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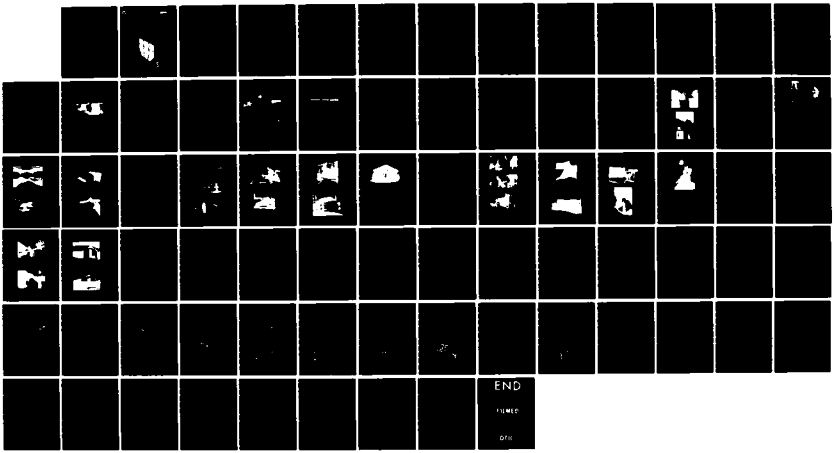

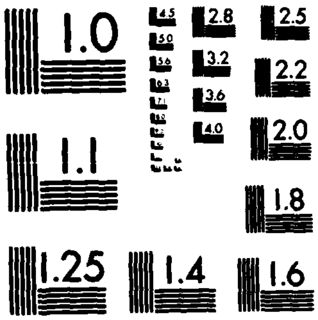

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US Army Corps of Engineers
Construction Engineering
Research Laboratory

TECHNICAL REPORT M-361
September 1984
Lightweight Relocatable Structures for the Theater of Operations

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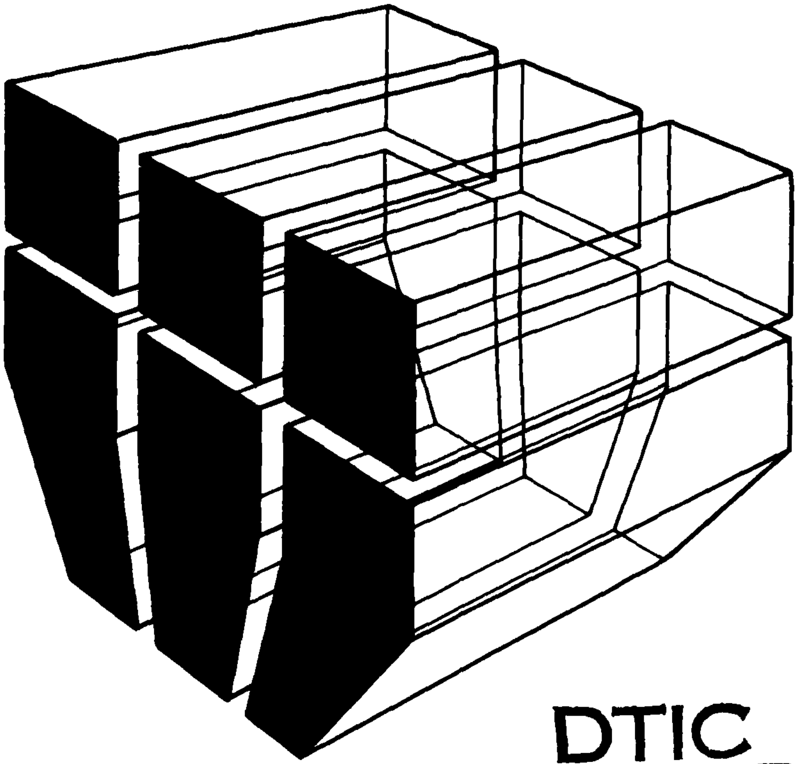
FIELD TESTING OF A LIGHTWEIGHT RELOCATABLE STRUCTURE IN A DESERT ENVIRONMENT



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This report describes the field tests of a commercially available, off-the-shelf lightweight relocatable structure (LRS) system selected for possible military application in a theater of operations. The structural system selected for the field tests was a panelized system manufactured by Kelly Klosure, Inc. The purpose of the tests was to determine the constructibility and habitability of the building system. The tests are being conducted in two stages: Stage I tests were conducted in a desert environment, and Stage II
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tests are being conducted in a temperate environment. This report documents the results of the Stage I tests.

The test results showed that the 20-ft-wide and 8-ft-high building can be erected manually by unskilled troop labor using only hand tools. However, for a 12-ft-high building assembled using 4- x 8-ft panels, a crane is needed to help lift assembled components for the erection. It took an average of 38 man-hours to assemble and erect a 20- x 40- x 8-ft building and 53 man-hours and 6 equipment-hours to assemble and erect a 20- x 40- x 12-ft building. The 8-ft fiberboard building maintained temperatures which were 4°C cooler than temperatures in the control building. Adding thermal mass and roof insulation to the fiberboard building increased the temperature difference to 7°C. On the average, the temperatures in the galvanized steel building stabilized at about 2°C above the outdoor temperature; in the fiberboard building, the temperatures leveled out at about 1°C below the outdoor temperature.

Based on overall constructibility and environmental performance, the fiberboard panel system is the better choice. Several modifications were made to the system during the field tests. It is recommended that these modifications be incorporated into system design and further field tests conducted before making a final evaluation.

The second phase of this study will evaluate the system's performance in a temperate climate and its durability.

FOREWORD

This research was performed for the Office of the Assistant Chief of Engineers (ACE) by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The work was done under Project 4A162731AT41, "Military Facilities Engineering Technology"; Task Area E, "Military Engineering"; Work Unit 049, "Lightweight Relocatable Structures (LRS) for the Theater of Operations (TO)"; and under FAD 2-2883, dated April 1983. The OCE Technical Monitors were Dr. C. Meyer and Mr. M. Shama, DAEN-ZCM.

Dr. A. Kao was the USA-CERL Principal Investigator. Dr. R. Quattrone is Chief of USA-CERL-EM. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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FIGURES (Cont'd)

FIELD TESTING OF A LIGHTWEIGHT RELOCATABLE STRUCTURE IN A DESERT ENVIRONMENT

1 INTRODUCTION

Background

The Army Facilities Component System (AFCS) provides facilities for two different construction standards: initial (0 to 6 months) and temporary (6 to 24 months). Most AFCS systems are designed to meet the demands of the temporary requirements, so they are assumed to meet or surpass initial construction standards. Since AFCS does not include many facilities that meet only initial construction standards, there is a need for building types which fulfill these requirements.

The U.S. Army Construction Engineering Research Laboratory (USA-CERL) was asked to identify and evaluate lightweight relocatable structures (LRS) (for use in AFCS). USA-CERL recently completed a study[1] to identify and evaluate LRS being used by the military and private industry that meet AFCS requirements for initial to temporary construction standards. The study concluded that, with some exceptions, the Department of Defense's current inventory of LRS does not meet current theater of operations (TO) needs.

Of the systems identified, most were found to be expensive and to exceed the requirements of military activities. Furthermore, they did not adapt effectively to various climates without the use of mechanical systems. Nevertheless, a commercial off-the-shelf system suitable for military applications was found which met the needs of AFCS structures under 60 ft* wide.

Objective

The objective of this phase of the study was to document the results of field testing the selected LRS in a desert environment in order to: (1) monitor and evaluate the erection procedures of the selected building system to determine its constructibility, durability, and habitability and (2) study the effect of building modifications and various building configurations on the system's habitability.

The second stage of the study will test the LRS in a temperate environment and evaluate the system's durability.

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[1] A. M. Kao, et al., Evaluation of Lightweight Relocatable Structures for use in Theaters of Operations, Technical Report M-314/ADA117038 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1982).

*Metric conversion factors are provided on p 51.

Approach

LRS were evaluated according to established military construction criteria, and the system which best met the requirements was chosen for field testing. A site for testing the system in a desert environment was chosen from several alternative locations, and the system was evaluated in terms of its constructibility, durability, and habitability. The test results were evaluated and modifications to improve system performance suggested.

Mode of Technology Transfer

It is recommended that the results of this field test be incorporated into Army Technical Manuals 5-301, 5-302, and 5-303.[2]

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[2] Army Facilities Component System-Planning, Technical Manual (TM) 5-301 (Headquarters, Department of the Army [HQ, DA], March 1982); Army Facilities Component System-Design, TM 5-302 (HQ, DA, March 1982); Army Facilities Component System-Logistics Data and Bills of Materials, TM 5-303 (HQ, DA, March 1982).

2 STRUCTURAL SYSTEM DESCRIPTION

AFCS Design Criteria

The major concern in LRS systems development has been their capability to be field-erected in the TO. The system must be easily shipped to and erectable in the field as well as capable of being modified to meet climatic or other TO demands. A system to be included in AFCS must satisfy the following criteria for construction through standardization:

1. Minimize the time needed to erect building components.

2. Minimize weight and volume logistical requirements.

3. Be container-compatible.

4. Minimize construction costs.

5. Minimize construction skills and required equipment and maximize simplicity of erection components.

Technical objectives of a potential system include:

1. Compatibility with existing AFCS interior design.

2. Easily relocatable.

3. Easily adaptable to different climatic conditions.

4. Adequate shelf life.

Based on its ability to adapt to these AFCS requirements, the system made by Kelly Klosure was chosen as the best commercial off-the-shelf system. This system offers a rapidly erectable structure, along with options for many building configurations. Field tests were done to evaluate the habitability, constructibility and durability of this system as they related to military application criteria.

Kelly Klosure Description

The lightweight relocatable structure is a modular panelized system, based on a 1 1/2- x 1 1/2- x 1/8-in. steel frame panel. The basic sizes of panels are 4 x 4 ft, 4 x 8 ft, and 4 x 12 ft. Three types of panel materials are available: galvanized steel, structural fiberboard, and fiberglass. Corrugated galvanized steel and structural fiberboard panels were used for the test.

The system is made up of a limited selection of materials. The galvanized panels are made from 28-gage corrugated steel. The fiberboard panel, manufactured by Simplex, has four plies of water-resistant recycled paper board. Each ply is 0.043 in. thick. The outside layers are one ply of 40 lb hard-sized kraft board. Both sides of the board are coated with 1.5 mil of polyethylene. The weight of the 4- x 8-ft galvanized steel is 61 lb, while that of the fiberboard is 58 lb.

The panel frame, eave angles, corner angles, ridge angles, and chord brackets are all made of M1020 merchants bar steel. Other building components include 2- x 6-in. wood chords, a 2- x 6-in. baseplate, lag bolts, guy wire system, and Kelly Klosure keys. The keys are made of zinc-plated steel. The system is "keyed" together, eliminating most nuts and bolts; this gives quick erection and takedown times (Figure 1). Since all the components interconnect readily, a variety of configurations may be assembled using different sizes of panels. Thus, a large variety of building sizes could be provided in a TO environment in a short period of time. The system is shipped in a storage rack of 24 to 30 panels, with additional components strapped on the top (Figure 2). Table 1 gives material costs for both galvanized steel and fiberboard for typical 20- x 8- x 40-ft and 20- x 12- x 40-ft buildings.

Construction and Erection Procedures

The Kelly Klosure system can be erected directly on unfinished ground, on a concrete slab, or on a suitable raised wood foundation. Appendix A provides details of the construction and erection procedures.

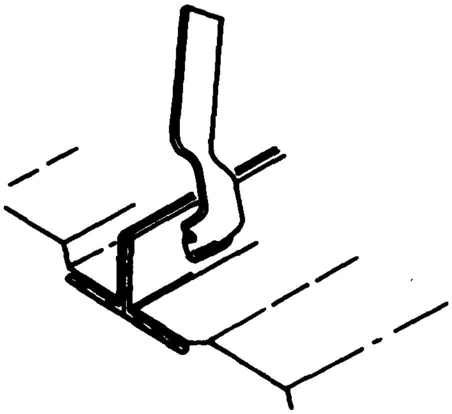

Figure 1. Kelly Klosure key.

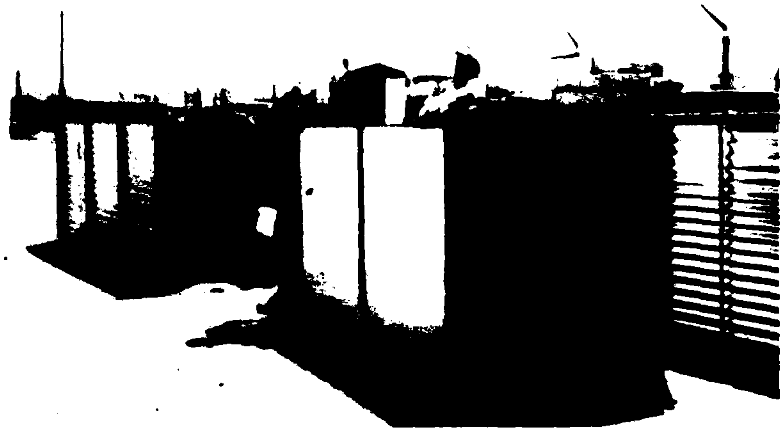

Figure 2. Panel storage rack.

Table 1

Material Costs for Galvanized Steel and Fiberboard Panels

Building Configuration	Panel Insert	Base Cost*
20 x 8 x 40 ft	Galvanized steel	$5055.00
20 x 8 x 40 ft	Structural fiberboard	$4422.00
20 x 12 x 40 ft	Galvanized steel	$7242.00
20 x 12 x 40 ft	Structural fiberboard	$6556.00

*The cost (June 1983) includes the 20 percent GSA discount to F.O.B., Fremont, Nebraska, but excludes the cost of the 2 x 4 lumber used for the chords and baseplate.

3 FIELD TEST PROGRAM

Test Location

Potential sites for Stage I testing included Yuma, AZ; Twenty-nine Palms, CA; and Fort Irwin, CA. Fort Irwin, CA, was chosen after evaluating the three alternatives with respect to diurnal temperatures, relative humidity, precipitation, wind speed, and manpower support available during July, August, and September of 1983 when the test was conducted. Located in the Mohave Desert, Fort Irwin exhibits the environmental characteristics typical of a desert climate. Fort Leonard Wood, MO, has been chosen for Stage II testing of the building system in a temperate climate.

Test Methods

The system was tested in two main areas: constructibility and environmental data. Field tests of various building configurations were conducted in four cycles. Figure 3 outlines the test schedule program. Three buildings were used in each cycle. One control building remained in the as-built condition throughout the test. The other two structures were modified during each test period to isolate environmental variables and to allow repeated constructibility testing. A time-tallying schedule was set up to record man-hours required for each task spelled out in the critical path method for the system. A checklist was completed to evaluate each building's performance.

Interior and exterior temperatures and other weather data were also collected with a portable data logger and weather station. The data were compiled and plotted on graphs to evaluate the system's habitability.

Support Systems Tested

Three other components/systems devised by USA-CERL were tested in addition to the basic components supplied by Kelly Klosure system: an insulating system, a fabric double roof system, and a ground anchor.

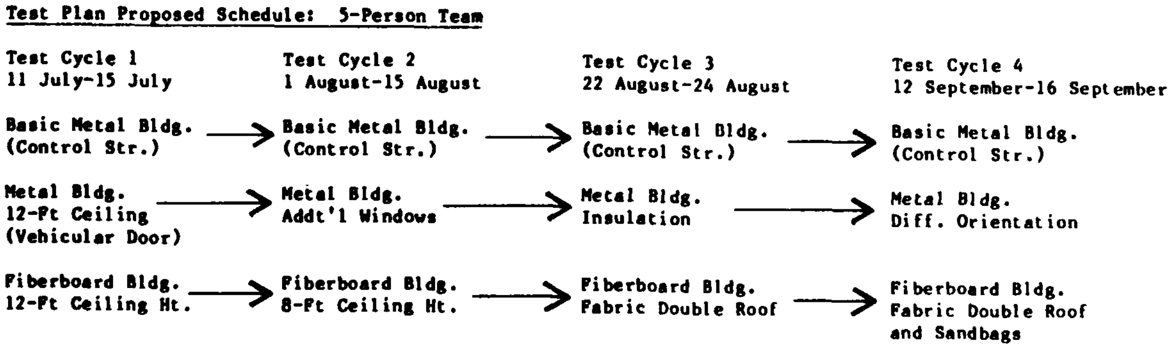

Figure 3. Test cycles.

Insulation

Using an existing 20- x 8- x 40-ft experimental structure, 2 in. of rigid insulation was tested on the walls and ceiling. The insulation used was a foil-faced, glass-reinforced, polyisocyanurate foam. With a 3/4-in. airspace, the insulation has an R-value of 17.2. USA-CERL developed and built a reusable bracket for the wall panels which incorporated the Kelly Klosure key for connecting it to the panels. For the top of the panels, a 4- x 1/8- x 10-in. steel plate was bent and slotted to match the panel key openings (Figure 4). Two brackets were required to hold the top of each 4- x 8-ft insulation panel to the sidewalls. Wood strips of 1 x 2 in. served as the molding and secured the insulation at the base. Ceiling brackets were designed to fit over the 2- x 6-in. chords (Figure 5). These were made of bent 20-gauge galvanized sheet metal 4 in. wide.

Fabric Roof

A double roof was created by suspending a tarp 12 in. above the existing 20- x 8- x 40-ft fiberboard building. The fabric was an 18 oz/sq yd vinyl-coated polyester fabric. Its edges were reinforced with double fabric and stitching. The centerline corresponding to the building ridge was also strengthened in this manner.

The galvanized assemblies used to support the fabric were built to be compatible with the Kelly Klosure system. The ridge assemblies were bolted to one side of the ridge angle and spaced 8 ft on center. The ridge cap had to be trimmed and replaced around these and then retaped to prevent sand and moisture seepage. A 12-in. extender pipe was connected to each assembly with a cotterless hitch pin. This was used to facilitate disassembly (Figure 6).

Steel Pipe Ground Anchor

Due to the site's extremely hard sandy-gravelly soil condition, the standard Kelly Klosure screw anchor could not be used. A common thick-walled 1-1/2-in. diameter steel pipe (Figure 7) was made for the testing. The pipes were driven into the ground with sledge hammers.

Description of Test Program and Test Building Construction

Site Preparation

Test buildings were constructed on a hard, level, sandy soil on the western edge of the main base at Fort Irwin (Figure 8). Although the site was fairly level, it had to be leveled with a grader so that the test buildings could be erected properly. A site about 40 x 200 ft was cleared and leveled. Figure 9 shows the test building layout.

First Test Cycle

The first test cycle began in mid-July and was completed in early August. Both test structures used 12-ft sidewalls to test their constructibility using only 4- x 8-ft panels and also to test the environmental effect of taller side walls

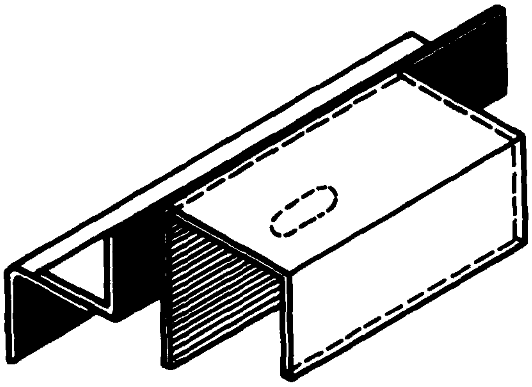

Figure 4. Wall insulation bracket.

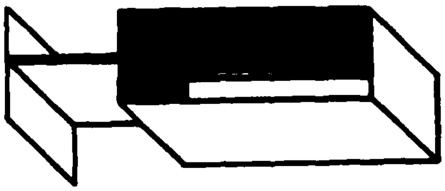

Figure 5. Ceiling insulation bracket.

