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TWO-YEAR SUMMARY OF FORT IRWIN CALIFORNIA FAMILY
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**US Army Corps
of Engineers**

Construction Engineering
Research Laboratory

USA-CERL

INTERIM REPORT P-86/06
June 1986

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

by
Robert D. Neathammer

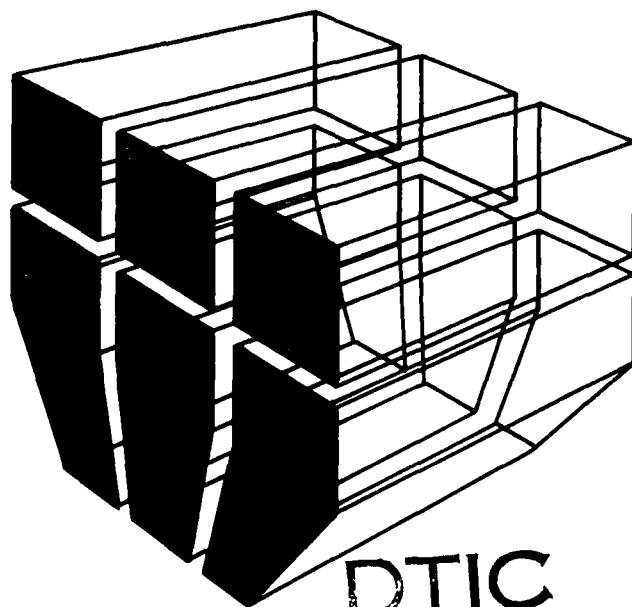
Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress directed the Department of Defense (DOD) to conduct a fair and reliable study that will compare the operation and maintenance (O&M) costs of manufactured housing to those of 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 reliably identify O&M costs and user satisfaction. In addition, it must be able to identify differences in O&M costs and the reasons for those differences.

This is the second of four interim reports on the progress of the study. USA-CERL will provide a yearly summary 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.



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Background Information

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

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FOREWORD

This research was conducted for the Assistant Chief of Engineers, Office of the Chief of Engineers (OCE) under Inter Army Orders (IAOs) from Fort Irwin and Headquarters, U.S. Army Forces Command, dated 22 Aug 83, 19 Sep 83, 14 May 84, and 15 Jan 85. The OCE Technical Monitor was Mr. Alex Houtzager, DAEN-ZCH-F.

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The Principal Investigator was Mr. Robert Neathammer. Assistance was provided by Mr. Robert Doerr, Mr. Thomas Napier, Ms. Mary Chionis, Mr. William Dolan, Mr. John Shonder, Mr. Victor Storm, and Ms. Darcy Weber. Mr. E. A. Lotz is Chief of USA-CERL-FS.

COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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TWO-YEAR SUMMARY OF 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, will 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 February 1983. The study will compare 200 two-bedroom manufactured units 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 reasons for the differences and their

importance for future construction criteria, construction methods, and occupant satisfaction.

Objective

The objective of this report is to present results of the O&M and occupant satisfaction data collection for both conventionally built and manufactured housing from construction through September 1985. First year data were reported in USA-CERL Interim Report (IR) P-85/14.²

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 (SR) P-140, *Fort Irwin Housing Comparison Test*.³ 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, gas range, gas water heater, garbage disposal, central air conditioning, and gas-fired forced air furnace. Each unit has two bedrooms, a kitchen, living-dining area, family room, one bathroom, utility room, 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

²R. D. Neathammer, *Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, IR P-85/14/ADA 159740 (USA-CERL, 1985).

³M. J. O'Connor, *Fort Irwin Housing Comparison Test*, SR P-140/ADA130349 (USA-CERL, 1983).

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

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, a kitchen, living-dining area, family-room, one bathroom, utility room, and a one-car garage. The fourplexes have two units on each level. There are two units on the second story in the five- and sixplexes with the additional unit(s) on the first level. The CBU also have a one-car garage, refrigerator, gas range, gas hot water heater, garbage disposal, central air conditioning, and gas-fired forced air furnace.

A detailed description of all units can be found in the Los Angeles District Office report.⁴

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 in IR P-85/14 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 International (BSI) representatives, to determine best methods of collecting the data. For O&M data, USA-CERL designed report forms (Ap-

pendix B of IR P-85/14). 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 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. 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, installation, differences inherent to manufactured or conventional construction and possible errors in specifications for the two projects.

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

⁴Fort 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.

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 May 1984, prior energy consumption data for the CBU will not be used in comparisons. (Energy consumption comparisons 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.

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 of IR P-85/14 give details.

House Tightness

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

Type	No. Units	Average Air Change Per Hr	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 Efficiency	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 Heat Loss (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 1985 are shown below.

