressurized) or force air out of the house (depressurized) depending on the direction of rotation. In either case, the pressure difference between the house and the outdoors can be read on the manometer. The fan speed is adjusted until a specified pressure difference exists (usually 0.1 or 0.2 in. of water). The fan speed required to achieve a given pressure is correlated to air flow, which indicates how tightly the house is sealed.

At Fort Irwin, each of the units was tested at 0.1 and 0.2 in. H₂O pressurized, and 0.2 in. H₂O depressurized. Some of the more obvious leaks (furnace

room doors, dryer vents, attic doors) were then taped, and the house was again tested at 0.2 in. H₂O depressurized.

As shown in Table C1, airtightness was adequate, requiring no corrective work.

Furnace Efficiency

The furnaces in all the units were propane-fired. Tests were performed with a Fuel Efficiency Monitor (FEM), a hand-held automatic flue gas analyzer which measures the flue gas temperature, oxygen content, and ambient conditions and uses this information to calculate and display the percent efficiency of the furnace.

Each housing unit was first cooled down to 70° to 80°F using the air conditioning system. The thermostats in the houses are of the "energy-saving" type, and include night setback and temperature limits. These were disconnected before each test so that the heating and air conditioning could be manually adjusted. The safety relief on the front of each furnace was covered so that room air would not be introduced into the flue. The furnace was then turned on, and a sample was taken of the intake air using the FEM. A 1/8-in. hole was then drilled in the flue of the furnace. After allowing a few minutes for the furnace to reach steady state, the FEM probe was inserted into the flue pipe and a sample was taken of the exhaust gas. The FEM took 2 to 3 min to calculate the furnace efficiency.

Table C1 shows the furnaces' operational efficiencies.

Wall Heat Transfer Characteristics

A Thermo Flow Energy Meter (TEM) was obtained to test the heat transfer characteristics of the walls. The TEM is an infrared radiometer which displays heat flow digitally in units of Btu/hr/sq ft. It can be used to detect insulation defects and to estimate the thermal resistance of exterior walls.

Due to unfavorable weather, the TEM could not be used to calculate R-values. The device is also useful for detecting insulation voids. No insulation voids were found.

**APPENDIX A:
LIST OF HOUSING UNITS**

Conventionally Built

3680 A-F	3705 A-E	3727 A-E
3681 A-D	3712 A-F	3731 A-D
3684 A-D	3715 A-F	3732 A-F
3685 A-F	3720 A-F	3738 A-F
3690 A-F	3721 A-E	3742 A-D
3691 A-D	3722 A-E	3743 A-F
3693 A-F	3723 A-E	3745 A-F
3694 A-D	3724 A-D	3737 A-D
3695 A-D	3724 A-E	3750 A-F
3700 A-F		

Manufactured (Each with four apartments, A-D)

3800	3821	3841
3801	3822	3842
3802	3823	3843
3803	3824	3844
3804	3825	3845
3805	3826	3846
3806	3827	3848
3807	3828	3850
3809	3829	3851
3811	3831	3852
3812	3832	3853
3813	3833	3854
3814	3834	3855
3815	3835	3856
3816	3837	3857
3818	3839	3858
3820	3840	

14. In general, how satisfied are you with:

	<u>Very</u> <u>Satisfied</u>	<u>Satisfied</u>	<u>Dissatisfied</u>	<u>Very</u> <u>Dissatisfied</u>	
a. The exterior of your building	_____	_____	_____	_____	34
b. Front/rear yards and play areas	_____	_____	_____	_____	35
c. The housing complex	_____	_____	_____	_____	36
d. Parking facilities	_____	_____	_____	_____	37
					sk38

15. Please list three things about your apartment you like most.

	39-40
	41-42
	43-44

16. Please list three things about your apartment you do not like.

	sk45
	46-47
	48-49
	50-51

17. Please make any general comments about your apartment.

	sk52
	53-54
	55-56
	57-58
	sk59-79

80 CD2

THANK YOU VERY MUCH FOR YOUR COOPERATION

DISTRIBUTION

Chief of Engineers

ATTN: DAEN-ACH-F (10)
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

Commander

National Training Center
ATTN: AFZJ-FER (2)

U.S. Army Corps of Engineers
Ft. Irwin Office (2)

U.S. Army Europe
ATTN: C/AEAEN-EH-H

NCEL ATTN: Library, Code L08A 93041

Defense Technical Info. Center 22314
ATTN: DDA (12)

FESA, ATTN: Library 22060
ATTN: DET III 79906

U.S. Army FESA
ATTN: FESA-EB (2)

U.S. Army Engineer Districts
ATTN: Library (41)

Commander

U.S. Army Engineer District,
Los Angeles
ATTN: SPLCO-CM (2)

U.S. Army Engineer Divisions
ATTN: Library (14)

Commander

U.S. Army Engineer Division,
South Pacific
ATTN: SPDED (2)

TRADOC

HQ, TRADOC, ATTN: ATEN-DEH
ATTN: DEH (19)

FORSCOM

FORSCOM Engr, ATTN: AFEN-DEH
ATTN: DEH (23)

Commander

U.S. Army Forces Command
ATTN: AFEN-RMO (2)

END

FILMED

11-85

DTIC