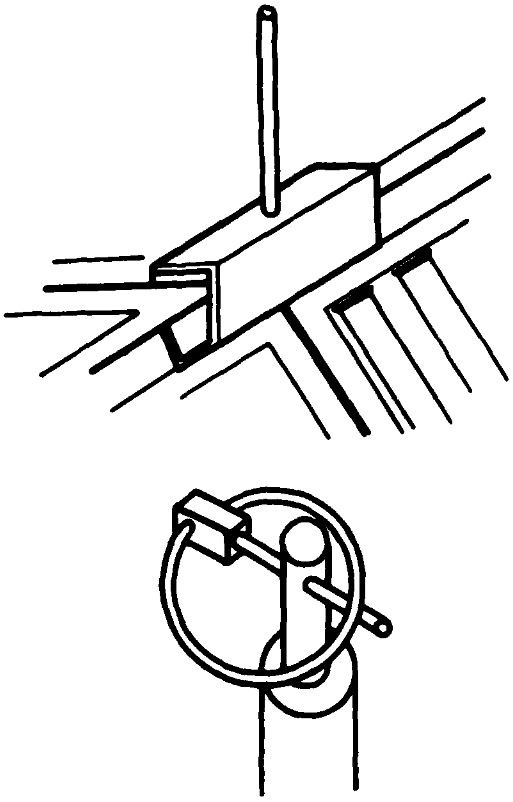

Figure 6. Ridge assembly.

Figure 7. Ground anchor.

Figure 8. Fort Irwin, CA.

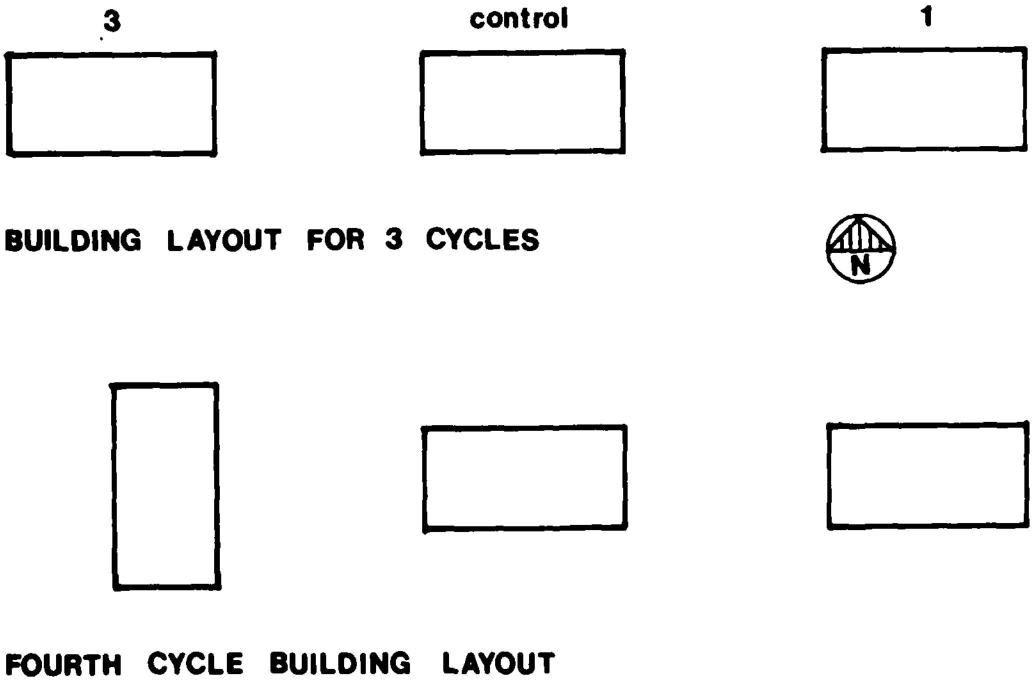

Figure 9. Plan of the test site.

on the interior living space. The control building (test Building 2, Figure 10), a 20-ft-wide x 40-ft-long x 8-ft-sidewall galvanized steel panel structure, was erected first so that personnel could become familiar with the system before erecting the more complicated 12-ft sidewall test structures. The control structure was assembled in about 6 hours with a six-person crew.

Building 3, a 20-ft-wide x 40-ft-long x 12-ft-sidewall galvanized steel panel structure (Figure 11), was erected next. Panel configuration was as shown in Figure 7; the sidewalls had 4- x 8-ft panels and 2-in. x 6-in. x 12-ft wood stiffbacks to form 8-ft wide bays. The first two bay sections, starting with the endwall with the vehicle door opening, were erected manually; however, due to the weight and lateral instability of the double-wide 12-ft-tall bay composed of 4- x 8-ft-wide panels, it was deemed safer to use a crane. A 5-ton hydraulic crane was used to complete the structure. Four 4- x 8-ft window panels, one 4- x 8-ft construction grade personnel door, and one 11-ft, 6-in.- x 12-ft sliding vehicle door were incorporated into the structure.

Building 1, a 20-ft-wide by 40-ft-long x 12-ft-sidewall fiberboard panel structure (Figure 12), was erected last. Panel configuration was the same sidewall format as Building 3, but instead of one vehicle and one personnel door, two personnel doors were used.

Second Test Cycle

The second test cycle began in early August and ran until the end of the month. The control building remained unchanged; however, Building 1, the 12-ft-sidewall fiberboard building, was changed to an 8-ft-sidewall building using the same panel configuration as the control building (Figure 10) but using only fiberboard panels. Building 3, the galvanized steel panel structure with 12-ft sidewalls, was also changed to the same general building configuration as the control building; however, fourteen 4- x 8-ft window panels were used instead of only four (Figure 13). Thus, from Building 1, the effect on the interior thermal environment of a different panel material could be measured and compared to the control building and from Building 3 the effect of added ventilation could be measured.

Third Test Cycle

In the third test cycle, which ran from the end of August to the middle of September, the only change to Building 1 (20- x 40- x 8-ft fiberboard panel structure) was to suspend a fabric roof 12 in. above the surface of the actual fiberboard panel roof (Figure 14). The double roof was added to find out how shading the roof surface would affect the building's interior environment. Building 3 was altered by adding 2-in.-thick, 4- x 8-ft sheets of foam insulation board throughout the structure. A ceiling was created by suspending 4- x 8-ft sheets underneath the wooden chords. Four- x 8-ft sheets were attached to the sidewalls, and holes for four windows were cut through the insulation. Gaps between insulation panels were sealed with tape.

Fourth Test Cycle

The fourth test cycle ran from mid-September to early October. The only change made to Building 1 was to stack sandbags against the outside of the structure (Figure 15) and to add 2-in.-thick insulation board to the underside

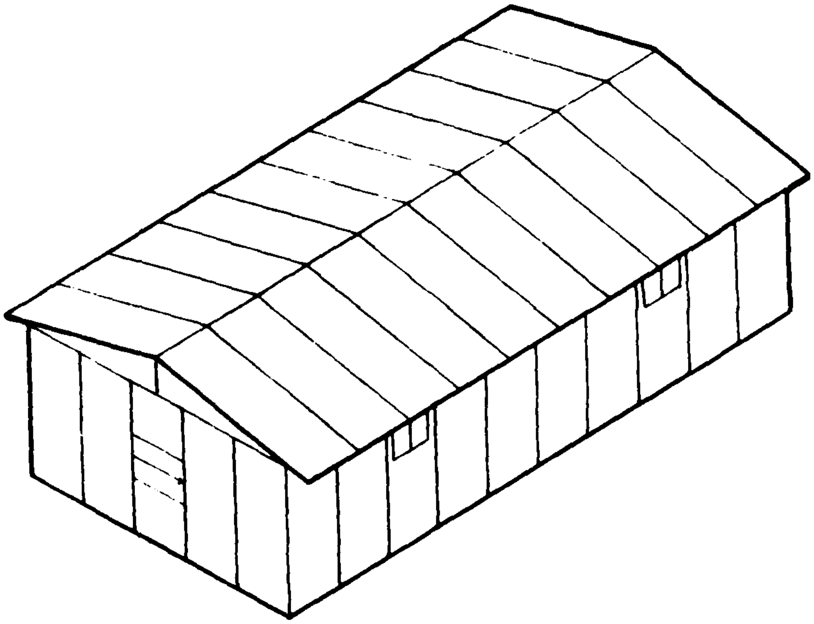

Figure 10. Control structure (20 x 8 x 40 ft).

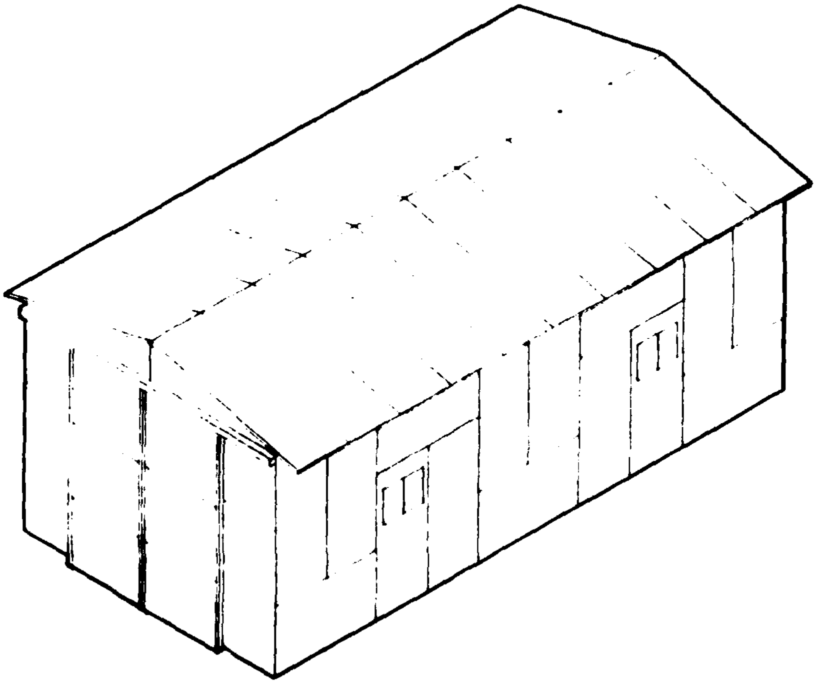

Figure 11. Test structure 3--galvanized steel building (20 x 12 x 40 ft).

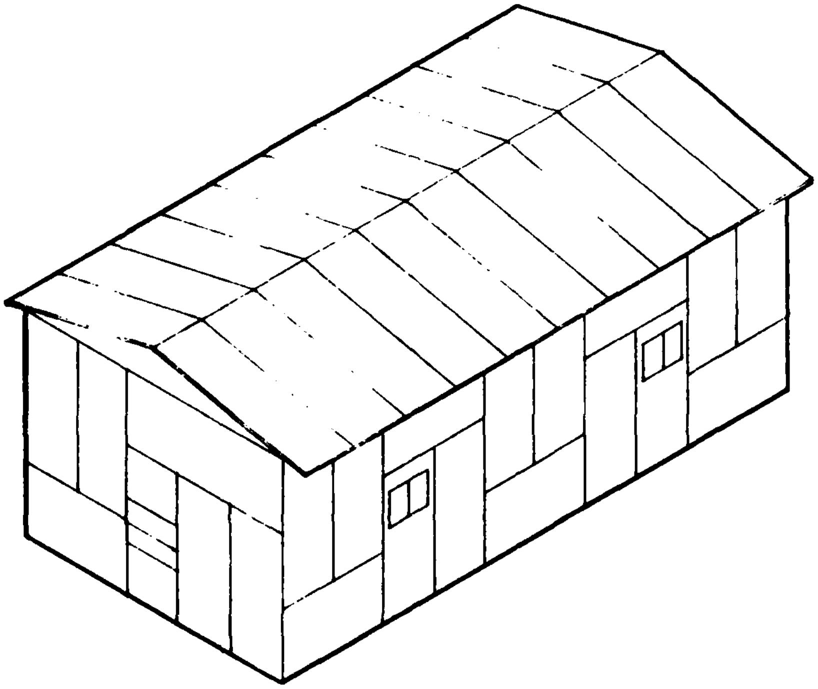

Figure 12. Test structure 1--structural fiberboard building (20 x 12 x 40 ft).

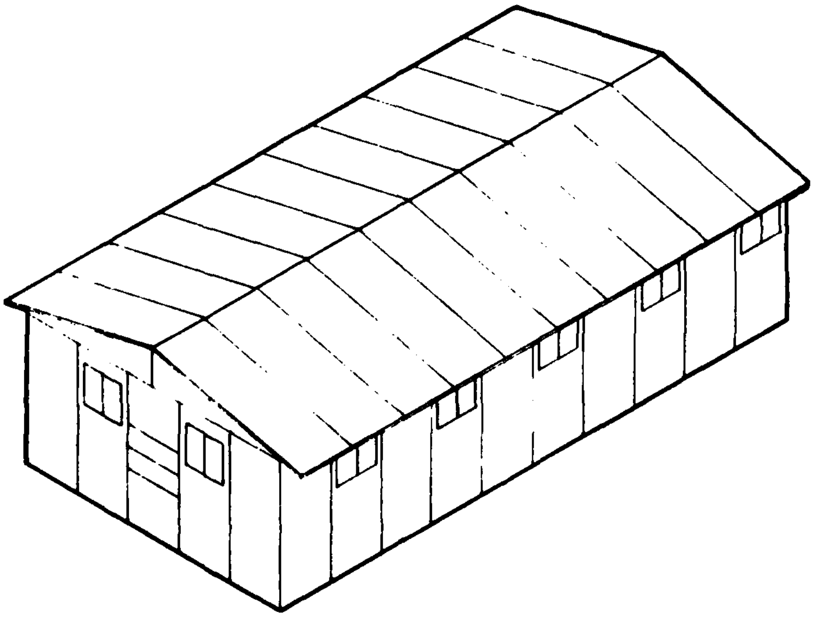

Figure 13. Test structure 3--galvanized steel building with additional windows (20 x 8 x 40 ft).

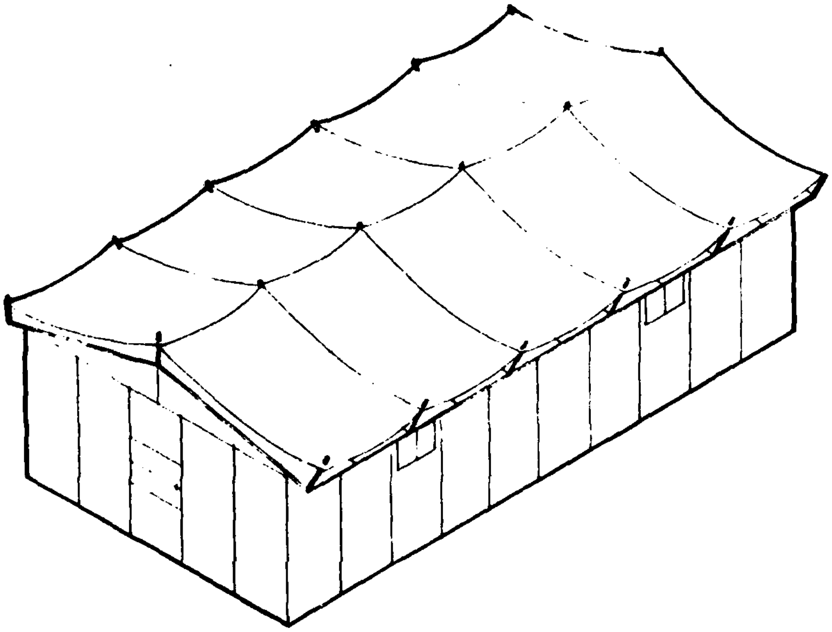

Figure 14. Test structure 1--fiberboard building with fabric roof (20 x 8 x 40).

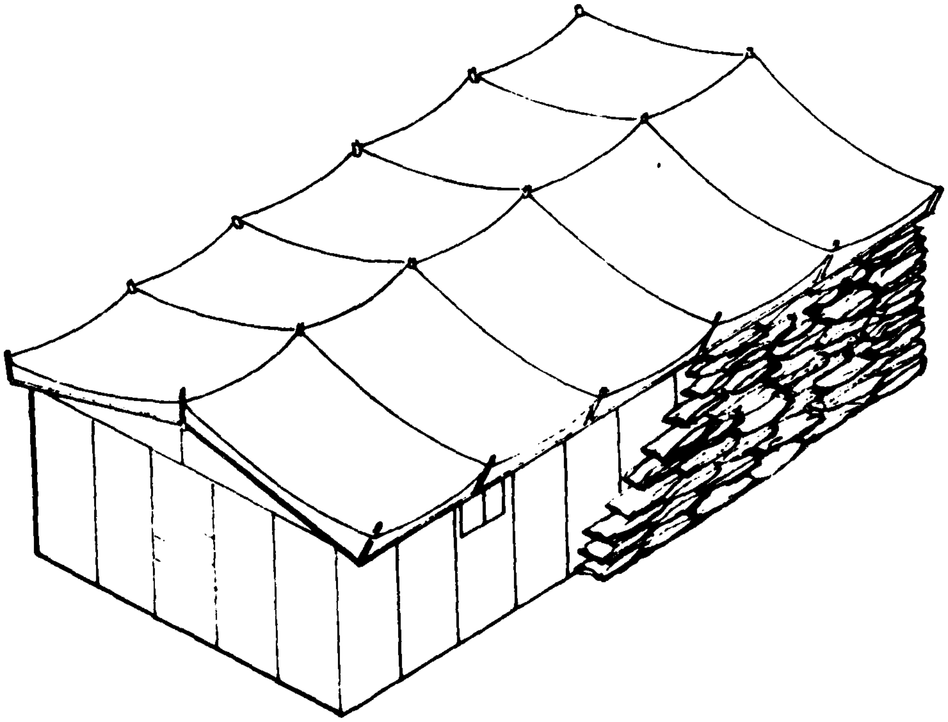

Figure 15. Test Structure 1--fiberboard building with sandbags.

of the wood chords to form a "ceiling." Building 3 was changed to the same panel configuration as the control building (20- x 40- x 8-ft galvanized steel panel structure with four window panels and two personnel doors); however, Building 3 was rotated 90 degrees so that its main axis was oriented north-south. This cycle was designed to test the effect of adding thermal mass to a structure and of changing the building's orientation.

Instrumentation

One main objective of the test was to determine the system's habitability. To do this, data from the control building were compared to data obtained from the test structures, using the outdoor conditions as a baseline.

The instrumentation used in the tests was a Campbell Scientific CR7 measurement and control system (Figure 16). The CR7 monitored both temperature and relative humidity inside and outside the buildings. It also recorded the exterior wind speed, wind direction, and solar radiation. Thermocouples and/or thermistors were mounted at the 1-ft, 4-ft, 6-ft, 8-ft, and 12-ft levels within each building. Relative humidity probes were mounted at the 6-ft level. Wind speed, wind direction, and solar radiation probes were mounted on a steel pipe attached to the control building (Figure 17).

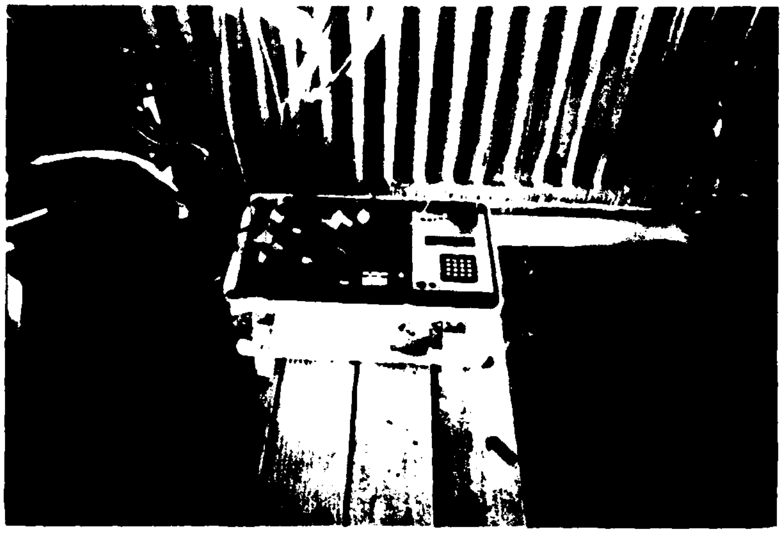

Figure 16. CR7 instrumentation.

Figure 17. Exterior weather station.