Type	No. Months	Total Cost (\$)	Cost/Unit Month (\$)	Cost/Unit Year (\$)
MHU	3820	53350	13.97	168
CBU	4255	70412	16.55	199

Frequencies of Maintenance Per Housing Unit

For the MHU the number of service orders for a housing unit ranges from 0 to 36. For the CBU the range is 1 to 50. 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.

Self-Help Repairs

Total self-help costs (not included in the overall costs shown above) are:

MHU	\$467
CBU	\$370

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
50	1	36	2
47	1	33	1
39	1	30	3
37	1	26	1
36	1	25	1
35	1	24	4
34	1	23	1
32	1	22	2
31	1	21	4
30	2	20	4
29	2	19	7
28	3	18	8
27	3	17	5
26	1	16	6
25	3	15	9
24	2	14	4
23	3	13	12
22	1	12	9
21	4	11	10
20	5	10	9
19	4	9	11
18	8	8	13
17	8	7	17
16	5	6	16
15	3	5	13
14	9	4	5
13	10	3	7 (4)
12	12	2	23 (5)
11	11	1	39 (6)
10	12	0	3
9	7		
8	2		
7	6		
6	1		
5	2		
4	2		
3	4 (1)		
2	3 (2)		
1	14 (3)		

(1) One of these was a service call for the building as a whole, not an apartment.

(2) Two of these were service calls for the building as a whole, not an apartment.

(3) All 14 of these were service calls for the building as a whole, not an apartment.

(4) One of these was a service call for the building as a whole, not an apartment.

(5) Thirteen of these were service calls for the building as a whole, not an apartment.

(6) Thirty-four of these were service calls for the building as a whole, not an apartment.

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

Component No.	Description	Conventional Housing Units	Manufactured Housing Units	Cost (\$)	
				CBU	MHU
		(N=2347)*	(N=2295)	(Total = 70412)	(Total = 53350)
0101	Roofing Surface	-- **	60 (3%)	--	3723 (7%)
0104	Gutters and Downspouts	80 (3%)	45 (2%)	1091 (1.5%)	607 (1%)
0206	Exterior Doors and Frames	135 (6%)	128 (6%)	2739 (4%)	2326 (4%)
0207	Storm and Screen Doors	60 (3%)	-- **	1522 (2%)	--
0208	Windows and Frames	-- **	37 (2%)	--	839 (2%)
0209	Stormwindows and Screens	35 (2%)	--	862 (1%)	--
0212	Interior Drywall	38 (2%)	35 (2%)	1273 (2%)	728 (1%)
0214	Interior Doors	174 (7%)	121 (5%)	4404 (6%)	2086 (4%)
0220	Garage Door	97 (4%)	42 (2%)	2505 (4%)	850 (2%)
0301	Resilient Flooring	--	62 (3%)	--	1157 (2%)
0601	Heating Plant	69 (3%)	--	1569 (2%)	--
0607	Heating Controls	72 (3%)	--	2925 (4%)	--
0608	Other Heating	55 (2%)	54 (2%)	1139 (2%)	938 (2%)
0704	A/C Refrigerant	142 (6%)	70 (3%)	6531 (9%)	3236 (6%)
0706	A/C Controls	35 (2%)	--	1723 (2%)	--
0707	A/C Other Cooling	79 (3%)	84 (4%)	1541 (2%)	1657 (3%)
0801	Water Heater	43 (2%)	68 (3%)	1308 (2%)	3650 (7%)
0803	Piping, Supply	53 (2%)	81 (4%)	1613 (2%)	2463 (5%)
0804	Faucets and Shower Heads	65 (3%)	112 (5%)	1486 (2%)	2075 (4%)
0805	Lavatories	56 (2%)	53 (2%)	908 (1%)	1010 (2%)
0806	Water Closets	117 (5%)	113 (5%)	2482 (4%)	2342 (4%)
0807	Bathtub, Shower Unit	--	63 (3%)	--	989 (2%)
0902	Panel Box	--	45 (2%)	--	1090 (2%)
0904	Wall Receptacles	44 (2%)	56 (3%)	762 (1%)	934 (2%)
0906	Light Fixtures	93 (4%)	46 (2%)	2284 (3%)	594 (1%)
1001	Garbage Disposal	82 (3%)	77 (3%)	1831 (3%)	1304 (2%)
1002	Dishwasher	59 (3%)	84 (4%)	2483 (4%)	1533 (3%)
1003	Range	152 (10%)	213 (9%)	4756 (7%)	4197 (8%)
1201	Water Supply	48 (2%)	48 (2%)	837 (1%)	624 (1%)

*N = Number of Service Orders.

