TIME STUDIES ON A COMPONENT HOUSE

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Research Report 60-2
UNIVERSITY OF ILLINOIS
SMALL HOMES COUNCIL-
BUILDING RESEARCH COUNCIL
TIME STUDY OF A COMPONENT HOUSE

Research Report 60-2

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This publication is a report of time study performed by the University of Illinois Small Homes Council - Building Research Council pursuant to an agreement for cooperative investigation between the University and the Lumber Dealers Research Council and the Plywood Fabricator Service, Inc.

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ERRATA

Page A-5  Line 1 should read:
Beam #5 (B6) - 15'-11" x 11 5/8"

Page A-10 Line 35 should read:
Beam #14 (B1A) - 23'-11" x 15 5/8"

Page A-18 Last two lines should read:
Elapsed time for 27 pieces:  4 minutes 25 seconds
Average man-minutes for 27 pieces: 8.8 minutes

Page A-22 Line 7 should read:
II. Gable ends - over-hang - 16'-1" x 1'-7½"

Page A-27 Line 22 should read:
Average time per panel: 51 man-minutes

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INTRODUCTION

This report is a discussion and presentation of a time study of a research house designed to demonstrate the use of many components. The house was conceived and sponsored by three organizations—the Douglas Fir Plywood Association, the Lumber Dealers Research Council, and the Plywood Fabricators Service, Inc. The Small Homes Council—Building Research Council was engaged in making time studies in the prefabrication and field assembly of these component units.

In order that a number of different component systems could be tried, the house was divided into three distinct sections: (1) living-dining-informal room wing; (2) bedroom wing; and (3) the foyer-kitchen section which served as a connecting element between sections (1) and (2). The separate garage formed a fourth element. (See Plan 1.)

The house design incorporated a number of new components, as well as components which have been used successfully for several years. The floor system used throughout the house was composed of floor panels supported by box beams. This system is a new design by the Douglas Fir Plywood Association. The bedroom wing and foyer of the house were constructed over a crawl space; the living room and kitchen areas were both built over a basement.

The major portion of the walls of the house made use of the wall-panel framing system developed by the Small Homes Council—Building Research Council in cooperative investigation carried on with the Lumber Dealers Research Council. Some variations were made in the bedroom wing to accommodate slight plan discrepancies. In the living room wing, large panels were used in some areas so that sliding glass doors could be installed. Also, a number of special wall panels were used in forming one end of the living section.

In the bedroom wing the nail-glued king-post truss developed by the Small Homes Council—Building Research Council was used. In the living room, new cathedral beams and roof panels designed by the Douglas Fir...
Plywood Association were used to give an open ceiling with exposed decorative beams. Flat stressed-skin roof panels formed the roof section over the kitchen and foyer.

A rigid-frame structure was used for the garage.

Since concrete work was completed before the SHC-BRC began these time studies, no data were collected on foundation placement and preparation. The time study was concerned chiefly with the fabrication and erection of the various wood and plywood components. As the number of components in the roof structure of the foyer-kitchen area of the house was relatively small, no data were collected on fabrication and erection of this section.

The floor panels, wall panels, and king-post trusses were fabricated by the Thompson Lumber Company of Champaign, Illinois. The larger components (box beams, rigid frames, large cathedral beams, and roof panels) were fabricated by Walco, Inc., of Chesterton, Indiana.

**METHOD OF TIME STUDY**

The times recorded for the various operations and reported in this study are essentially the fabrication and erection times only, although in some instances they do include the times for conferences and discussions about the particular component being fabricated or erected at the moment.

Time for coffee breaks, pauses, posing for photography, instructions from the supervisor concerning other projects, and other lost time, was not counted as production time. It should be made completely clear that times reported do not represent payroll hours, and that payroll hours would be larger due to the lost time mentioned above. Some of these special times are recorded in the Appendix.
The floor system used throughout the house was composed of preformed sections which were carried on plywood box beams spaced 24'-6" on centers. The basic floor panel size was 24'-6" square. The beam spacing varied from 1'-9" to 3'-2" to allow a flexible arrangement of rooms and use in the house. The two plywood sheathing panels were 3/8" exterior-type A-C or C-C grade Douglas Fir plywood Association grade-marked plywood. The plywood was glued to each side of the solid-wood framing material (Figs. 2, 3).