4 FIELD TEST RESULTS

Constructibility Test Results

Baseplate Construction

The three 20- x 40-ft baseplates were built with 2- x 6-in. lumber at the start of the test. Because the instructions were explicit, there were no major problems with the baseplate layout (Figure 18). However, problems did arise in driving the 18-in. baseplate stakes due to the hard, rocky soil. Sledge hammers of 3 lb, 5 lb, and 10 lb were tried, with the 5-lb hammers being most effective (Figure 19).

It was determined during the erection of the 12-ft fiberboard building that a level baseplate was needed to insure that the final sections would be connected properly.

20- x 8- x 40-Ft Building Erection

8-Ft Control Building. The 20- x 8- x 40-ft control building was the first structure assembled. Construction times were recorded for the various tasks; Appendix B summarizes the number of man-hours required for each. A six-person team assembled the building in 34.5 man-hours (Table 2). This included the time taken to familiarize the crew with the project. The crew worked in teams in order to complete specific tasks as quickly as possible (Figures 20 and 21). The interior of a completed building is shown in Figure 22.

By mid-morning, the more direct sunlight made all materials too hot to handle. Gloves had to be worn when working with the panels and especially when capping the corners and roof (Figure 23). A lighter-colored frame or painting the panel a lighter color might reduce the heat absorption.

Driving the ground anchors caused some trouble, again because of the hard, rocky soil. The need for a stronger stake material was indicated when the heads of the experimental ground anchors deformed when being driven into the ground. Consequently, the eyebolt holes for the guy-wire hooks deformed, and new ones had to be field-drilled. This problem occurred at all three test structures. Future anchors should have the eyebolt position lower to help avoid these problems. Also, a system which eliminates exterior guy wire bracing should strengthen the total design.

8-Ft Building Disassembly. Disassembly of the 20- x 8- x 40-ft building went smoothly. It took 20 man-hours to complete. Taking down the building did not require any additional equipment. The keys were removed using only a hammer and a drift pin. The crew rolled down the sections in the same way that they had put them up. Since the building was to be reassembled later, it was not necessary to disassemble the smaller component pieces, such as the chord brackets and ridge angles.

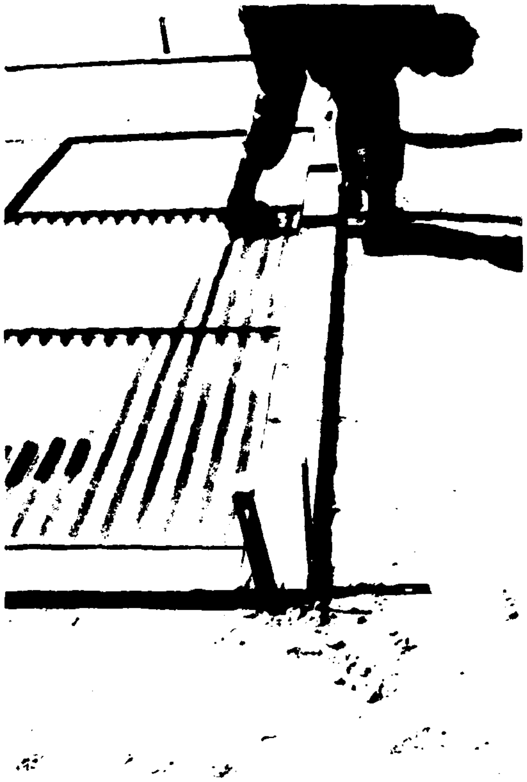

Figure 18. Baseplate layout.

Figure 19. Baseplate stake driving.

Table 2

Summary of Man-Hours Required for Erection of a
20- x 8- x 40-Ft Corrugated Metal Building

Activity	Description	No. of People	Total Man-hours	Total Equipment
0-10	Level Ground	2	4	[illegible]
10-20	Layout Baseplate	3	3 3/4	
20-30	Assemble Endwall	5	2 1/2	
20-30	Assemble Midsections	3	5 1/4	
30-40	Roll Up Endwall	8	2 hrs	
40-50	Roll Up Midsections	8	6 hrs	
50-60	Key Sections Together	2	2 hrs	
50-60	Add Guy Wires	2	1 1/2 hrs	
50-60	Assemble Endwalls	3	3/4 hrs	
60-70	Roll Up Endwall	8	2 hrs	
70-80	Key Endwall Section Together	2	1/2 hrs	
70-80	Add Guy Wires	2	1/2 hrs	
70-80	Add Foam Fillers	1	3/4 hrs	
70-80	Add Corner Caps	2	1 hr	
70-80	Tape Joints	3	2 hrs	
		Total	34.5 hrs	[illegible]

*Grader

Figure 20. Interior of control building.

Figure 21. Eave angle assembly.

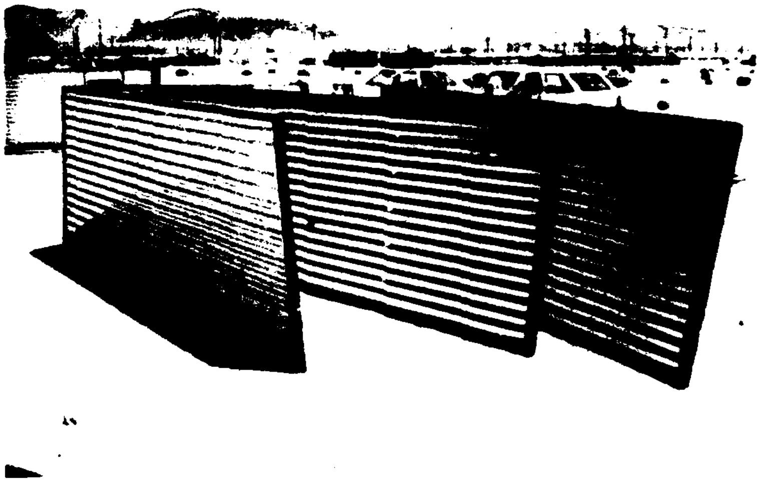

Figure 22. Assembled roof panels.

Figure 23. Ridge cap installation.

Reassembly of 20- x 8- x 40-Ft Building

During the second cycle, the 20- x 8- x 40-ft galvanized steel and structural fiberboard building, were erected with no major problems (see Figure 24).

For the fiberboard building, the same 4- x 8-ft window panels employed in the previous assembly could be used. The galvanized steel building required additional window panels as part of the test modifications. All other parts except some of the keys could be reused. The unusable keys were those which had been bent during the initial erection procedure or twisted when they were taken out.

The twisted chords and brackets did not pose any problems when the two new buildings were assembled. The only trouble occurred when assembling the endwall of the galvanized building. Window panels had been laid out on either side of the personnel door (Figure 25). While keying the sections together, one of the glass panels shattered.

The two 20- x 8- x 40-ft buildings were put up smoothly in 1-1/2 days, whether standard panels (Figures 26 and 27) or window panels (Figures 28 and 29) were used.

20- x 12- x 40-Ft Building Erection

12-Ft Galvanized Building. After completion of the control building, assembly of the 20- x 12- x 40-ft galvanized steel building began. Since 4- x 8-ft panels were to be used, the building sections were assembled in 8-ft widths. As part of the test for constructibility, a portion of the structure was erected manually.

The procedure began as indicated in the erection guide. The endwall was laid out along the short edge of the baseplate, modifying it slightly because an equipment door was to be installed later in one endwall. Modifying the endwall eliminated 4- x 8-ft panels in a 12- x 12-ft area, creating a void in the endwall. Since a complete endwall weighed 1550 lb, other modifications were made to facilitate the erection. Rather than constructing a full 8-ft section, the endwall was divided into two parts. A partial section was made up of an endwall with the equipment door void, a 4-ft roof section, and sidewalls (Figure 30). This was rolled up in the same manner as the control building, using a six-person team. Guy wires and lag bolts were added to stabilize the section. Working out the strategy for doing this task took a large amount of time.

The remaining portion, comparable to a basic midsection for the control building, was made up of two 4- x 8-ft panels and a 4-ft-wide roof section. The reduced section had to be lifted above the standing endwall. Adding the reduced section was much harder because this partial section was unstable. There was no lateral bracing in each section to prevent side-sway. One possible solution would to be use temporary bracing during erection. Manually bracing the joints as the section was lifted helped to stabilize it. The roof section was finally keyed to the lower panels.

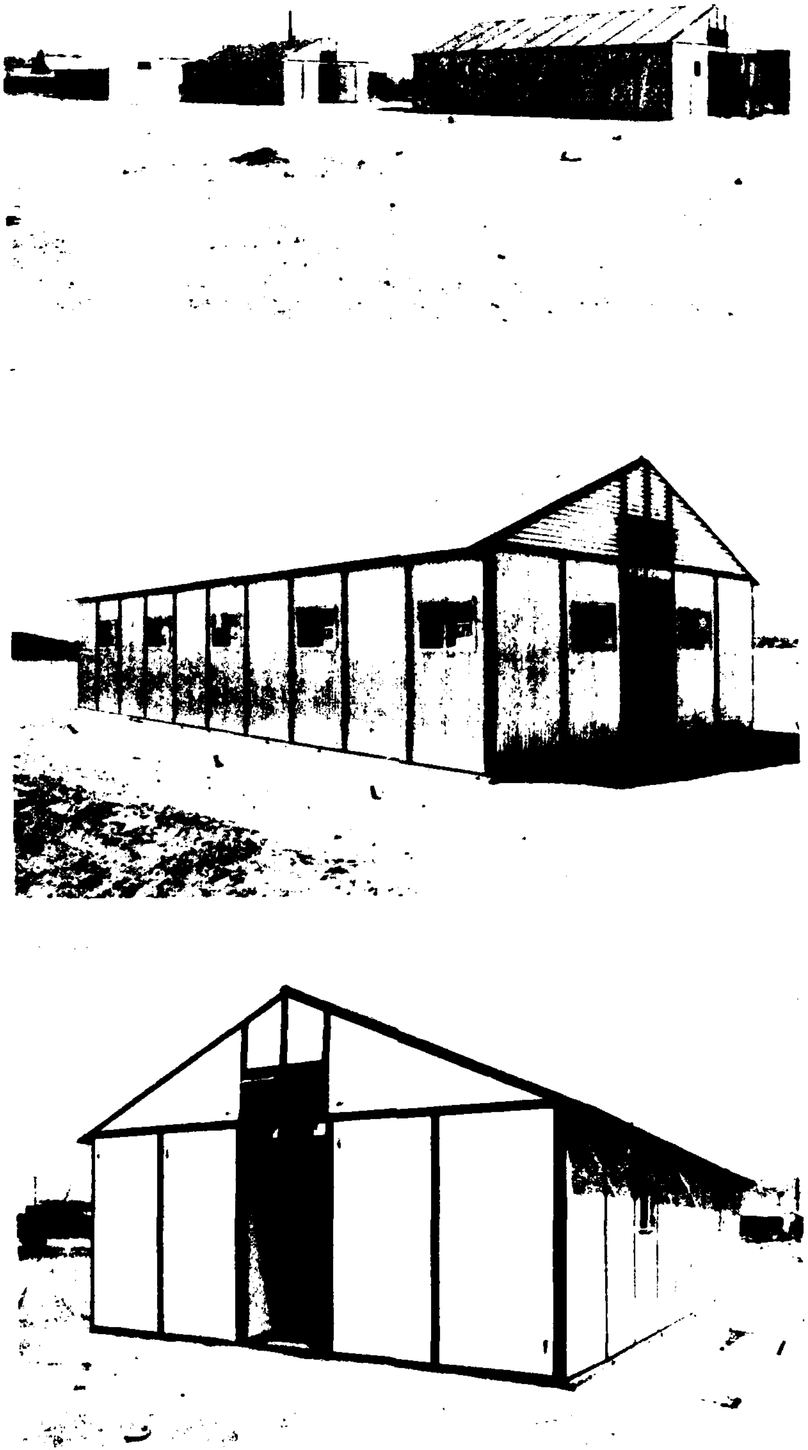

Figure 24. Second cycle buildings.

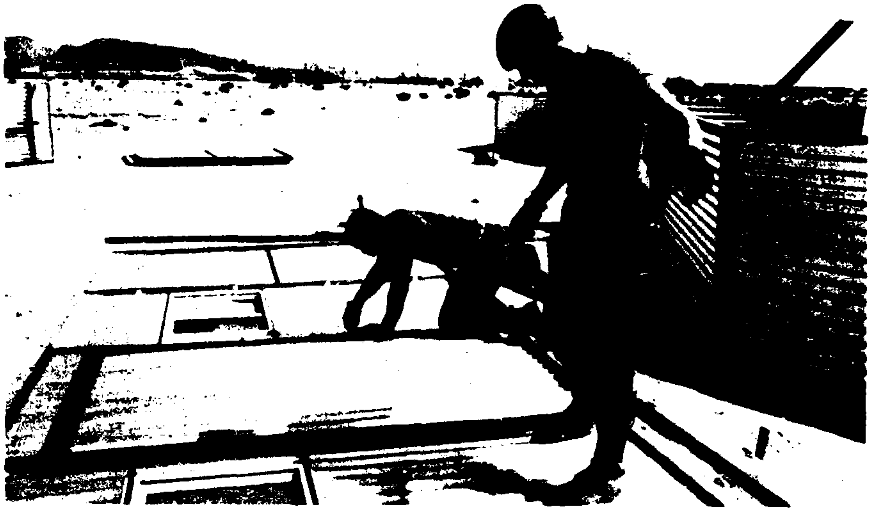

Figure 25. Endwall layout and assembly.

Figure 26. Standard section erection.

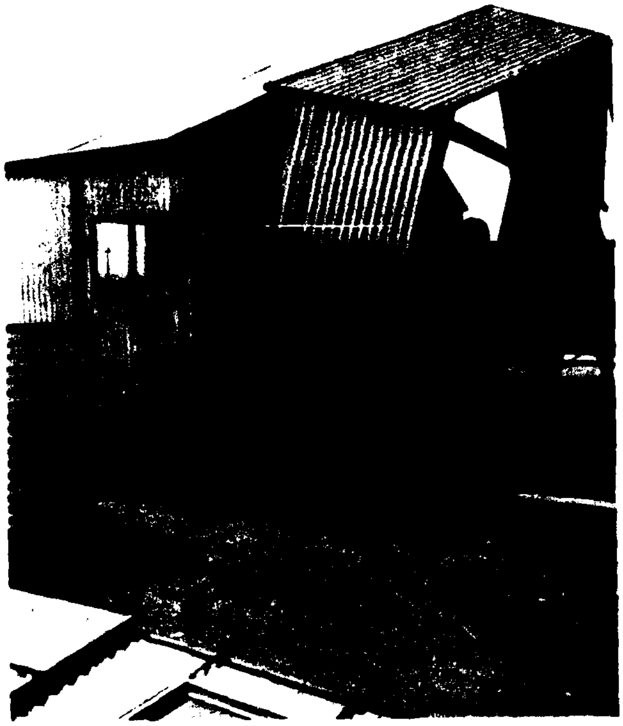

Figure 27. Panel connection.

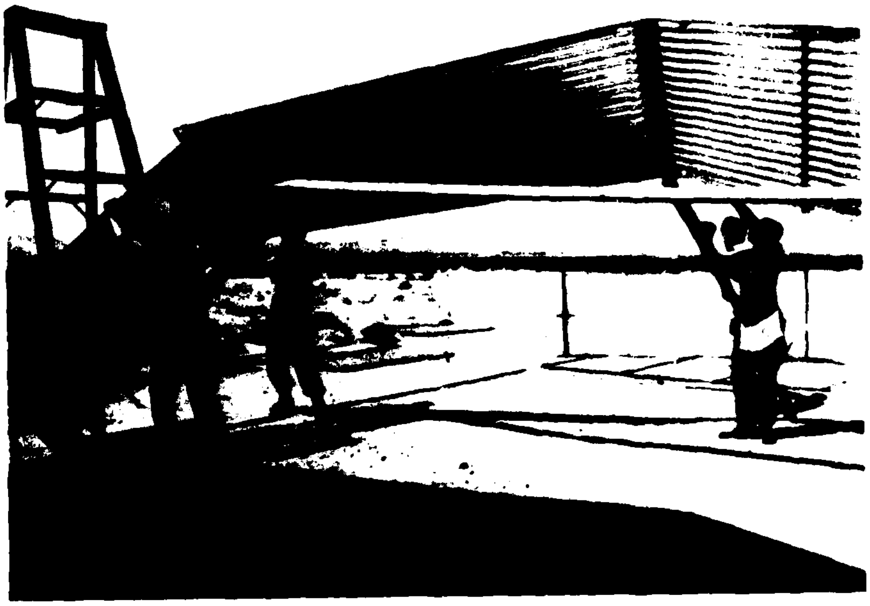

Figure 28. Rolling up window section.

Figure 29. Keying window section.

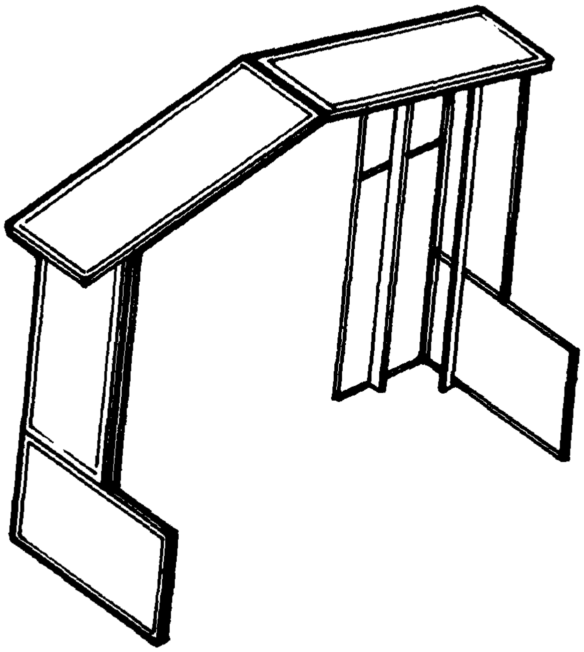

Figure 30. Partial section of 12-ft galvanized building.

Since manually erecting the endwall was hazardous, the construction was temporarily delayed until a crane could be used. Even with a crane, the process was relatively slow. It took time to guide the sections to their correct positions on the baseplate and to stabilize them until they could be anchored (Figure 31). The sections were keyed together and lag-bolted to the baseplate in the same way as for the control building. Guy wires were added to every other section to support the building laterally.

Putting together the equipment door was the most time-consuming task, since it is made up of many small pieces which have to be bolted together. It is not as easy to assemble as the rest of the system.

The total time needed to erect the 12-ft galvanized steel building was 1-1/2 days. This did not include taping the panel joints or adding the ridge and corner caps or the gable louvers. These tasks were postponed until the end of the cycle.

12-Ft Fiberboard Building. Assembly of the the 20- x 12- x 40-ft structural fiberboard building employed the same procedure for the endwall as used for the 12-ft galvanized building. The endwall section was laid out along the edge of the baseplate (Figure 32). Since the surrounding site was not level, there were some problems keying the panels together (Figures 33 and 34). These were resolved and a full section was prepared to be rolled up manually. A seven-person team then erected the 8-ft-wide, 12-ft-tall section. With the center of gravity so high, two people had to guide the section at the top with 2- x 6-in. lumber. Since the endwalls offered some lateral stability, the side-sway problem was eliminated. Using fiberboard panels reduced the weight of the section and made the job slightly easier (Figure 35).

The remaining sections were assembled and erected with a crane. The procedure for the fiberboard went more smoothly than that of the 12-ft galvanized building. This was probably because the crew had more experience repeating the same task, and because the fiberboard panels were lighter and easier to work with.

12-Ft Fiberboard Building Disassembly. The 20- x 12- x 40-ft buildings were disassembled during the second test cycle. They were replaced with 20- x 8- x 40-ft buildings of the same materials. Appendix B summarizes the disassembly times recorded for each building.

The fiberboard building was rolled down first, using a crane. To minimize the crane time, the hoisting cables were added to each section before its arrival. The 8-ft sections were separated and scattered around the site by the crane. Again there was a problem in trying to roll them down because each section was unstable.