** = Less than 2%.

6 ENERGY COSTS

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

Electricity Consumption

The average usage (kWh) per housing unit is shown in Table 3. For the 17-month period, an MHU used an average total of 14,080 kWh while a CBU used an average of 13,358 kWh. This is a difference of 722 kWh $\div$ 17 months = 42.5 kWh/month. At the Aug 85 rate of \$0.0825/kWh an MHU cost \$3.50 more than a CBU for electricity per month.

Table 3

Monthly Electricity Consumption (kWh)

	MHU	CBU
May 84	780	704
Jun 84	1007	959
Jul 84	1218	1170
Aug 84	1263	1132
Sep 84	1001	907
Oct 84	557	582
Nov 84	445	433
Dec 84	486	471
Jan 85	484	463
Feb 85	427	417
Mar 85	423	444
Apr 85	633	549
May 85	679	661
Jun 85	1179	1013
Jul 85	1451	1425
Aug 85	1420	1312
Sep 85	643	707

Gas Consumption

Type of gas is liquid propane. The average usage (cu ft) per housing unit monthly data were:

	MHU	CBU
May 84	900	710
Jun 84	680	640
Jul 84	570	530
Aug 84	620	590
Sep 84	580	530
Oct 84	1410	1110
Nov 84	2400	2070
Dec 84	3560	3180

	MHU	CBU
Jan 85	3540	3220
Feb 85	2940	2780
Mar 85	2700	2390
Apr 85	1460	1270
May 85	960	820
Jun 85	610	570
Jul 85	650	580
Aug 85	660	670
Sep 85	700	650

For the 17-month period, an MHU used an average total of 25,000 cu ft while a CBU used an average total of 22,410. This is a difference of 2590 cu ft $\div$ 17 months = 152.4 cu ft/month. At the Aug 85 cost of \$0.0228/cu ft an MBU cost \$3.47 more than a CBU for gas per month.

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 of IR P-85/14.

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. Special surveys were done in Sep 84, Apr 85, and Jun 85 of all families who had lived in their quarters at least 1 year. Of these, 122 (52 percent) returned questionnaires. Overall, of 337 vacating occupants only 60 (18 percent) returned questionnaires. Special surveys will be conducted again in FY86.

For analysis purposes, only occupants who had lived in their quarters for at least 12 months were considered, since they would have been through both heating and cooling seasons.

The responses from occupants of the two types of units were compared by performing cross tabulations.

The following paragraphs show results for key questions and for questions for which occupants of the two housing types differed significantly (95 percent confidence). There were 80 responses from occupants of CBU and 48 for MHU.

Q5. How would you rate the condition of your quarters?

	Excellent	Better than Average	Below Average	Poor
CBU	23%	35	40	2
MHU	10	50	29	10

There is a statistically significant difference between occupants of the two housing types.

Q6. In general, how satisfied have you been with these quarters?

	Very Satisfied	Satisfied	Dissatisfied	Very Dissatisfied
CBU	22%	59	15	4
MHU	12	67	21	0

No significant difference was found.

Q7B. There was a major difference between CBU and MHU for satisfaction with bathroom tubs and showers:

	Satisfied	Not Satisfied	No Opinion
CBU	70%	27	2
MHU	48	48	4

Q7J. There was a statistically significant difference between first and second floor occupants of the two housing types for satisfaction of living/dining room floors. Second floor units have carpet while first floor have tile/vinyl. Second floor occupants were more satisfied.

	Satisfied	Not Satisfied	No Opinion
CBU First Floor	42%	53	5
CBU Second Floor	82	14	4
MHU First Floor	44	52	4
MHU Second Floor	70	26	4

Q7J1. There was a significant difference between occupants of CBU and MHU for cleanability of living/dining room floors, caused by the CBU first floor occupants' responses:

	Hard to Clean	Easy to Clean	No Opinion
CBU First Floor	65%	35	0
CBU Second Floor	20	75	5
MHU First Floor	24	68	12
MHU Second Floor	20	65	15

Q7K. There was a statistically significant difference for satisfaction with bedroom floors as second floor (carpet) occupants were more satisfied:

	Satisfied	Not Satisfied	No Opinion
CBU First Floor	51%	49	0
CBU Second Floor	96	0	4
MHU First Floor	56	40	4
MHU Second Floor	74	22	4

Q7K1. There was a statistically significant difference between first floor and second floor occupants for cleanability of bedroom floors with more first floor occupants (vinyl/tile) rating it as hard to clean:

	Hard to Clean	Easy to Clean	No Opinion
CBU First Floor	57%	43	0
CBU Second Floor	10	80	10
MHU First Floor	28	60	12
MHU Second Floor	10	75	15

Q9-10. There was no difference between CBU and MHU for noise/odor annoyance from other quarters.

8 CONCLUSION

This interim report has presented results of the O&M and occupant satisfaction data collection for conventionally built and manufactured housing units at Fort Irwin, CA. The data cover a 2-year period from construction through September 1985.

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