Stiffeners were placed every four feet along the length of the beams (Fig. 2). The stiffeners were designed in 8" spaced soffit and consisted of 1-3/8" x 4-1/2" lumber for the stem of the beam with a 3/8" x 4-1/2" plywood top. The plywood section of the stiffener was used as a splice plate. Gluing was done with casein glue. Staples or ring-shank nails were used for the nailing—clamping operations, except for the beams near the basement recreation area where 4d casing nails were used.

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**PLAN I — GENERAL PLAN**
I. FLOOR SYSTEM

The floor system used throughout the house was composed of panelized sections which were carried on plywood box beams spaced at 4'-0" intervals. The basic floor panel size was 4' x 8'.

BOX BEAMS

The supporting box beams varied in dimension and in detail depending upon their location and use in the house. (See Plan #2.)

Description of Box Beams

Flanges of all beams were single or double 1-5/8" x 3-1/2" continuous members ripped from scaffolding-grade Douglas Fir. Edges were planed prior to assembly. The process of ripping and planing from larger material was performed to assure a more uniform lumber width. (Scaffolding-grade lumber is, of course, stress-graded; but it is only stress-graded for the middle third of the length of the piece. Also, by ripping the lumber it is possible to devaluate the stress grade, since conceivably it could result in defects occurring in improper areas of the cross section.)

The two plywood webs were 3/8" exterior-type A-C or C-C grade Douglas Fir Plywood Association grade-marked plywood. The plywood was nail-glued to each side of the solid-wood framing material (Figs. 2,3).

Stiffeners were placed every four feet along the length of the beam (Fig. 2). The stiffeners were designed in a "T" shape, and were composed of 1-5/8" x 3-1/8" lumber for the stem of the "T" with a 3/8" x 4-1/2" plywood top. The plywood section of the stiffener served also as a splice plate for the web.

Gluing was done with casein glue. Staples or ring-shank nails were used for the nailing-clamping operations, except for the beams over the basement recreation area where 4d casing nails were used.
PLAN 2 - SHOWING FLOOR BEAMS
The beams for the bedroom area were 11-7/8" deep by 23'-11" long. These beams were supported at each end and at the mid-point.

Beams over the major part of the basement were 15-7/8" deep by 23'-11" long, and were designed to span the entire basement without central supports.

Fabrication of Box Beams

The jig on which the beams were assembled consisted of plywood tables assembled with nails. Plywood stops were glued to the table tops.

The labor time involved in the fabrication of each beam appears in detail in the Appendix, in which the time is recorded for each operation. The total time for the fabrication of all 23 floor beams was as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire House (gross area = 2052 sq. ft.)</td>
<td></td>
</tr>
<tr>
<td>23 Box beams (total length 431.5 ft.)</td>
<td>6878 man-minutes (or 114.6 man-hours)</td>
</tr>
<tr>
<td>Time per foot of length</td>
<td>16 man-minutes</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross floor area</td>
<td>335 man-minutes (or 5.58 man-hours)</td>
</tr>
</tbody>
</table>

These averages included ripping and planing flanges, cutting plywood webs, ripping and preparing stiffeners, handling and placing parts in the jig, applying glue and nail-gluing, removing excess glue, and stacking the beam for shipment. In some instances, nails were set and puttied and the beam was sanded.