The problem stemmed from the 8-ft-wide sections made up of 4- x 8-ft panels. Part of the problem may be alleviated by using 4-ft-wide sections made up of 4- x 12-ft panels. The twisting and bending of the panels and components was more evident during disassembly. Close inspection showed that some chords and brackets were deformed and had hairline cracks. One chord bracket had to be replaced (Figure 36). The stiffbacks, which did not have to be reused, suffered more damage. Many ends cracked off when the panels were bent during disassembly. This problem occurred mainly when the 4- x 8-ft panel was

Figure 31. Sequence of erection of the 12-ft galvanized building with a crane.

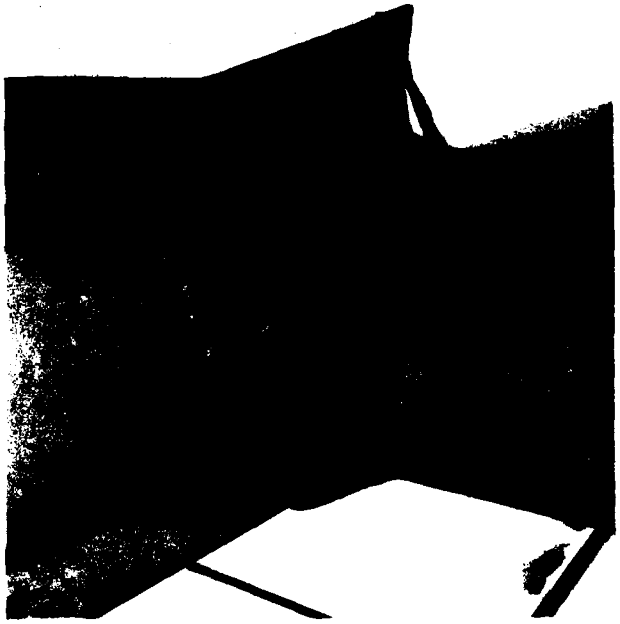

Figure 32. Endwall layout.

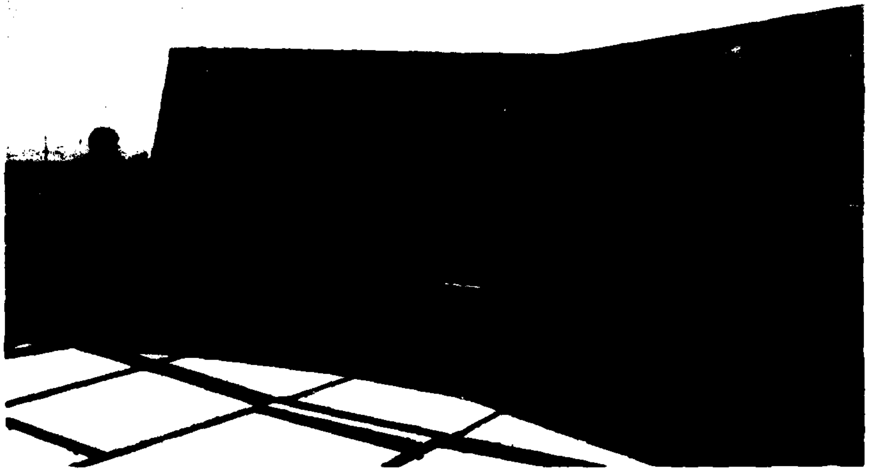

Figure 33. Assembly of fiberboard endwall.

Figure 34. Endwall completion.

Figure 35. Manual erection of fiberboard endwall.

Figure 36. Field-drilling chords for the brackets.

keyed horizontally at the base of the wall section. The stiffback had not been clamped to the base of the panel.

Once the building was down, it was separated into its components. Since some of the components would be used to construct the 20- x 8- x 40-ft building, they were not disassembled. For examples the stiffbacks were removed, but their brackets remained connected to the eave angle chord bracket. The roof sections were separated into only 4-ft sections, and the gable ends were not disassembled. Thus, reassembly of the 8-ft building required fewer man-hours than that of the control building.

Galvanized Steel Building Disassembly. Disassembly of the 12-ft galvanized steel building took more time than for the 12-ft fiberboard building because louvers and the equipment door had to be removed. Once the hoisting cables were clamped, the crane was used to roll down the building. Again, there were problems when bending of the sections resulted in twisted and cracked wood members and chord brackets. Total disassembly of two 20- x 12- x 40-ft buildings took five people 1-1/2 days.

Ground Anchor

In addition, there was an erosion problem around the staked baseplate because there were some problems in driving the anchors into the hard rocky soil. After heavy rains, a portion of the floor washed away and caused gaps in the baseplate. A small gully developed near one base, but affected only one ground anchor. However, during these storms, the ground anchors withstood the uplifting forces of the high winds.

Panel Tape

The standard brown vinyl panel joint tape was used for the first cycle. It came in 5-in.-wide x 100-ft-long rolls. The edges of each panel between the insert and the panel body had been caulked at the factory. Thus, only the seams between adjoining panels, corners, and along the ridge had to be taped. Extremely high temperatures and blowing sand and dust at the test site reduced the tape's performance, causing it to stretch and lose its adhesiveness. Once the tape was twisted or applied, it could not be changed. During the first cycle, the tape partially peeled off the building.

Three other sealing options were tried during the second cycle: a 4-in. embossed vinyl tape with backing, aluminum foil tape with backing, and a silicone rubber caulk. Table 3 summarizes the ratings of these sealants.

Table 3

Factory Ratings of Sealants

Tape Specifications	Application in Extreme Heat	U.V. Deterioration	Moldability	Stripping w/o Adhesives Seperation	
Kelly Klosure Vinyl Tape	4	3	3	3	
4-in. Embossed tape Acrylic adhesive 250°F adhesive breakdown Vinyl w/min. plasticizer Backing	1	3	2	3	Supplier requires large purchase
Aluminum foil tape 5 mil thick 350°F adhesive breakdown Backing	2	1	3	2	Not very pliable
Silicone rubber caulk Bonds to painter surface 10-yr warranty Waterproof-permanent flexibility	1	1	1	2	Need additional tools to put on

1 Excellent
2 Good
3 Fair
4 Poor

The tape samples were used on the control building. The aluminum foil tape was not pliable, and it had a backing which had to be removed. Because of its narrow width, the embossed vinyl tape never touched the fiberboard and top surface as the Kelly Klosure vinyl tape did. The only disadvantage of the embossed vinyl tape was the backing. Generally, the silicone caulking was easy to apply and was not affected by the extreme temperatures.

Insulation Installation

It took a five-person team 4-1/2 hours to put up the wall and ceiling insulation. The wall insulation brackets were easily keyed into place (Figure 37).

The bent chords and brackets created some problems with the ceiling insulation. The brackets, which had to be hooked over the chords, sometimes had to be bent slightly to install the insulation sheets. The brackets also could not be slid easily along the length of the chord. This was necessary for installing the center row of insulation.

For the endwalls, a different system was tested to hold the wall insulation in place. The insulation sheets were wired to the panels. Small sheet-metal channels served as wire guides to preserve the edge of the sheets. The only disadvantage to wiring the panels was that the wires were exposed. Vinyl-backed insulation sheets were unavailable, so two-sided foil-faced ones were used instead (Figure 38). However, these were not very durable and would not last for more than a few locations.

Fabric Roof

Installation of the fabric roof took a team of four people 3 hours to complete. The procedure was simple and straightforward. Bolting the ridge assemblies to the building was a two-person job; one worked from the outside of the roof, and the other worked from the inside at the peak. Putting on the side assemblies on the overhang took less time. One person could bolt the assembly to the roof panels. This portion of the job was done in 6 hours.

Rolling up the fabric was awkward due to its size and bulkiness. Maneuvering on the roof was tricky because the fiberboard surface was slick. Installation of the fabric, including adjusting the tension in the assemblies was done in 6 hours. Due to high temperatures and bending brackets the fabric sagged as soon as it was installed. However, it did remain elevated above the roof for the duration of the test (Figure 39).

Sandbags

Three thousand sandbags were filled at the site during the third test cycle. The sand bags were used to test the effects of adding thermal mass to a structure. Stacking the sand bags 6 to 7 ft high around the perimeter of the fiberboard building took a six-person team about 40 man-hours (Figure 40).

Summary

The results show that the 8-ft building is much easier to construct. Besides the added weight per section and the need for a crane, the 12-ft side-

Figure 37. Wall insulation brackets.

Figure 38. Installation of ceiling insulation.

Figure 39. Fiberboard building with the fabric double roof (third cycle).

Figure 40. Addition of sandbags to fiberboard building (fourth cycle).

wall buildings have the disadvantage of additional component pieces and greater instability because of their size and lack of lateral bracing. A ladder had to be used for all additional tasks for the 12-ft building, but not for the 8-ft building.

Habitability Test Results

The results presented in this section provide interpretion of the weather data collected at Fort Irwin. During the four test cycles, temperatures were recorded in each of the three structures at five different heights. Appendix C provides a sample of the computer output. The extreme temperatures were recorded from these data, and an average of all the temperatures for each day was evaluated. Appendix C lists the data for each of the four cycles.

The collected data were also plotted in two types of graphs to evaluate the relationships between variable conditions, such as comparisons between the control building and the other configurations. The two types of graphs are:

1. Temperatures for all three building and the outdoor temperatures at the 6-ft level.

2. Temperatures of one building and the outdoor temperature at the 1-, 4-, and 8-ft levels. Three graphs are drawn for each day--one for each building.

The temperatures at levels between 4 and 6 ft were chosen for comparison since most occupants will feel the zone between these two levels. Discussion of the data is divided into effects of the following:

1. Ceiling height (12 ft vs 8 ft)

2. Panel material (fiberboard vs metal)

3. More openings or ventilation (14 windows vs four windows)

4. Insulation R17 (ceiling and wall)

5. Double roof (fabric upper roof separated by 1 ft of air space)

6. Rotation of building

7. Increasing mass of the walls.

Effect of Ceiling Height--12 Ft vs 8 Ft

Figure 41 plots temperatures at the 6-ft levels for the control building, the 12-ft-high galvanized building, and the fiberboard building on a typical day. The results indicate that the height of the buildings (12 ft vs 8 ft) did not have much effect on the interior temperatures at the 6-ft level; it is less than 1°C cooler for the 12-ft-high building than for the 8-ft-high control building.

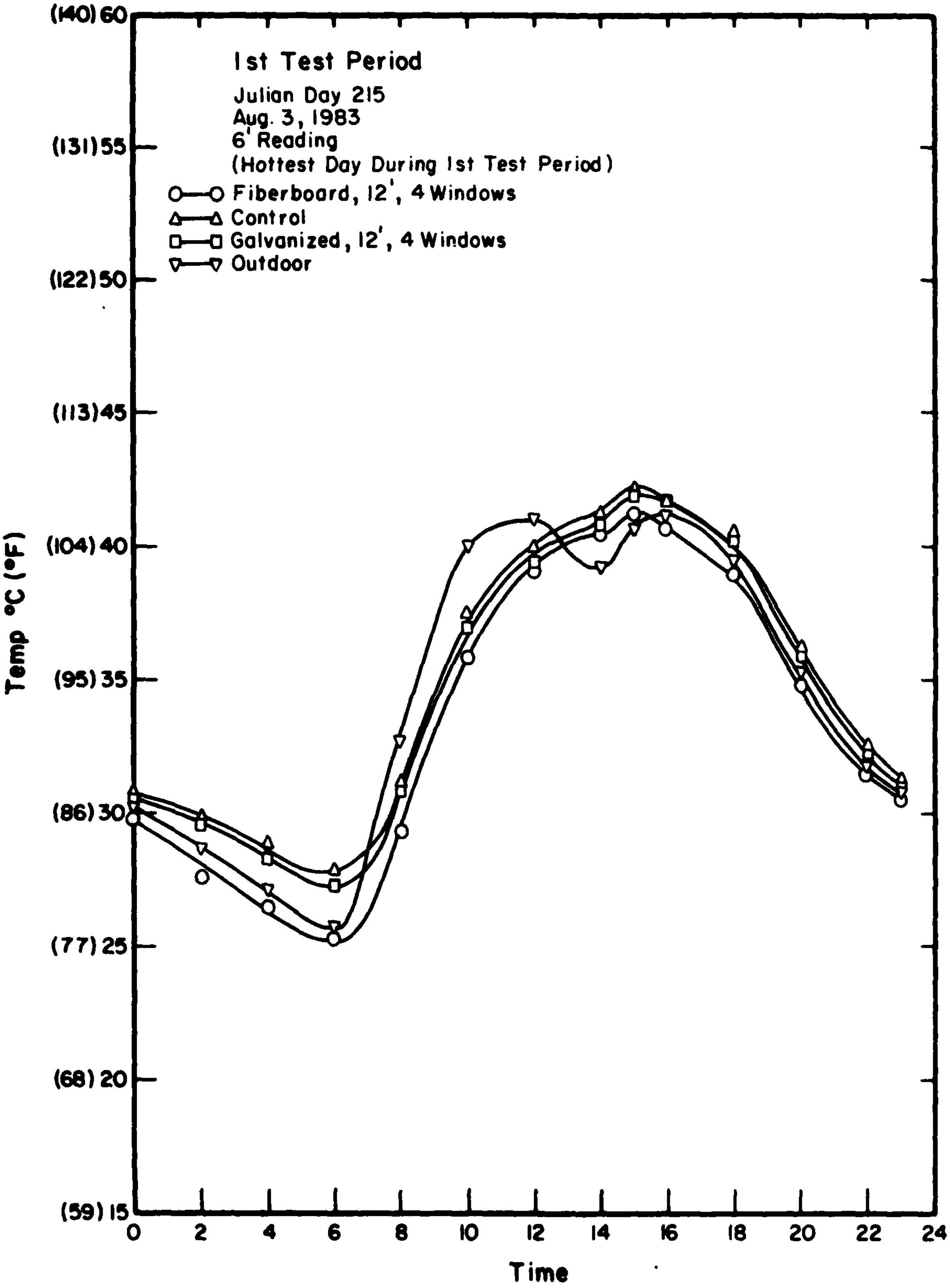

Figure 41. Temperatures at the 6-ft level for the three buildings.

When compared to the outdoor temperature, both the 8-ft and the 12-ft ceiling heights in the galvanized steel buildings were cooler (about 1°C) between 1600 and 2400 hours, and 2° to 3°C warmer between 0000 and 0600 hours.

Effect of Panel Material (Fiberboard vs Metal)

The effect of the panel materials was evaluated from both 8-ft- and 12-ft-high buildings (Figures 41 and 42). The interior temperature of the fiberboard building was only about 1°C cooler than that of the metal building at the 6-ft level between 0800 and 2400 hours, and 2° to 3°C cooler between 0000 and 0700 hours for the 12-ft-high building. However, for the 8-ft-high building, the fiberboard building was about 2° to 3°C cooler throughout much of the day and night except between 0900 and 1800 hours (Figure 42). At this time, the interior temperatures of both the fiberboard and the metal 8-ft-high buildings were about the same.

When compared to the outdoor temperature, the fiberboard building was an average of less than 1°C cooler both day and night except between 0700 and 1200 hours. During these hours, it was 3° to 4°C cooler than the outdoor temperature.

Effect of More Openings and Ventilation

For the 8-ft-high galvanized metal building with 14 windows, the interior temperatures were compared to those of the 8-ft-high control building (Figure 42). The building with more windows seemed to be about 1°C cooler than the control building (four windows) between 1300 and 2000 hours. However, there was not much difference during the rest of the day. As with the control building, the indoor temperatures of both buildings were generally 1° to 3°C warmer than the outdoor temperature, except between 0800 and 1200 hours. During the morning, the outdoor temperature was an average of 1° to 2°C warmer than the indoor temperature.

Effect of Insulation--R17 (Ceiling and Wall)

When insulation was added to the galvanized steel building, heat was trapped above the 8-ft ceiling. As a result, the temperatures above the ceiling were 3°C higher than in the control building between 1000 and 1600 hours (Figure 43). The positive effect of the insulation is evident below the 8-ft ceiling height. The temperatures stayed 7° to 8°C cooler than in the control building during most of the daytime between 0900 and 1800 hours (Figure 44).

These temperature differences became smaller at night. The insulated building was only 1°C cooler than the galvanized steel control building. With the insulation, the building was 1° to 2°C warmer than the outdoor temperature at night and 4° to 5°C cooler in the daytime.

Effect of Double Roof (Fabric Upper Roof Separated by 1-Ft Air Space)

With the fabric double roof on the fiberboard building, the interior was only slightly cooler (1°C) than in the control building at the habitability heights (4 to 6 ft) (Figure 44). The temperatures in the fiberboard building at night and early morning were 3° to 4°C cooler than in the control building, which was about the same as for the fiberboard building without the fabric

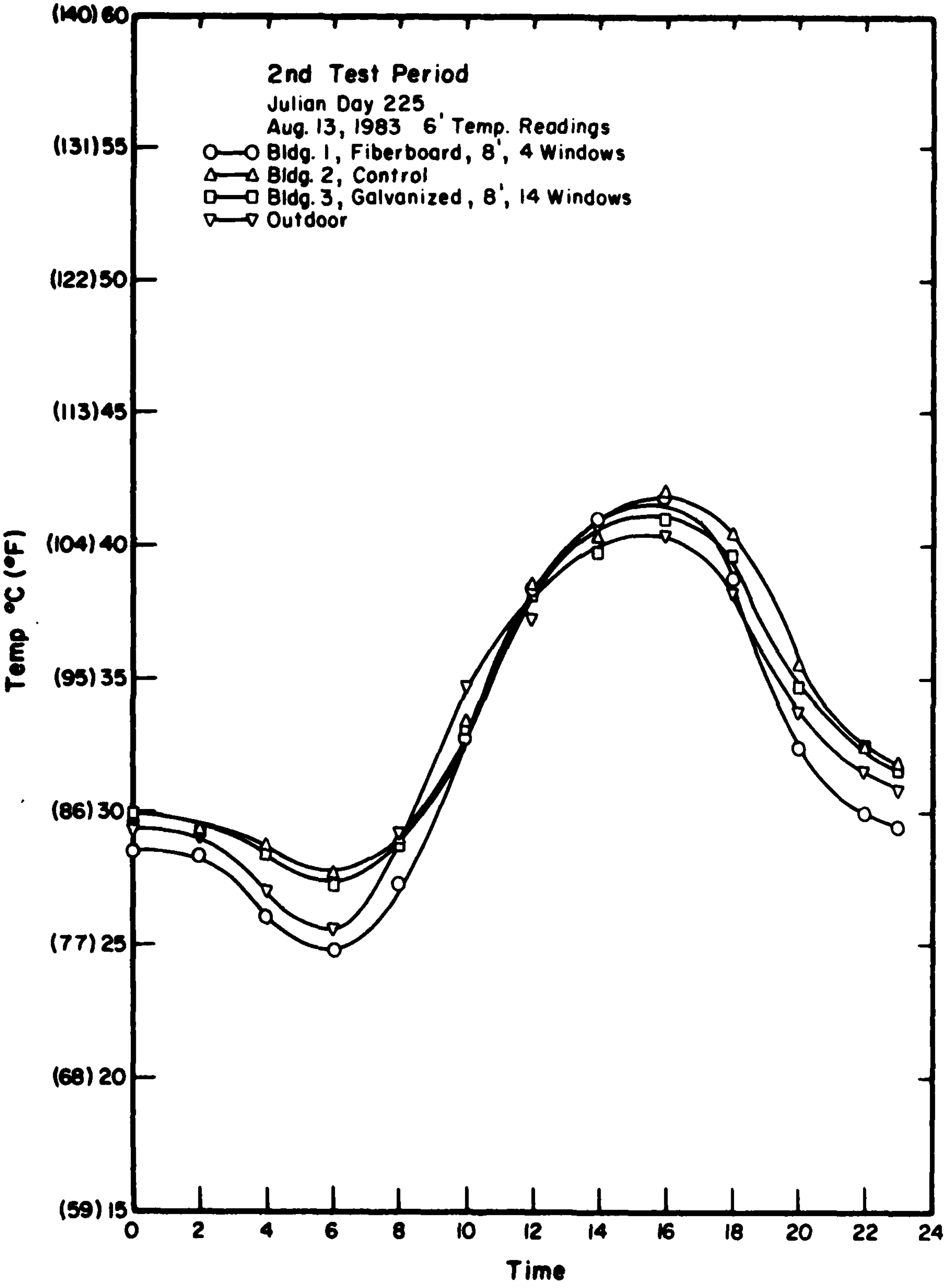

Figure 42. Effect of panel material (fiberboard vs galvanized steel buildings).

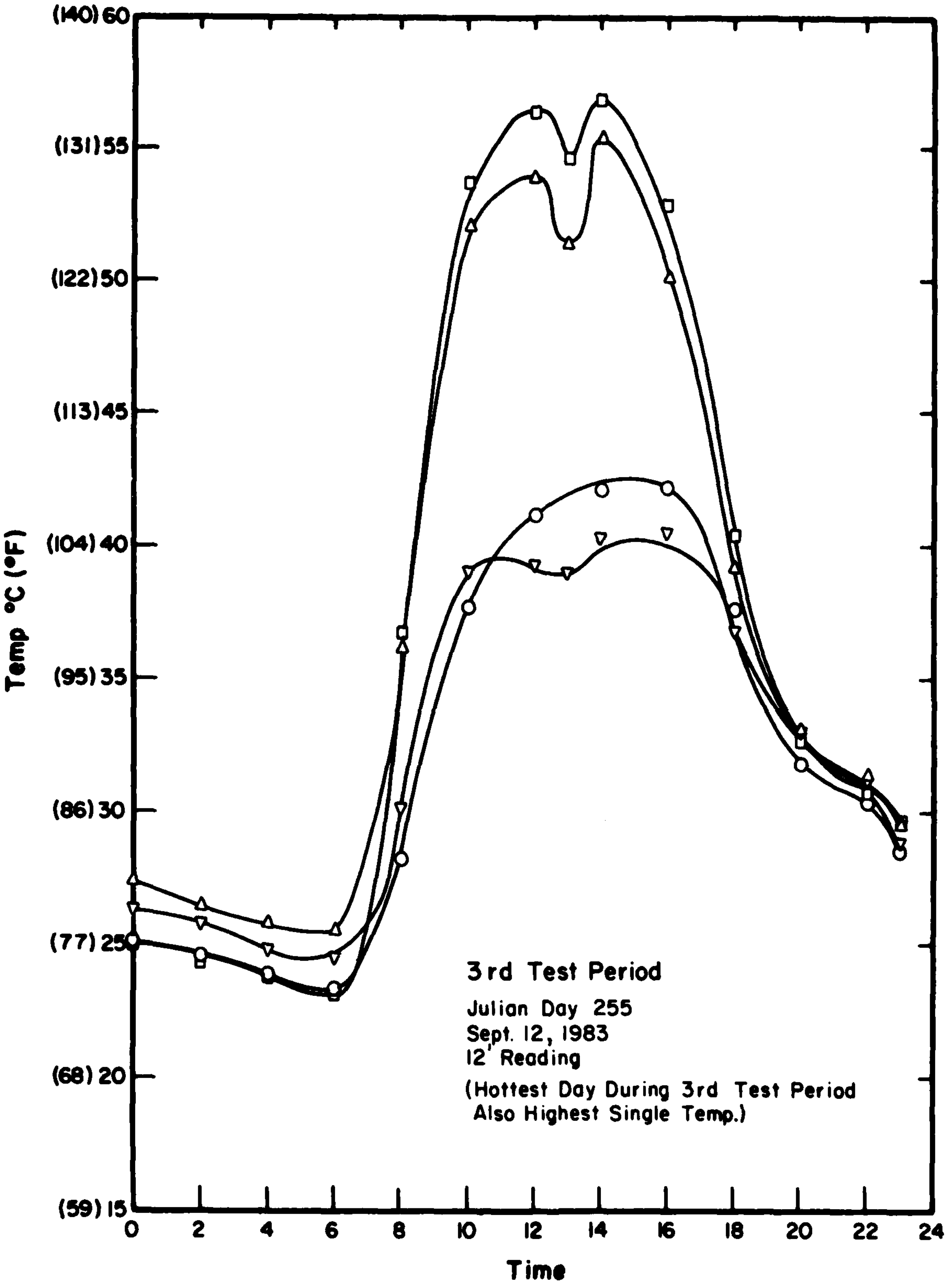

Figure 43. Effect of insulation in the building.

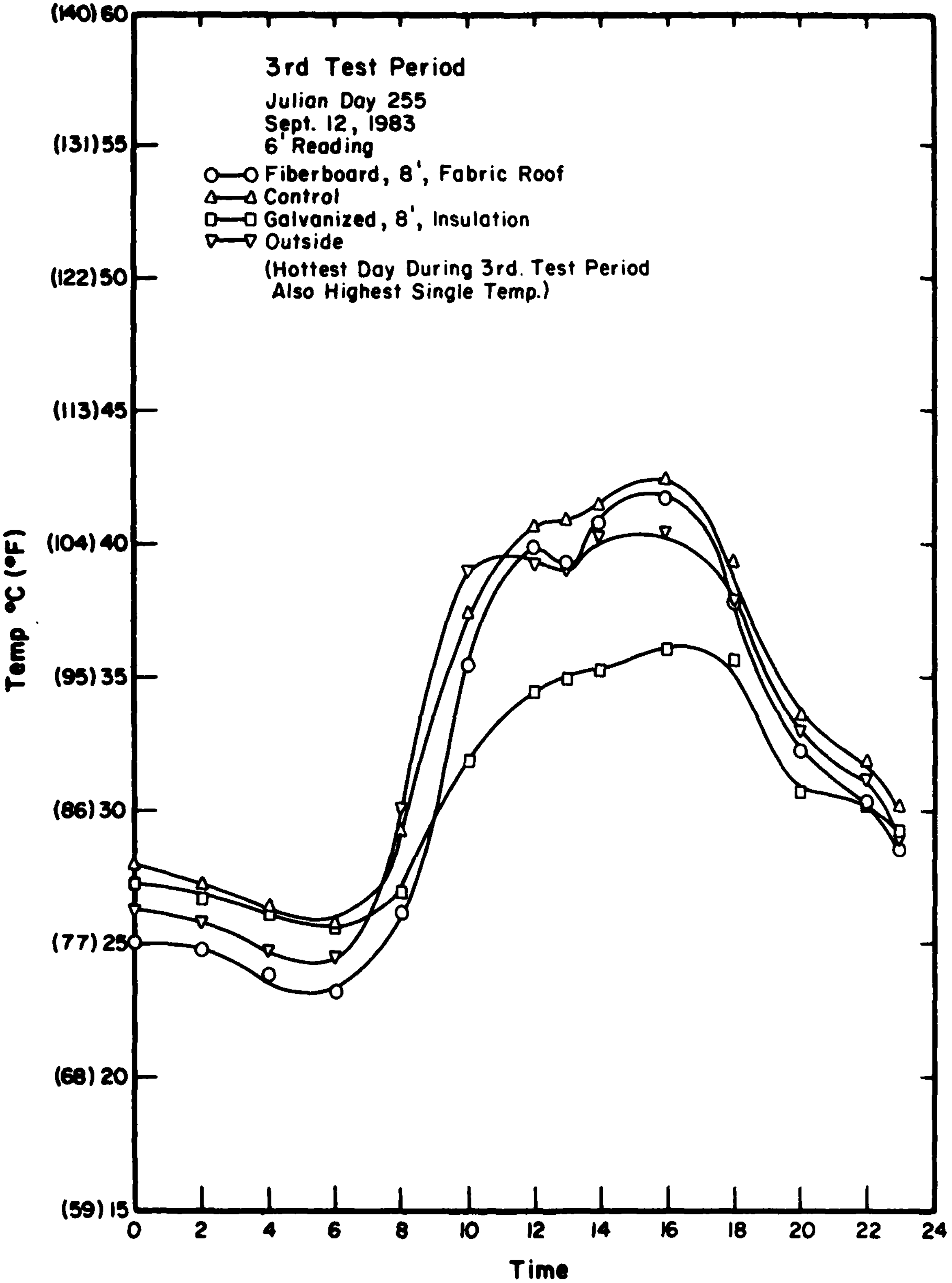

Figure 44. Effect of fabric double roof on building temperatures.

upper roof. Thus, the double fabric has very little effect on a building's interior temperature.

Effect of Building Rotation

To study the effect of building rotation on the interior temperatures, a test building was erected with its long axis perpendicular to the control building's long axis. The long axis of the control building was in an east-west direction. Both the test and the control buildings have a length-to-width ratio of 2 to 1. Figure 44 plots the results. No temperature difference was noted during the daytime; however, at night, the test building (oriented in the north-south direction) was about 1°C cooler than the control building. This might result from the west-to-east wind which prevails at night in the area. Although the building oriented in the north-south direction should theoretically be warmer during the daytime since it should receive more solar radiation, the results did not indicate this to be the case. This could be due to the small-aspect ratio of 2 to 1 used in the test.

Effect of Increasing Walls' Mass

Adding sandbags to the fiberboard building tested the constructibility of a sandbag wall and helped evaluate the effect of the mass around the perimeter. The test results indicated that the wall mass greatly reduced the difference between the night and day temperatures in the building (Figure 45). The difference in night and day temperatures for the control building in a typical 17.5°C (minimum) to 30°C (maximum) day was 14°C (23°F); for the sandbagged building, the difference was reduced by 50 percent to 7°C. During the cool night, the building with the wall mass was also much warmer than both the outdoor temperature and the control building; during the day, it was cooler than the control building.

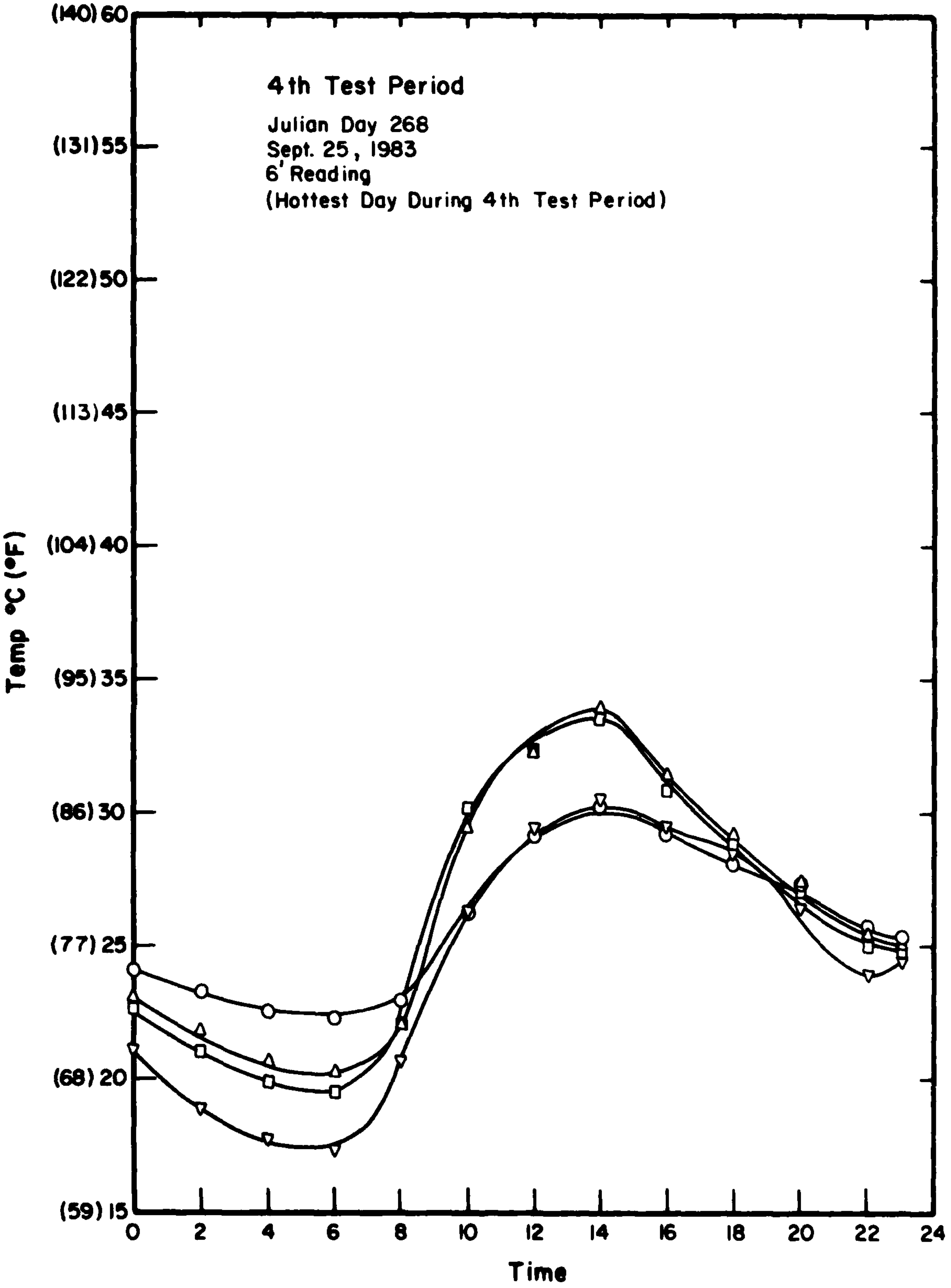

Figure 45. Effect of thermal mass added to building.

5 CONCLUSIONS AND RECOMMENDATIONS

The Fort Irwin experiment confirmed some preliminary assumptions about the Kelly Klosure system's performance in the TO. The results showed that both the fiberboard and the corrugated metal panel systems can satisfactorily fulfill AFCS requirements for both initial and temporary (0 to 24 months) construction. Nevertheless, several improvements are required.

In terms of constructibility, as well as relocatability and transportability, the fiberboard building is better than the galvanized steel system. The fiberboard panels are slightly lighter than the galvanized steel panels, and the fiberboard insert remained cooler than the galvanized steel insert. However, the frames of both panel types became too hot to handle in the desert sun, and working gloves were necessary to handle them. A lighter-colored frame or painting the galvanized panel a lighter color might reduce the heat absorption.

There were large differences in the constructibility of the 8-ft and 12-ft buildings made of 4- x 8-ft panels. The 8-ft buildings were erected easily in considerably less time with no heavy equipment. However, the 12-ft buildings needed additional accessories, and due to the size of each section, required a crane for erection. Putting the 12-ft buildings up manually became too dangerous because the individual sections were unstable. The stiffbacks did not provide any lateral bracing that could reduce side-sway of the section. One possible solution would be to use temporary bracing during erection.

Assembly of the 12-ft building with the crane was slow but steady. However, during disassembly, building sections were unstable, and two or three attempts were required to lower each section. The problem stemmed from 8-ft-wide sections made up of 4- x 8-ft panels. Part of the problem may be alleviated by using 4-ft-wide sections made up of 4- x 12-ft panels.

Erection of the 8-ft buildings during the second test cycle took less time than erecting the similarly configured control building. With the repetition of construction tasks, the number of man-hours required to complete the building was reduced. Erection of the endwalls and midsections went more smoothly when reassembling the 8-ft buildings.

In the area of durability, some of the fiberboard panels lost their polyethylene surface coatings when the wide standard tape was being removed. This problem was eliminated by using embossed vinyl tape with backing and a silicone rubber caulking.

The ground anchors should be made of a stronger steel and have the hole for the eyebolt positioned lower. Although the guy wires did keep the building adequately anchored in the high winds encountered during the testing, such a modification will make installation of the anchors easier. A system which eliminates exterior guy wire bracing would strengthen the total design.

The habitability benefits gained through building modifications made during the testing were greatest from the rigid insulation and the thermal mass of sand bags. The insulation could be installed quickly and greatly reduced the building's interior temperature. The sandbags balanced the temperatures during the day and night by time-lagging the heat transfer through the walls so that the greatest heat transfer occurred long after the outdoor temperature had peaked.

The modifications included in the Fort Irwin field tests also indicated that the performance of the fiberboard panel system can be moderately improved by adding insulation and thermal mass. However, durability of the fiberboard system is not as good as that of the galvanized steel system.

Other improvements could further enhance the system. Use of vinyl-faced insulation sheets might increase the number of useful relocations for each sheet. Changing from standard glass windows to plexiglass could help prevent window breakage, and increasing the number of rivets connecting the fiberboard insert to the frame might increase the panel's durability.

It is recommended that the suggested modifications be made and that the modified systems undergo further field testing before making a final evaluation of this system.

METRIC CONVERSION FACTORS

1 in. = 25.4 cm
1 ft = .3048 m
1 oz = 28.3495g
1 sq yd = .836 m^2
1 mil = .0254 mm
1 lb = .453 kg
1 ton = 1.016 tonne
°C = (°F - 32) (5/9)

APPENDIX A:

KELLY KLOSURE SYSTEM CONSTRUCTION AND ERECTION PROCEDURES

Site Preparation

The construction process begins with site preparation. Enough ground should be leveled for the building baseplate and for structural assembly around the perimeter of the baseplate. The standard dimensions of the Kelly Klosure buildings used are 20 ft, 3-3/4 in. x 40 ft, 5-1/2 in. from the outside of one panel to the outside of the other (Figure A1).

The panel corner connection (Figure A2) shows where the additional length is developed. This creates a true 20- x 40-ft interior area. The baseplate is made up of 2- x 6-in. lumber laid end to end and toenailed at the splices; 10- to 20-ft length lumber may be used (Figure A3). The baseplate is anchored by 18-in. steel stakes, nailed to the wood. These should be spaced 3 ft on center for each piece of lumber (Figure A4).

Different types of baseplates could be used to support the system. These vary from the simple 2- x 6-in. baseplate to a notched concrete slab bordered with wood members (Figure A5).

Other options include a concrete slab base with the 2- x 6-in. baseplate anchor bolted to the slab (Figures A6 and A7). This has the flexibility of the simple 2- x 6-in. baseplate while offering a more usable, permanent floor system.

The construction critical path method for one 20- x 8- x 40-ft building gives a breakdown of the various tasks for erecting the structure. The following sections summarize the manpower and additional equipment requirements for each task.

Erection Procedures

8-Ft Building Section Assembly

The panels are shipped in simple steel angle frames holding 30 panels at each end. They create their own shipping crate of about 3 x 4 x 8 ft or 3 x 4 x 12 ft. The additional building components are either strapped to the panels or packed in smaller containers. Assembly can begin after the panels are separated from the shipping racks.

The first task is to trim the ends of the wooden 20-ft chords and drill 9/16-in.-diameter holes for the bolt connection to the chord bracket (Figure A8) or assemble the steel chords. The procedure outline below requires only the component pieces and does not require any tools beyond a hammer, drift pin, vise grip, 9/16-in. socket, and ratchet. The keys connect the panels and angles, with 9/16-in. nuts and bolts used for the other smaller pieces.

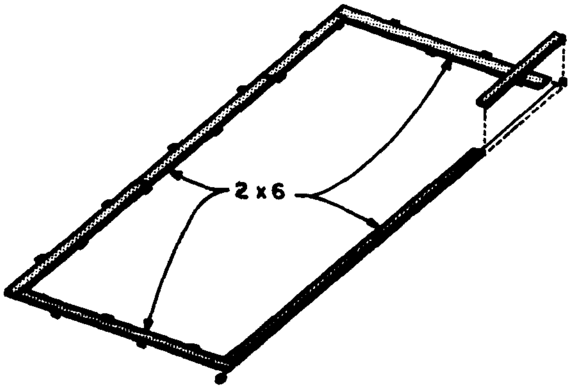

Figure A1. Baseplate layout.

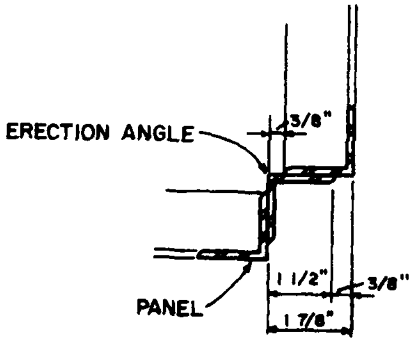

Figure A2. Panel connection.