It is obvious that the fabrication of the box beams for the floor system took a considerable amount of time. Part of the excess time may have been caused by inexperience with the process, and another part by the variety of beam sizes and forms. Also, beams used over the basement area were fabricated with considerable care in order to guarantee a fine appearance. Finish nails were used in the nail-gluing process, and these nails were set and puttied. The finished beam was then planed and sanded. These operations added to the fabrication time when compared to the fabrication time of the other finished beams.
Fig. 1. Recessed pockets in foundation walls

Fig. 2. Stiffener materials with plywood surface for gluing exterior webs

Fig. 3. Completed beam

Fig. 4. Applying 2x4 splines to top flange of beam

Fig. 5. Beams in place with splines attached

Fig. 6. Fastening plywood to ribs
More representative of normal construction where appearance is not a factor would be the times involved in the fabrication of the floor beams (type B8) for the crawl space (See Plan #2). The first of these 8 beams was not typical, however, as it was the first of all beams fabricated. The fabrication time for seven B8 beams (11-7/8" x 23'-11") ranged from 172 man-minutes to 228 man-minutes with an average of 197 man-minutes per beam:

**Bedroom Wing (gross area = 855 sq. ft.)**

| Time per beam | 197 man-minutes (or 3.28 man-hours) |
| Time per foot of beam | 8.2 man-minutes |
| Time per 100 sq. ft. of gross floor area | 184 man-minutes* |

### Erection of Box Beams

The box beams were placed on 4'-0" centers and rested in pockets on the foundation walls (Fig. 1) and, in the case of the bedroom wing, on concrete piers in the center. Since the pockets in the foundation walls had not been accurately leveled, the beams were shimmed with ceramic or slate pieces and allowed to ride free in the pocket. No termite shield was applied. Special erection problems occurred in the area around the fireplace where some beams served as supports for cross beams (See Plan 2). Field erection time includes the carrying, placing, and shimming of the beams. Three men positioned the beams in 545 man-minutes. Expressed in terms of the area of the floor, this amounted to 26.6 man-minutes per 100 square feet of gross floor area.

Since the beams used in the bedroom wing were of uniform size, the labor on this section is more representative of a typical rectangular house. The time involved in setting 8 beams was 150 man-minutes, or 18.8 man-minutes per beam. Expressed in terms of the gross

* The eighth beam was included at 197 man-minutes.
area of the bedroom wing, the erection time amounted to 17.5 man-minutes per 100 square feet.

FLOOR SPLINES

Description of Floor Splines

The design of the floor system called for the use of splines to receive and support the long edges of the floor panels. This detail resulted in 2 x 4 members being placed on edge along the top of each of the box beams. Similarly, 2 x 4 members were placed along the wall plates around the perimeter of the house. Splines were toe-nailed to the top of the box beams and plates (Figs. 4,5).

Erection of Floor Splines

Erecting approximately 875 lineal feet of 2 x 4 floor splines for the entire house required 239 man-minutes, or an average of 27.3 man-minutes per 100 lineal feet of spline. Expressed in terms of area, 11.6 man-minutes were required per 100 square feet of gross floor area.

FLOOR PANELS

Description of Floor Panels (Plan #3)

The basic standard floor panel (F-1) consisted of 1/2" x 4'x8' C-D interior plywood sheets stapled to seven cross ribs each 46-3/8" long (Fig. 6). The ribs were 2 x 4's spaced 16" on center. At one end of the panel no rib was installed. At the opposite end of the panel the rib was fastened so that the plywood covered only half of the rib; the remainder of the rib extended beyond the plywood in order to receive the plywood edge of the adjoining panel. All ribs were cut to a length of 46-3/8" in order to allow room for the splines along the side of the panels during the field erection operation. Where the dimensions of the house required it, special-sized panels were manufactured.
PLAN 3 - SHOWING FLOOR PANELS
Small plywood filler pieces were used in other areas to complete the floor system.

Fabrication of Floor Panels

All panels were fabricated in a floor panel jig. (The standard jig of the wall-panel framing system may be adapted to this purpose.) Fabrication time included cutting, handling, stapling, and final stacking of the completed panels for removal by fork-lift truck. Plywood filler pieces were also cut.