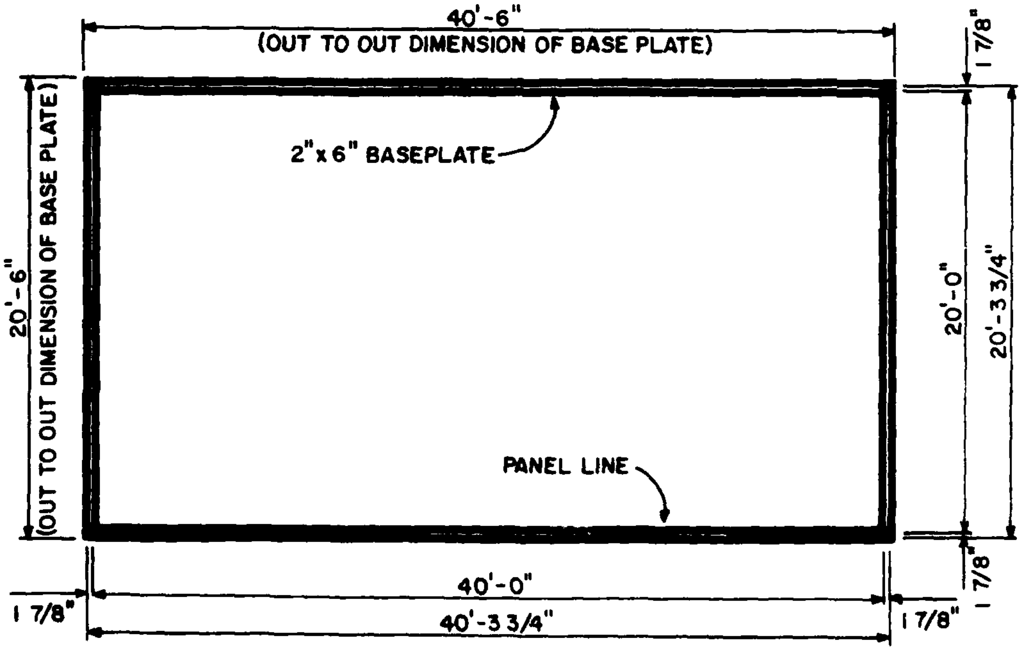

Figure A3. Baseplate detail.

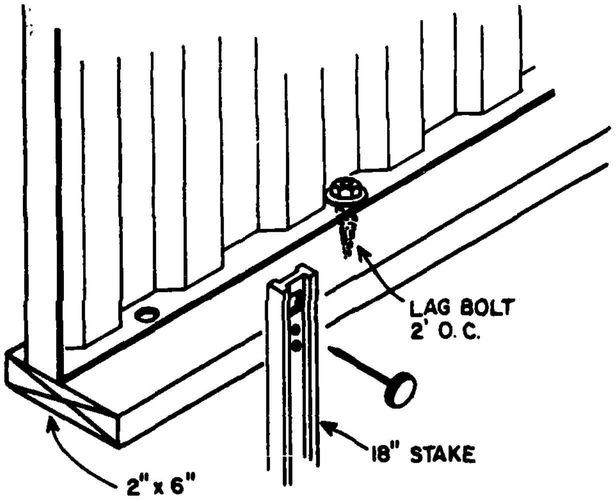

Figure A4. Baseplate used at Fort Irwin.

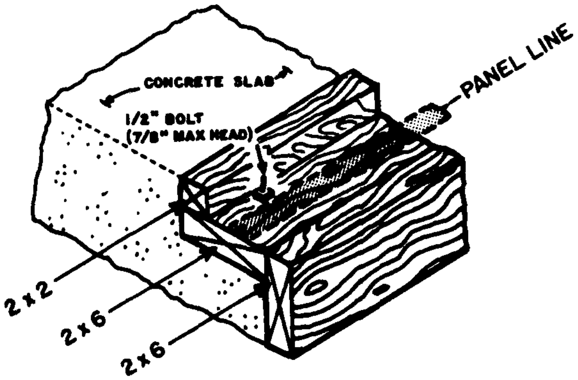

Figure A5. Option 1 for baseplate.

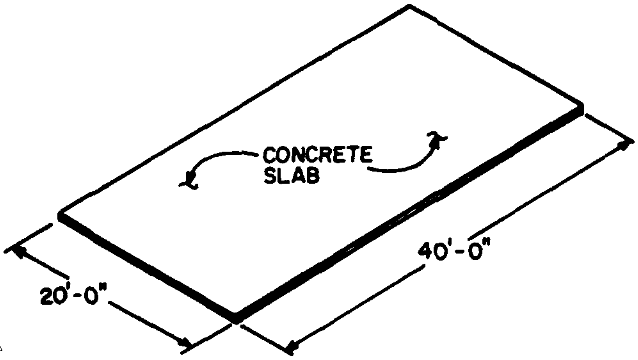

Figure A6. Option 2 floor slab.

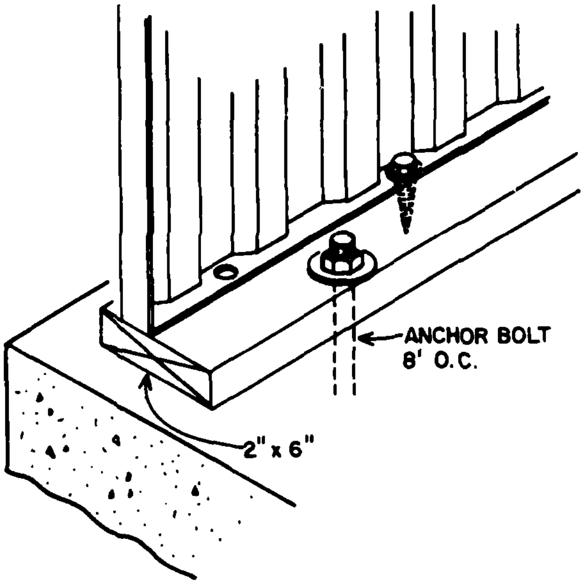

Figure A7. Option 2 baseplate layout.

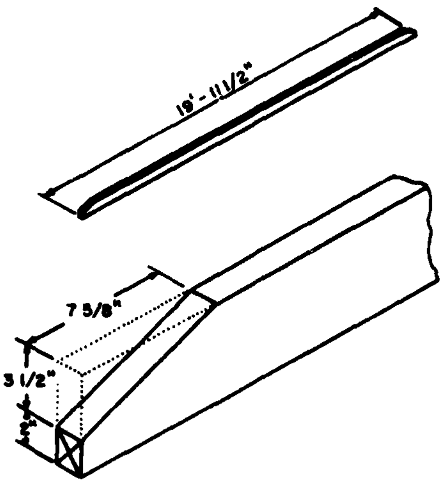

Figure A8. Detail of chord dimensions.

The process for erecting a 20- x 8- x 40-ft building is as follows:

1. Bolt the chord bracket to the eave angle (Figure A9).

2. Finger-tighten the eave angle assemblies to the 4- x 12-ft panels with flat head screws.

3. Key a ridge angle to two 4- x 12-ft panels for a roof section.

4. Attach a precut chord between the two roof panels with two bolts at each end. This may be done for all roof sections in an assembly-line process.

5. Lay out the endwall section at one end of the base plate. This section is made up of four standard 4- x 8-ft panels, a door panel centered in the wall, and two gable panels (Figure A10).

6. Key the endwall panels together, and key erection angles to the sides of the panel group.

7. Attach the roof section and side walls to the endwall panels.

8. Loop guy wires around the corner angles.

For the midsections, key the sidewall panels to the already assembled roof sections. Standard panels may be replaced with window panels in some sections. After the midsections have been erected, the second endwall can be assembled in the same manner as the first one.

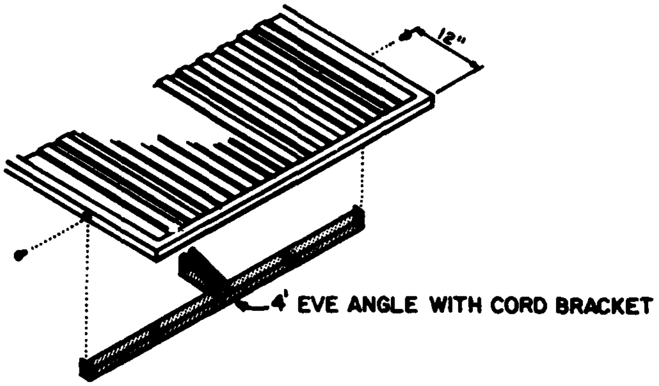

Figure A9. Eave angle connection.

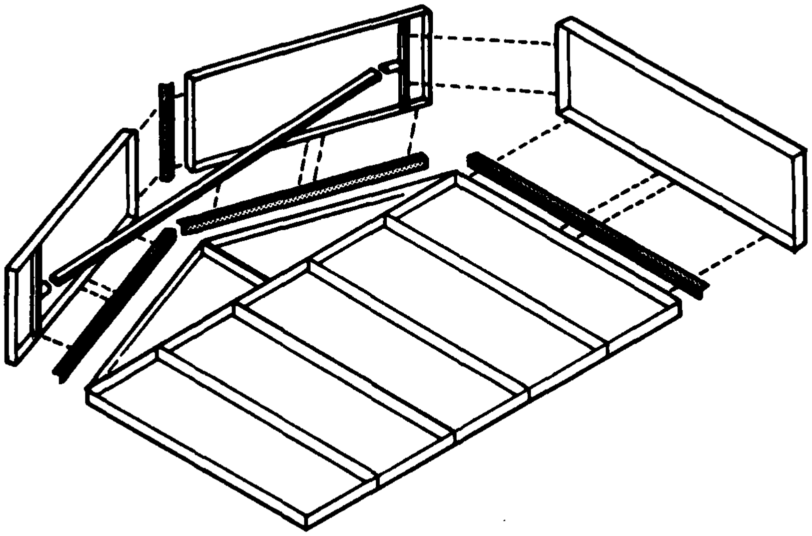

Figure A10. 8-ft endwall layout.

Building Erection

After the sections are assembled, the endwall is erected. A five-person team is needed to "roll up" the endwall section of the galvanized steel building. After it is pushed up, it is centered on the 2- x 6-ft baseplate and lag-bolted into place. Two bolts are used for each panel section. Guy wires must be connected to solidly anchored ground anchors immediately to stabilize the section. The first midsection is then rolled up in the same manner next to the anchored endwall. They are keyed together, beginning at the peak and progressing down the sides. The midsection is then lag-bolted to the baseplate (Figures A4 and A7).

This procedure continues for the remaining seven midsections and the second endwall (Figure A11). (Guy wires are spaced according to the building sidewall height.) Guy wires anchoring the building are checked for tautness, and all seams between panels are sealed with tape (Figure A12). At the corners and along the ridge, caps are placed over the tape to reduce possible leaks in the building (Figures A13 and A14). Foam filler is inserted under the eave to fill the void between panels (Figure A15).

12-Ft Building Section Assembly

The 12-ft building sidewall may be made up of 4- x 12-ft panels or of a group of 4- x 8- ft panels. The latter was used at Fort Irwin. Three 4- x 8-ft panels are combined to create an 8- x 12-ft sidewall. Roof sections are assembled by the same procedure used for the 8-ft building, but are stacked two-high to form an 8-ft-wide roof section and bay. Stiffbacks (2- x 6-in. lumber, 12 ft long) must be used to stabilize the structure. Brackets to hold

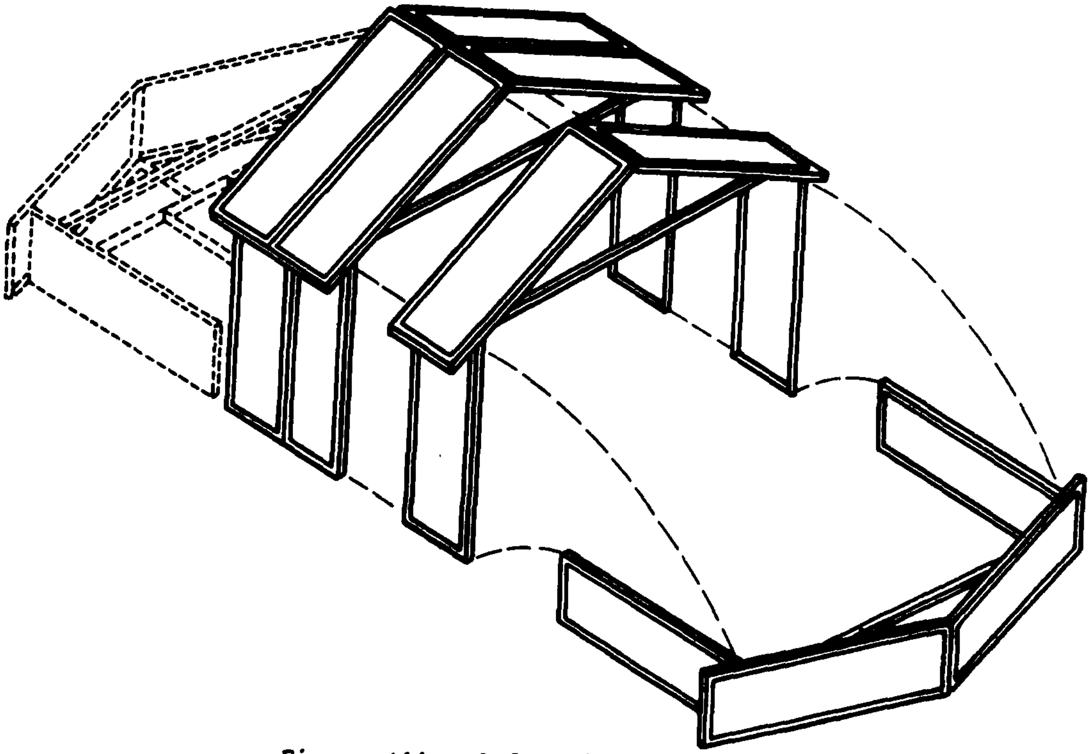

Figure A11. 8-ft building erection.

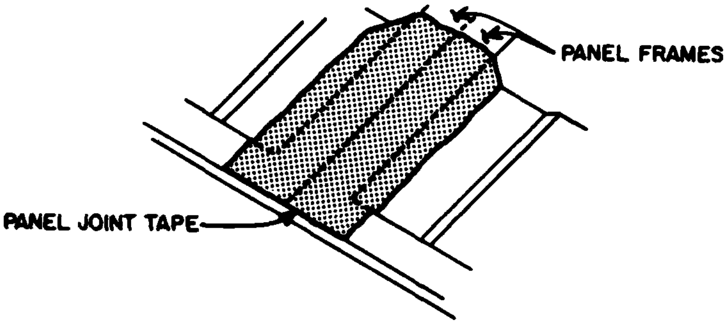

Figure A12. Panel joint taping.

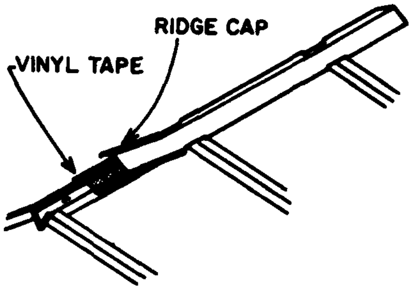

Figure A13. Ridge taping and capping.

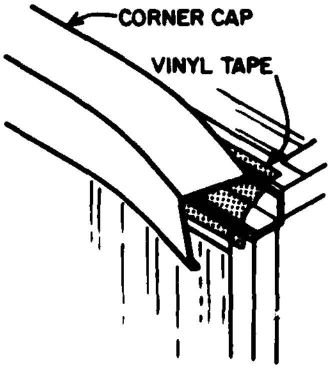

Figure A14. Corner taping and capping.

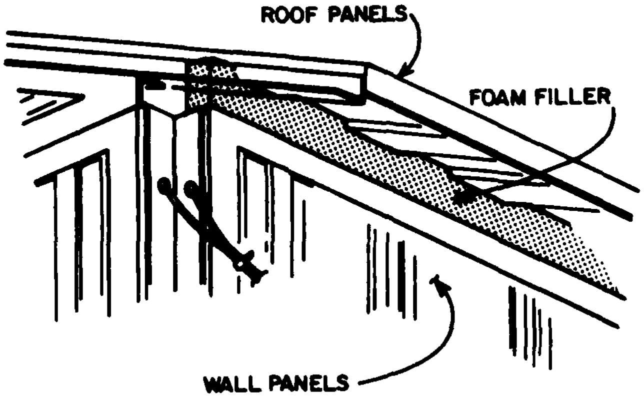

Figure A15. Foam filler insulation.

them are added with the chord brackets to the eave angle (Figure A16). The chord is bolted in the same manner described on p 55 (Figure A17). Stiffbacks are connected later.

The following steps are followed to assemble an endwall:

1. Key together five 4- x 8-ft panels, one door panel, two gable panels, and one 4- x 12-ft panel. These should be assembled at the 20-ft-wide end of the baseplate.

2. Clamp stiffbacks to the panels (Figure A18).

3. Key on the corner angles.

4. Stack two roof sections one on top of the other, and key them together.

5. Attach the new roof section to the endwall panels.

6. Key three 4- x 8-ft panels together to create an 8- x 12-ft sidewall.

7. Key the sidewall panels to the endwall section (Figure A19).

8. Add stiffbacks to the sidewalls and bolt through the stiffback bracket.

9. Loop guy wires around the corner angles.

The midsections are assembled in a comparable manner as follows:

1. Stack two roof sections one on top of the other.

2. Assemble sidewalls composed of three 4- x 8-ft panels on the ground separately. Place window panels according to their location on the blueprints.

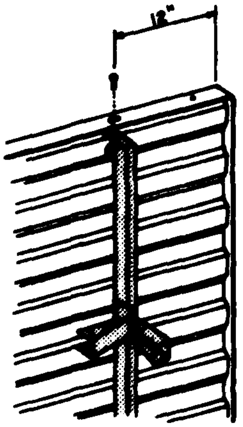

Figure A16. Eave angle connection for 12-ft building.

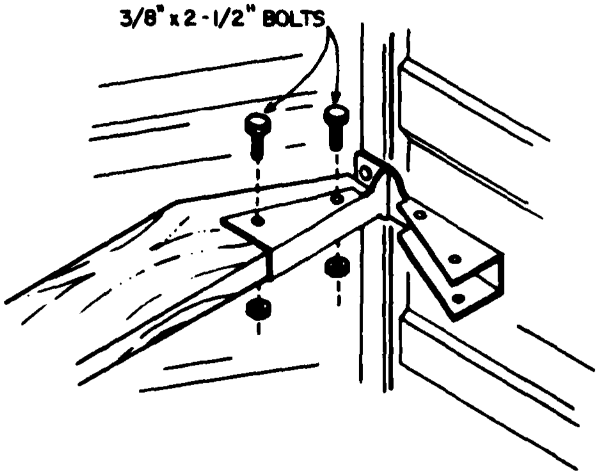

Figure A17. Chord attachment.

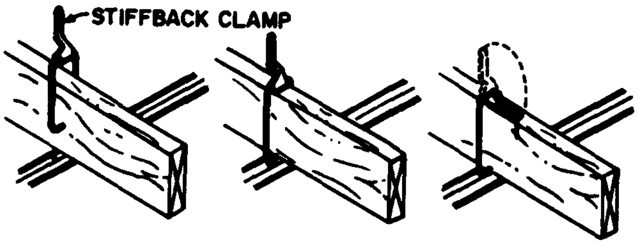

Figure A18. Stiffback clamping procedure.

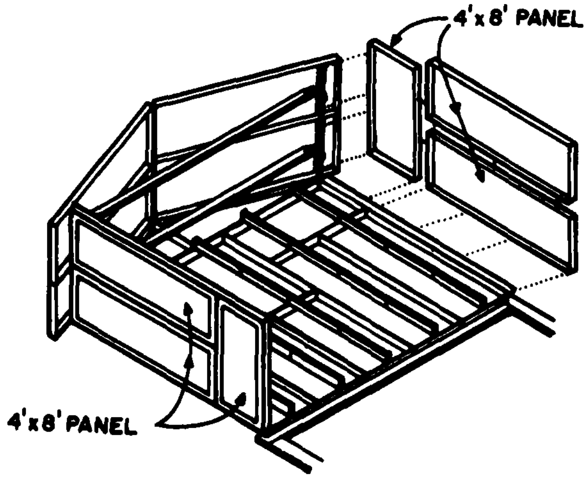

Figure A19. Assembly of 12-ft endwall.

3. Key each sidewall to the composite roof section.

4. Clamp the stiffbacks into place.

5. Hook guy wires over the chord bracket.

This procedure is repeated for the other two sections and for the second endwall. Of the sections assembled, an endwall composed of galvanized panels weighs about 1250 lb, and the midsection weighs 750 lb. Hoisting cables must be added to each section so that a crane can lift it. The increase in height and weight of each section makes it difficult to manually roll up. Thus, although rollup can be done manually, it is not recommended unless absolutely necessary.

Building Erection

Use of a crane is preferable for putting up the 12-ft buildings. The endwall is raised up and guided into place on the baseplate; it is then lag-bolted in place and guy wires added to stabilize the section. The first mid-section is lifted into place next to the endwall and keyed to it beginning at the ridge. It is then lag-bolted to the baseplate (Figure A20). This process continues for the remaining sections and endwall. As was done for the 8-ft building, the seams are taped and caps are added to the corners and building ridge. Foam filler is also inserted into eave voids.

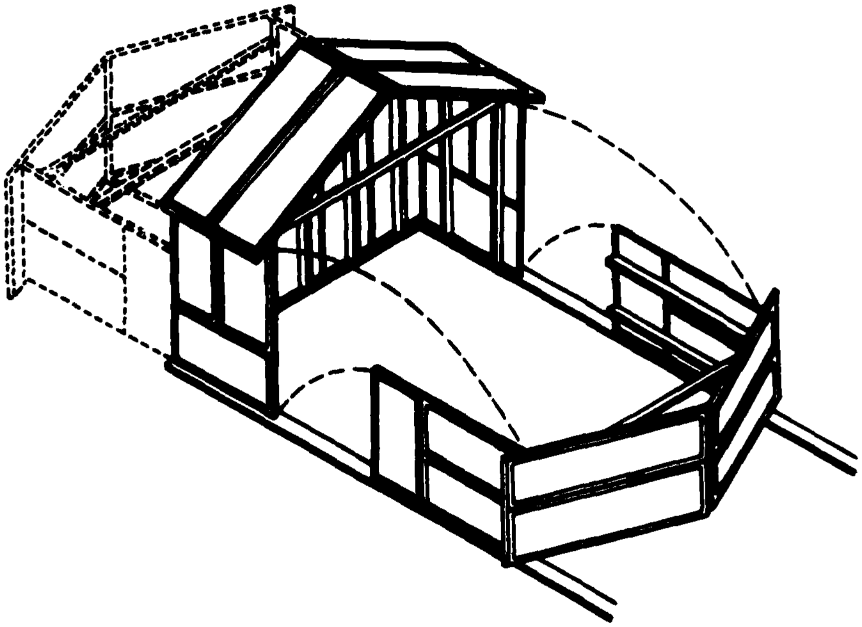

Figure A20. Erection of a 12-ft building.

Equipment Doors

To facilitate moving large objects into the building, a 12-ft-wide x 11-ft, 6-in.-tall equipment door may replace or be added to a standard door (Figure A21). The equipment door is made up of several small panels which are bolted together (Figure A22). The end product is an 11-ft, 6-in. x 12-ft sliding panel door.

Construction CPM

The construction CPM (Figure A23) for one 20- x 8- x 40-ft building gives a breakdown of the various tasks for erecting the structure. A summary of the manpower and additional equipment and tool requirements for each of these tasks follows.

Manpower and Additional Equipment Requirements

The following task list provides: (1) a description of each task, (2) the number of people required to complete the task, and (3) the equipment required to erect a 20- x 40-ft building.

1. 2- x 6-in. chord:

   a. Cut the chords to 20-ft lengths, trim the edges, and drill two holes as shown in Figures A8 and A17.

   b. Crew size: 2.

   c. One electric circular saw and one heavy-duty drill.

2. Ground preparation:

   a. Level the ground and surrounding area for an assembly area and building the baseplate.

   b. Crew size: 2.

   c. One grader and one water truck.

3. Receive building components:

   a. Deliver panels to the site. Remove the shipping racks frame from the truck.

   b. Crew size: 4.

   c. Forklift.

4. Building site layout:

   a. Lay out parallel lines with 50-ft string and establish the corner angle with a Kelly Klosure panel.

   b. Crew size: 2.

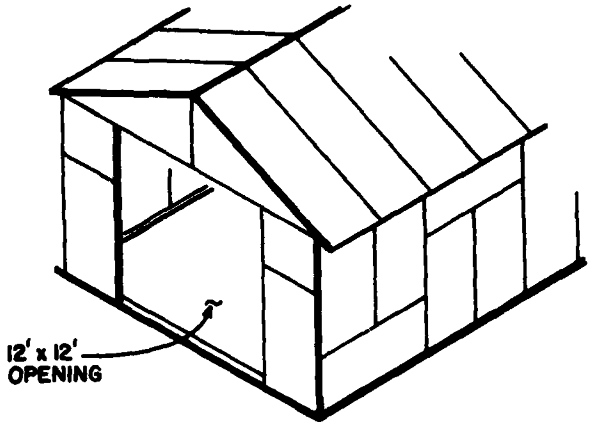

Figure A21. Equipment door opening.

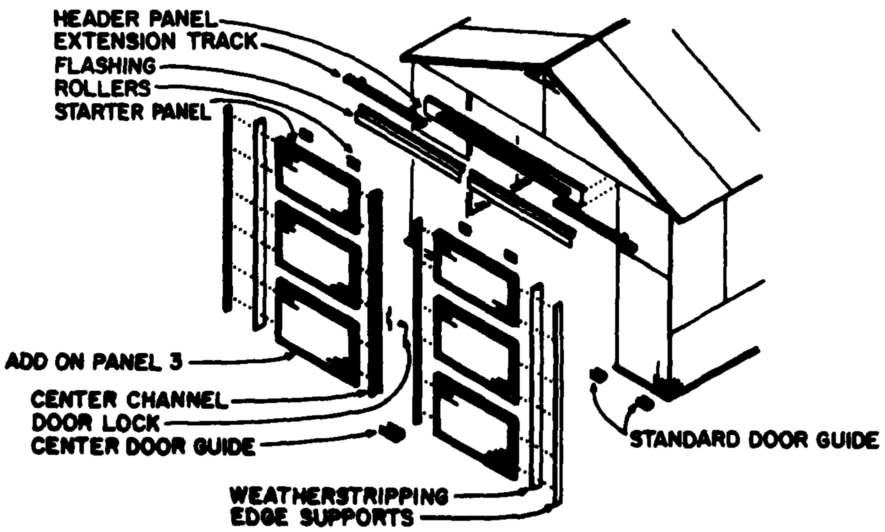

Figure A22. Equipment door assembly.

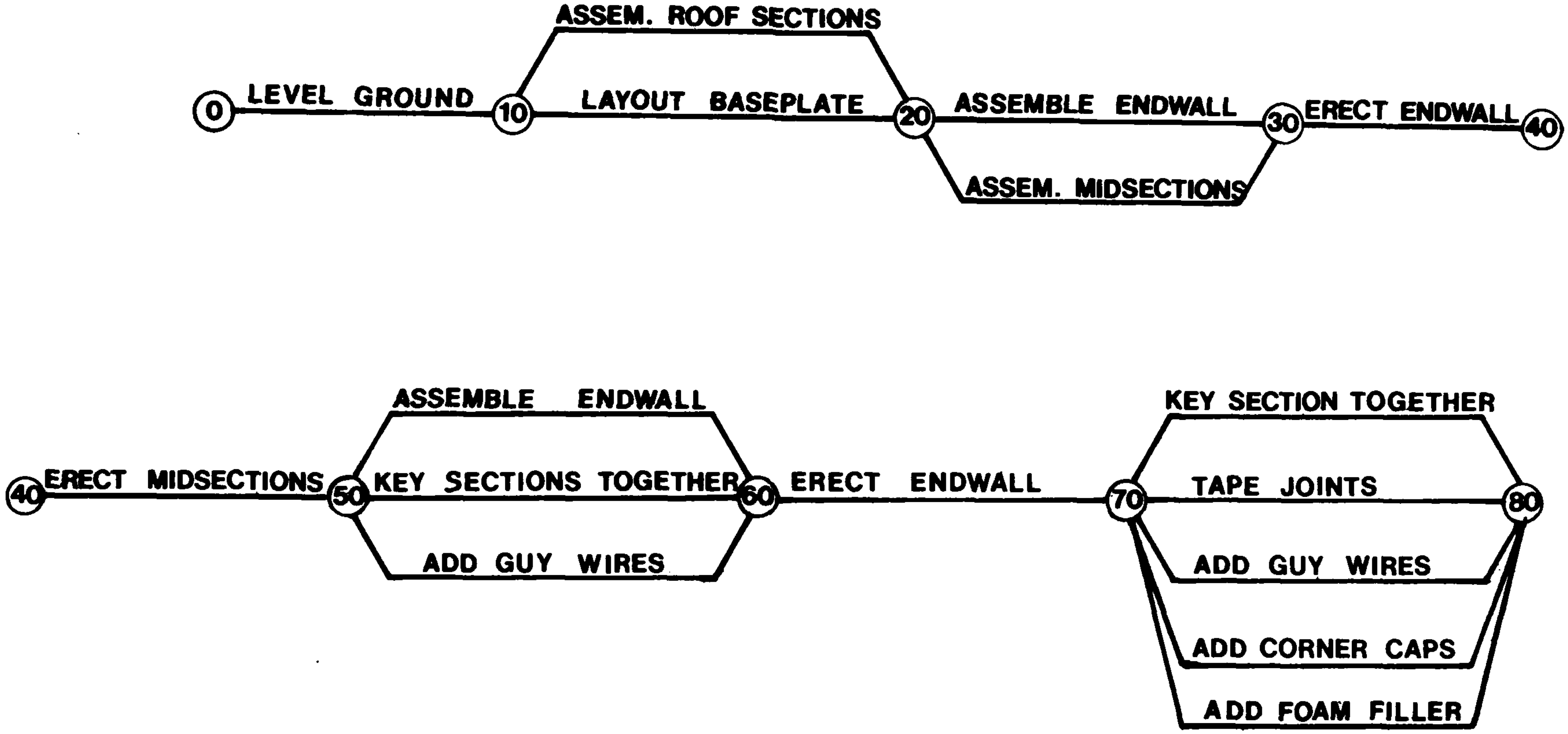

Figure A23. 20- x 8- 40-ft test structure construction CPM.

5. Assemble sections:

a. Bolt eave angles and chord brackets. Finger-tighten bolt eave angle to roof section, key roof sections together, and key in the side-walls.

b. Crew size: 3 teams of 2 people.

6. Building erection--endwall:

a. Roll up the endwall using 2- x 4-in. or 2- x 6-in. lumber to guide the ridge and position the building on the correct spot on the baseplate.

b. Crew size: 6.

7. Building erection--midsections:

a. Roll up midsections, lag-bolt them to baseplate, and key them to neighboring panels along the gable roof and the side walls.

b. Crew size: 6 (5 to roll up building, and 1 to key roof sections together).

8. Louver installation:

a. Bolt the louvers into place, with the louvers opening outward.

b. Crew size: 2.

c. Two 10-ft stepladders.

9. Corner caps:

a. Install corner caps, trimming them when necessary, around the guy wires.

b. Crew size: 1.

10. Ridge cap:

a. Install the ridge cap over the ridge panel frames. Trim end to eliminate any overhang.

b. Crew size: 1

11. Seam tape:

a. Tape or caulk all seams between panels. Tape or caulk over the corner and ridge caps.

b. Crew size: 1.

APPENDIX B:

BUILDING TEMPERATURE COMPARISONS

Temperature Differentials between Test Buildings, Exterior and Control Bldg.

TEST CYCLE 1

	EXTERIOR	CONTROL		BLDG #1		BLDG. #3		
DAY	TEMP AVG.	TEMP AVG.	DELTA EXT.	DELTA T EXT.	DELTA T CNTRL	DELTA T EXT.	DELTA T CNTRL	SOLAR AVG.
JULY 29								
0000-6000	23.8	25.6	1.8	-0.7	-2.5	1.4	-0.4	0.001
0600-1200	32.1	32.3	0.2	-2.6	-2.8	-0.2	-0.3	0.606
1200-1800	38.7	40.1	1.4	0.1	-1.3	1.4	-0.1	0.816
1800-2400	32.0	33.7	1.7	-1.1	-2.8	1.7	-0.0	0.038
JULY 30								
0000-6000	26.7	28.4	1.7	-0.8	-2.5	1.4	-0.3	0.000
0600-1200	31.7	32.7	0.9	-0.8	-1.7	0.8	-0.2	0.463
1200-1800	36.0	38.6	2.6	1.1	-1.5	1.8	-0.8	0.644
1800-2400	31.4	32.9	1.5	-1.1	-2.6	1.1	-0.4	0.017
JULY 31								
0000-6000	26.5	28.2	1.8	-0.6	-2.3	1.3	-0.5	0.001
0600-1200	34.0	34.0	-0.0	-1.9	-1.9	-0.2	-0.2	0.557
1200-1800	40.0	41.1	1.1	0.3	-0.9	0.9	-0.3	0.725
1800-2400	34.5	35.0	0.5	-0.6	-1.1	0.4	-0.1	0.045
AUG. 1								
0000-6000	27.4	29.2	1.8	-0.6	-2.5	1.4	-0.4	0.000
0600-1200	34.5	35.0	0.5	-1.2	-1.7	0.4	-0.1	0.506
1200-1800	32.9	35.7	2.8	1.0	-1.8	1.9	-0.9	0.534
1800-2400	29.1	31.6	2.5	-0.2	-2.7	1.9	-0.6	0.031
AUG. 2								
0000-6000	24.0	26.8	2.8	-0.2	-3.0	1.9	-0.9	0.000
0600-1200	32.5	33.0	0.6	-1.3	-1.9	0.4	-0.2	0.566
1200-1800	38.9	40.7	1.7	0.8	-0.9	1.6	-0.1	0.725
1800-2400	33.8	34.5	0.8	-0.5	-1.3	0.7	-0.1	0.026
AUG. 3								
0000-6000	27.9	29.4	1.5	-0.7	-2.1	1.0	-0.5	0.000
0600-1200	36.1	34.5	-1.6	-3.3	-1.7	-2.1	-0.5	0.563
1200-1800	40.4	41.2	0.9	-0.0	-0.9	0.7	-0.2	0.765
1800-2400	33.9	34.8	0.9	-0.4	-1.3	0.5	-0.3	0.033
AUG. 4								
0000-6000	27.4	29.1	1.7	-0.7	-2.4	1.2	-0.6	0.000
0600-1200	33.3	34.0	0.7	-1.9	-2.6	0.3	-0.4	0.572
1200-1800	39.9	41.1	1.2	0.1	-1.0	1.1	-0.1	0.786
1800-2400	34.8	35.8	1.0	-0.9	-1.9	0.9	-0.1	0.035
AUG. 5								
0000-6000	28.9	30.4	1.5	-0.8	-2.3	1.3	-0.3	0.001
0600-1200	35.8	36.1	0.3	-1.9	-2.2	0.2	-0.1	0.566
1200-1800	42.2	43.9	1.8	0.7	-1.1	1.8	-0.0	0.761
1800-2400	36.4	37.5	1.2	-0.8	-2.0	1.3	0.1	0.035

BLDG. #1: 20'x 12'x 40' FIBERBOARD WITH 4 WINDOWS
BLDG. #3: 20'x 12'x 40' GALVANIZED WITH 4 WINDOWS

Test Cycle 1 (continued)

	EXTERIOR	CONTROL		BLDG #1		BLDG. #3		
DAY	TEMP	TEMP	DELTA	DELTA T		DELTA T		SOLAR
	AVG.	AVG.	EXT.	EXT.	CNTRL	EXT.	CNTRL	AVG.
AUG. 6								
0000-6000	30.5	31.9	1.5	-0.6	-2.1	1.1	-0.4	0.000
0600-1200	36.1	36.4	0.2	-1.6	-1.8	0.2	-0.1	0.521
1200-1800	38.4	40.0	1.6	0.8	-0.8	1.3	-0.4	0.545
1800-2400	32.7	33.7	1.0	-0.3	-1.3	0.8	-0.2	0.028
AUG. 7								
0000-6000	24.4	26.9	2.5	0.5	-2.0	1.5	-1.0	0.000
0600-1200	30.3	31.8	1.5	-0.0	-1.5	1.0	-0.5	0.492
1200-1800	34.6	37.2	2.6	1.8	-0.9	2.4	-0.3	0.602
1800-2400	30.4	32.2	1.7	-0.1	-1.9	1.3	-0.5	0.021

BLDG. #1: 20'x 12'x 40' FIBERBOARD WITH 4 WINDOWS
BLDG. #3: 20'x 12'x 40' GALVANIZED WITH 4 WINDOWS

TEST CYCLE 2

	EXTERIOR	CONTROL		BLDG #1		BLDG #3		
DAY	TEMP	TEMP	DELTA	DELTA T		DELTA T		SOLAR
	AVG.	AVG.	EXT.	EXT.	CNTRL	EXT.	CNTRL	AVG.
AUG. 13								
0000-0600	27.8	29.0	1.1	-0.8	-1.9	0.9	-0.2	0.000
0600-1200	32.7	32.6	-0.1	-1.3	-1.2	-0.4	-0.3	0.395
1200-1800	39.4	41.0	1.6	1.4	-0.2	0.7	-0.9	0.728
1800-2400	33.2	34.6	1.4	-1.2	-2.6	1.1	-0.3	0.030
AUG. 14								
0000-0600	29.5	30.7	1.1	-1.0	-2.1	0.9	-0.2	0.000
0600-1200	33.8	33.9	0.0	-1.0	-1.1	-0.1	-0.2	0.346
1200-1800	38.6	40.7	2.1	1.7	-0.4	1.4	-0.7	0.615
1800-2400	30.9	31.7	0.7	-0.2	-0.9	0.3	-0.4	0.008
AUG. 15								
0000-0600	25.9	27.6	1.7	0.1	-1.6	1.0	-0.8	0.000
0600-1200	30.0	31.8	1.8	0.3	-1.5	0.9	-0.9	0.494
1200-1800	30.6	33.1	2.5	1.1	-1.3	1.3	-1.1	0.336
1800-2400	29.0	30.4	1.4	-0.3	-1.7	0.7	-0.7	0.011
AUG. 16								
0000-0600	26.9	28.1	1.2	-0.4	-1.6	0.8	-0.5	0.000
0600-1200	28.0	29.9	1.9	0.3	-1.6	1.2	-0.8	0.184
1200-1800	24.0	26.7	2.7	1.1	-1.5	1.6	-1.0	0.244
1800-2400	22.9	25.2	2.3	0.5	-1.8	1.8	-0.5	0.012
AUG. 17								
0000-0600	22.4	24.7	2.3	0.4	-1.8	1.7	-0.5	0.000
0600-1200	23.3	25.8	2.5	0.7	-1.7	1.9	-0.6	0.161
1200-1800	23.1	25.5	2.5	0.9	-1.5	1.7	-0.8	0.200
1800-2400	22.2	23.7	1.5	0.3	-1.2	1.1	-0.4	0.005
AUG. 18								
0000-0600	21.0	22.7	1.7	0.5	-1.2	1.3	-0.4	0.000
0600-1200	21.2	22.7	1.5	0.4	-1.1	1.1	-0.4	0.075
1200-1800	23.5	25.7	2.2	1.0	-1.1	1.5	-0.6	0.367
1800-2400	20.3	22.0	1.7	0.7	-1.0	1.1	-0.6	0.003
AUG. 19								
0000-0600	19.8	21.7	1.9	0.5	-1.3	1.3	-0.5	0.000
0600-1200	20.8	21.9	1.1	0.2	-0.9	0.5	-0.6	0.115
1200-1800	20.7	21.9	1.2	0.4	-0.9	0.6	-0.7	0.131
1800-2400	20.6	21.7	1.1	-0.0	-1.1	0.6	-0.5	0.007
AUG. 20								
0000-0600	18.8	20.1	1.3	-0.3	-1.6	0.7	-0.6	0.000
0600-1200	22.9	23.8	0.8	-0.6	-1.4	-0.4	-1.2	0.416
1200-1800	27.7	31.4	3.7	2.2	-1.5	1.5	-2.2	0.729
1800-2400	24.0	25.1	1.1	-0.7	-1.9	-0.0	-1.2	0.019

BLDG. #1: 20'x 8'x 40' FIBERBOARD WITH 4 WINDOWS
BLDG. #3: 20'x 8'x 40' GALVANIZED WITH 14 WINDOWS

Test Cycle 2 (continued)

	EXTERIOR	CONTROL		BLDG #1		BLDG #3		
DAY	TEMP AVG.	TEMP AVG.	DELTA EXT.	DELTA T EXT.	CNTRL	DELTA T EXT.	CNTRL	SOLAR AVG.
AUG. 21								
0000-0600	19.8	20.8	1.0	-0.5	-1.5	0.2	-0.8	0.000
0600-1200	25.7	24.8	-0.9	-2.4	-1.4	-2.3	-1.3	0.508
1200-1800	30.1	32.0	1.9	0.8	-1.2	-0.2	-2.1	0.719
1800-2400	24.3	25.2	0.9	-1.3	-2.2	-0.2	-1.1	0.025
AUG. 22								
0000-0600	19.0	20.7	1.7	-1.0	-2.7	0.6	-1.1	0.000
0600-1200	26.1	24.9	-1.2	-3.3	-2.1	-2.8	-1.6	0.530
1200-1800	29.7	32.0	2.4	0.8	-1.5	0.4	-2.0	0.756
1800-2400	24.0	25.5	1.5	-1.5	-3.0	0.3	-1.2	0.026
AUG. 23								
0000-0600	19.2	21.2	2.0	-1.6	-3.6	0.8	-1.2	0.000
0600-1200	25.4	27.1	1.7	-1.4	-3.1	-0.2	-1.9	0.527
1200-1800	30.7	33.5	2.8	1.0	-1.7	0.8	-2.0	0.749
1800-2400	25.1	26.6	1.5	-1.6	-3.0	0.2	-1.2	0.024
AUG. 24								
0000-0600	20.5	22.2	1.7	-1.6	-3.3	0.6	-1.0	0.000
0600-1200	27.6	27.1	-0.5	-2.8	-2.3	-2.0	-1.5	0.518
1200-1800	31.5	33.9	2.4	0.9	-1.5	0.6	-1.8	0.736
1800-2400	26.7	27.9	1.2	-1.9	-3.1	0.1	-1.1	0.022
AUG. 25								
0000-0600	20.6	22.7	2.2	-1.9	-4.1	1.0	-1.2	0.000
0600-1200	27.0	28.5	1.4	-1.2	-2.6	-0.1	-1.5	0.512
1200-1800	32.8	35.5	2.7	1.1	-1.5	0.8	-1.9	0.732
1800-2400	26.6	28.5	1.9	-2.0	-3.9	0.5	-1.5	0.022
AUG. 26								
0000-0600	21.4	23.2	1.8	-1.9	-3.7	0.8	-1.0	0.000
0600-1200	28.9	29.8	0.9	-1.8	-2.7	-0.5	-1.4	0.515
1200-1800	35.2	37.9	2.7	0.8	-1.9	0.7	-2.0	0.737
1800-2400	28.3	29.8	1.5	-2.4	-3.9	0.1	-1.4	0.022
AUG. 27								
0000-0600	24.2	25.3	1.1	-2.7	-3.8	0.3	-0.9	0.000
0600-1200	31.3	31.9	0.5	-2.0	-2.5	-0.8	-1.3	0.494
1200-1800	38.0	39.5	1.5	0.7	-0.9	-0.2	-1.7	0.724
1800-2400	31.7	32.0	0.3	-1.3	-1.6	-0.4	-0.6	0.022
AUG. 28								
0000-0600	26.4	27.2	0.7	-2.1	-2.8	0.0	-0.7	0.000
0600-1200	33.7	32.8	-0.9	-3.3	-2.5	-2.2	-1.3	0.500
1200-1800	37.7	39.0	1.3	0.3	-0.9	-0.5	-1.8	0.717
1800-2400	30.6	31.1	0.5	-1.3	-1.8	0.1	-0.5	0.020

BLDG. #1: 20'x 8'x 40' FIBERBOARD WITH 4 WINDOWS
BLDG. #3: 20'x 8'x 40' GALVANIZED WITH 14 WINDOWS

TEST CYCLE 3

	EXTERIOR	CONTROL		BLDG #1		BLDG #3		
DAY	TEMP AVG.	TEMP AVG.	DELTA EXT.	DELTA T EXT.	CNTRL	DELTA T EXT.	CNTRL	SOLAR AVG.
SEPT. 3								
0000-0600	26.6	27.9	1.3	-0.4	-1.6	0.6	-0.6	0.000
0600-1200	32.0	31.8	-0.2	-2.0	-1.8	-3.4	-3.2	0.487
1200-1800	38.4	38.6	0.1	-0.8	-0.9	-3.2	-3.4	0.696
1800-2400	30.0	31.1	1.1	-0.2	-1.3	-0.1	-1.2	0.016
SEPT. 4								
0000-0600	23.8	25.9	2.1	-0.2	-2.3	2.0	-0.0	0.000
0600-1200	29.8	31.3	1.5	-0.9	-2.4	-1.2	-2.7	0.495
1200-1800	36.0	39.1	3.1	1.4	-1.7	-3.1	-6.2	0.697
1800-2400	27.7	30.4	2.7	-0.4	-3.1	0.6	-2.1	0.015
SEPT. 5								
0000-0600	23.8	25.6	1.8	-0.9	-2.7	1.6	-0.2	0.000
0600-1200	30.1	31.3	1.3	-1.1	-2.3	-1.7	-2.9	0.489
1200-1800	37.1	39.2	2.1	0.5	-1.5	-3.5	-5.5	0.699
1800-2400	30.6	31.7	1.2	-0.6	-1.8	-0.9	-2.1	0.014
SEPT. 6								
0000-0600	25.2	27.0	1.7	-0.9	-2.7	1.2	-0.6	0.000
0600-1200	31.7	32.4	0.7	-1.7	-2.5	-2.7	-3.4	0.493
1200-1800	37.4	39.3	1.9	0.7	-1.2	-3.9	-5.8	0.691
1800-2400	30.9	32.0	1.1	-0.5	-1.6	-1.0	-2.1	0.013
SEPT. 7								
0000-0600	26.3	27.9	1.6	-0.5	-2.0	0.8	-0.8	0.000
0600-1200	31.4	31.6	0.2	-1.4	-1.6	-2.8	-3.0	0.469
1200-1800	35.9	37.7	1.8	0.9	-0.9	-3.2	-5.0	0.665
1800-2400	29.0	30.3	1.3	0.1	-1.2	-0.2	-1.5	0.009
SEPT. 8								
0000-0600	24.5	26.1	1.5	0.1	-1.5	1.4	-0.2	0.000
0600-1200	30.9	30.3	-0.6	-2.0	-1.4	-3.4	-2.8	0.473
1200-1800	35.8	36.4	0.6	-0.2	-0.8	-3.0	-3.7	0.647
1800-2400	29.3	30.2	1.0	-0.2	-1.2	-0.1	-1.1	0.011
SEPT. 9								
0000-0600	24.2	26.2	2.0	-0.2	-2.2	2.0	-0.0	0.000
0600-1200	32.7	31.3	-1.4	-2.8	-1.3	-4.3	-2.9	0.476
1200-1800	37.1	37.6	0.5	-0.2	-0.7	-3.9	-4.4	0.605
1800-2400	30.6	31.3	0.8	-0.6	-1.4	-1.1	-1.9	0.008
SEPT. 10								
0000-0600	27.6	28.3	0.7	-0.6	-1.3	-0.3	-1.0	0.000
0600-1200	31.2	32.1	0.9	-0.5	-1.5	-1.9	-2.8	0.346
1200-1800	36.8	39.6	2.9	1.8	-1.1	-2.9	-5.7	0.618
1800-2400	29.7	31.6	1.9	-0.4	-2.2	-0.3	-2.2	0.014

BLDG. #1: 20'x 8'x 40' FIBERBOARD WITH A FABRIC ROOF
BLDG. #3: 20'x 8'x 40' GALVANIZED WITH INSULATION

Test Cycle 3 (continued)

	EXTERIOR	CONTROL		BLDG #1		BLDG #3		
				DELTA T		DELTA T		
DAY	TEMP AVG.	TEMP AVG.	DELTA EXT.	EXT.	CNTRL	EXT.	CNTRL	SOLAR AVG.
SEPT. 11								
0000-0600	25.1	26.7	1.6	-0.7	-2.3	1.2	-0.4	0.000
0600-1200	33.4	33.6	0.2	-1.6	-1.8	-3.3	-3.5	0.469
1200-1800	38.2	41.1	2.8	1.7	-1.1	-3.4	-6.3	0.659
1800-2400	30.0	31.9	1.8	-0.5	-2.3	-0.3	-2.2	0.010
SEPT. 12								
0000-0600	25.0	26.8	1.8	-0.9	-2.7	1.4	-0.4	0.000
0600-1200	33.6	33.9	0.3	-1.6	-1.9	-3.7	-4.0	0.465
1200-1800	39.5	41.4	1.9	0.9	-0.9	-3.8	-5.7	0.680
1800-2400	32.0	33.1	1.1	-0.5	-1.7	-0.7	-1.9	0.010
SEPT. 13								
0000-0600	24.9	27.4	2.5	-0.3	-2.8	2.2	-0.3	0.000
0600-1200	32.2	33.0	0.9	-1.2	-2.0	-2.3	-3.2	0.462
1200-1800	38.8	40.5	1.7	0.7	-1.0	-3.6	-5.3	0.648
1800-2400	31.0	32.4	1.5	-0.6	-2.1	-0.5	-2.0	0.009
SEPT. 14								
0000-0600	25.4	27.7	2.3	-0.5	-2.8	1.9	-0.5	0.000
0600-1200	31.6	32.6	1.1	-1.3	-2.3	-2.0	-3.0	0.440
1200-1800	39.2	40.8	1.6	0.7	-0.8	-4.1	-5.7	0.640
1800-2400	30.2	32.1	1.9	-0.7	-2.7	-0.1	-2.0	0.008
SEPT. 15								
0000-0600	26.0	27.9	1.9	-0.4	-2.3	1.3	-0.6	0.000
0600-1200	31.8	33.0	1.1	-1.0	-2.1	-2.2	-3.4	0.451
1200-1800	38.0	40.6	2.7	1.4	-1.2	-3.2	-5.9	0.627
1800-2400	30.9	32.4	1.5	-0.9	-2.4	-0.7	-2.2	0.007
SEPT. 16								
0000-0600	25.0	27.4	2.4	-0.1	-2.4	2.0	-0.3	0.000
0600-1200	29.6	31.2	1.6	-0.3	-1.9	-1.0	-2.6	0.443
1200-1800	36.9	38.8	2.0	1.0	-0.9	-3.0	-5.0	0.610
1800-2400	31.7	32.5	0.8	-0.7	-1.5	-0.9	-1.8	0.007
SEPT. 17								
0000-0600	25.0	27.2	2.2	-0.3	-2.5	1.9	-0.3	0.000
0600-1200	30.6	31.1	0.5	-0.9	-1.5	-2.5	-3.0	0.447
1200-1800	37.5	38.9	1.4	1.0	-0.3	-3.1	-4.4	0.623
1800-2400	30.4	31.2	0.8	0.0	-0.8	-0.2	-1.0	0.006
SEPT. 18								
0000-0600	24.4	26.6	2.2	-0.4	-2.6	2.3	0.1	0.000
0600-1200	30.1	31.0	0.9	-1.1	-2.0	-1.7	-2.5	0.454
1200-1800	37.4	38.2	0.8	0.4	-0.4	-2.9	-3.7	0.626
1800-2400	29.4	30.2	0.8	0.2	-0.6	0.1	-0.7	0.006

BLDG. #1: 20'x 8'x 40' FIBERBOARD WITH A FABRIC ROOF
BLDG. #3: 20'x 8'x 40' GALVANIZED WITH INSULATION

TEST CYCLE 4

	EXTERIOR	CONTROL		BLDG #1		BLDG #3		
DAY	TEMP AVG.	TEMP AVG.	DELTA EXT.	DELTA T EXT.	DELTA T CNTRL	DELTA T EXT.	DELTA T CNTRL	SOLAR AVG.
SEPT. 24								
0000-0600	18.5	21.0	2.4	4.0	1.6	2.0	-0.5	0.000
0600-1200	25.2	25.9	0.6	-1.0	-1.6	0.7	0.1	0.442
1200-1800	28.4	32.8	4.4	0.6	-3.8	4.1	-0.3	0.605
1800-2400	22.8	25.5	2.7	2.7	-0.0	2.2	-0.5	0.004
SEPT. 25								
0000-0600	18.5	21.4	2.9	4.6	1.7	2.2	-0.7	0.000
0600-1200	24.4	26.6	2.3	1.0	-1.3	2.4	0.1	0.426
1200-1800	29.5	32.1	2.6	0.0	-2.6	2.2	-0.4	0.431
1800-2400	25.5	26.5	1.0	1.0	-0.0	0.6	-0.4	0.002
SEPT. 26								
0000-0600	23.3	24.0	0.7	1.2	0.6	0.5	-0.2	0.000
0600-1200	21.7	23.4	1.7	1.9	0.2	1.4	-0.3	0.122
1200-1800	24.1	27.1	3.0	1.3	-1.7	2.4	-0.7	0.411
1800-2400	20.8	22.8	1.9	2.7	0.7	1.4	-0.6	0.001
SEPT. 27								
0000-0600	15.8	19.1	3.3	5.4	2.1	2.6	-0.7	0.000
0600-1200	20.7	23.4	2.7	1.8	-0.9	2.9	0.2	0.395
1200-1800	25.8	31.1	5.3	1.3	-4.0	5.1	-0.1	0.596
1800-2400	21.5	24.0	2.5	2.5	0.0	2.1	-0.4	0.003
SEPT. 28								
0000-0600	18.2	19.8	1.6	2.9	1.3	1.4	-0.2	0.000
0600-1200	21.5	22.3	0.8	0.2	-0.6	0.7	-0.0	0.334
1200-1800	26.1	29.3	3.3	0.2	-3.1	2.8	-0.4	0.522
1800-2400	20.0	21.4	1.5	2.3	0.9	0.9	-0.5	0.002
SEPT. 29								
0000-0600	16.6	18.6	2.0	3.4	1.4	1.5	-0.5	0.000
0600-1200	19.2	20.3	1.0	1.1	0.0	1.0	-0.0	0.270
1200-1800	22.0	23.6	1.7	0.9	-0.7	1.2	-0.5	0.495
1800-2400	15.8	17.9	2.0	3.5	1.4	1.6	-0.4	0.003
SEPT. 30								
0000-0600	14.3	16.6	2.3	4.1	1.8	1.8	-0.5	0.000
0600-1200	18.0	21.0	3.0	2.1	-0.9	3.3	0.4	0.348
1200-1800	21.2	22.8	1.7	0.4	-1.3	1.2	-0.4	0.225
1800-2400	17.1	18.6	1.5	2.4	0.9	1.2	-0.2	0.001
OCT. 1								
0000-0600	15.0	16.1	1.1	2.8	1.6	1.1	-0.0	0.000
0600-1200	16.5	18.8	2.4	2.0	-0.4	2.2	-0.2	0.350
1200-1800	20.7	23.1	2.4	0.5	-1.9	1.9	-0.5	0.441
1800-2400	16.1	17.7	1.6	2.3	0.7	1.2	-0.4	0.002

BLDG. #1: 20'x 8'x 40' FBR. BD.; CEIL'G INSUL., SANDBAGS, & FAB. ROOF
BLDG. #3: 20'x 8'x 40' GALVANIZED ROTATED 90'

Test Cycle 4 (continued)

	EXTERIOR	CONTROL		BLDG #1		BLDG #3		
DAY	TEMP AVG.	TEMP AVG.	DELTA EXT.	DELTA T EXT.	CNTRL	DELTA T EXT.	CNTRL	SOLAR AVG.
OCT. 2								
0000-0600	12.8	15.1	2.3	3.6	1.3	1.7	-0.6	0.000
0600-1200	19.5	20.1	0.7	-1.3	-1.9	0.8	0.1	0.423
1200-1800	23.5	27.4	3.9	-0.4	-4.3	3.4	-0.6	0.548
1800-2400	16.5	19.5	2.9	2.7	-0.2	2.4	-0.6	0.002
OCT. 3								
0000-0600	13.1	15.9	2.7	3.6	0.8	2.2	-0.5	0.000
0600-1200	18.8	21.1	2.3	0.3	-2.0	2.8	0.5	0.415
1200-1800	24.3	27.9	3.6	0.1	-3.6	3.4	-0.2	0.560
1800-2400	17.9	20.4	2.5	2.2	-0.3	2.0	-0.5	0.002
OCT. 4								
0000-0600	13.4	16.3	2.9	3.9	0.9	2.2	-0.7	0.000
0600-1200	21.0	22.9	1.9	-0.7	-2.5	2.3	0.5	0.403
1200-1800	26.5	29.4	2.9	-0.5	-3.4	2.9	-0.0	0.524
1800-2400	21.3	22.6	1.4	0.8	-0.6	1.0	-0.3	0.001
OCT. 5								
0000-0600	15.5	17.0	1.5	2.4	0.9	1.2	-0.3	0.000
0600-1200	18.7	19.7	0.9	0.2	-0.7	0.8	-0.2	0.250
1200-1800	22.9	25.6	2.6	-0.6	-3.2	2.1	-0.5	0.429
1800-2400	17.3	19.8	2.6	2.4	-0.2	2.0	-0.6	0.001
OCT. 6								
0000-0600	14.0	16.6	2.6	3.4	0.8	2.2	-0.5	0.000
0600-1200	19.3	21.1	1.8	-0.3	-2.1	2.1	0.3	0.315
1200-1800	25.7	29.3	3.6	-1.1	-4.8	3.4	-0.2	0.503
1800-2400	20.5	22.3	1.8	0.8	-1.0	1.2	-0.6	0.001
OCT. 7								
0000-0600	18.5	20.0	1.5	1.5	-0.1	1.1	-0.5	0.000
0600-1200	20.6	21.8	1.2	0.0	-1.2	1.2	-0.0	0.172
1200-1800	25.0	27.9	2.9	-0.9	-3.7	2.6	-0.3	0.403
1800-2400	18.9	20.9	2.1	1.8	-0.3	1.5	-0.6	0.001
OCT. 8								
0000-0600	15.8	18.1	2.3	2.8	0.5	1.8	-0.5	0.000
0600-1200	21.6	23.6	2.0	-0.5	-2.5	2.6	0.6	0.398
1200-1800	26.6	29.9	3.2	-0.8	-4.1	3.1	-0.1	0.484
1800-2400	21.1	22.7	1.6	0.9	-0.7	1.2	-0.4	0.001
OCT. 9								
0000-0600	17.7	19.2	1.5	1.9	0.4	1.2	-0.3	0.000
0600-1200	22.6	23.2	0.6	-1.4	-2.0	0.7	0.2	0.380
1200-1800	26.5	28.4	2.0	-0.9	-2.9	1.6	-0.4	0.475
1800-2400	20.1	21.5	1.4	1.3	-0.1	0.9	-0.5	0.001

BLDG. #1: 20'x 8'x 40' FBR. BD.; CEIL'G INSUL., SANDBAGS, & FAB. ROOF
BLDG. #3: 20'x 8'x 40' GALVANIZED ROTATED 90'

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