A complete listing of all the panel sizes and fabrication times for all operations is included in the Appendix. A summary of these times follows:

**Entire House (gross area = 2052* sq. ft.)**

<table>
<thead>
<tr>
<th>Number and Description of Panels</th>
<th>Man-Minutes Per Panel</th>
<th>Total Man-Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>53(F-1) 4'-0&quot; x 8'-0&quot; panels</td>
<td>4.53 min.</td>
<td>240.3</td>
</tr>
<tr>
<td>3(F-2) 2'-4&quot; x 8'-0&quot; panels</td>
<td>4.83</td>
<td>14.5</td>
</tr>
<tr>
<td>2(F-3) 1'-8&quot; x 4'-0&quot; panels</td>
<td>3.50</td>
<td>7.0</td>
</tr>
<tr>
<td>2(F-4) 3'-0&quot; x 4'-0&quot; panels</td>
<td>4.00</td>
<td>8.0</td>
</tr>
<tr>
<td>3(F-5) 2'-4&quot; x 4'-0&quot; panels</td>
<td>3.66</td>
<td>11.0</td>
</tr>
<tr>
<td>3(F-6) 4'-0&quot; x 5'-4&quot; panels</td>
<td>4.00</td>
<td>12.0</td>
</tr>
<tr>
<td>27 Plywood Filler panels</td>
<td></td>
<td>8.8</td>
</tr>
</tbody>
</table>

Total 301.6

Time per 100 square feet of gross area: 14.7 man-minutes.

Erection of Floor Panels

Erection time for the floor panels included handling the panels at the site, placing and nailing the floor panels to the splines, placing and nailing the plywood filler panels, plus the necessary field cutting and installation of subfloor around the fireplace area. The time involved was as follows:

* The net area of the floor construction was approximately 61 square feet less due to the stairway and fireplace openings.
Entire House (gross area = 2052 sq. ft.)

93 panels and fillers 540 man-minutes
Time per 100 sq. ft. of gross area 26.3 man-minutes

FLOOR SYSTEM LABOR

The following table summarizes the labor time used in fabricating and erecting the floor system. Since the bedroom wing represents a more typical condition of construction, the table also gives the fabrication and erection times involved in this wing alone. The comparison is made on the basis of 100 square feet of gross area.

<table>
<thead>
<tr>
<th>Item</th>
<th>Entire House</th>
<th>Bedroom Wing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2052 sq. ft.)</td>
<td>(855 sq. ft.)</td>
</tr>
<tr>
<td>Fabricate Beams</td>
<td>331.0</td>
<td>184.0</td>
</tr>
<tr>
<td>Erect Beams</td>
<td>26.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Erect Splines</td>
<td>11.6</td>
<td>11.6</td>
</tr>
<tr>
<td>Fabricate Floor Panels</td>
<td>14.7</td>
<td>14.7</td>
</tr>
<tr>
<td>Erect Floor Panels</td>
<td>26.3</td>
<td>26.3</td>
</tr>
<tr>
<td></td>
<td>410.1</td>
<td>254.1</td>
</tr>
</tbody>
</table>

EVALUATION OF FLOOR SYSTEM

In an effort to evaluate the floor system, the estimated time required to erect a 24'-8" x 34'-8" (855 square feet) conventional floor system was calculated. (This size is the same as that of the bedroom wing.)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Board Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girder</td>
<td></td>
</tr>
<tr>
<td>3 - 2x8x34'</td>
<td>= 136.0</td>
</tr>
<tr>
<td>Joists</td>
<td></td>
</tr>
<tr>
<td>27 - 2x8x12'</td>
<td>= 432.0</td>
</tr>
<tr>
<td>27 - 2x8x14'</td>
<td>= 504.0</td>
</tr>
<tr>
<td>Header</td>
<td></td>
</tr>
<tr>
<td>2 - 2x8x14'</td>
<td>= 37.3</td>
</tr>
<tr>
<td>8 - 2x8x12'</td>
<td>= 128.0</td>
</tr>
<tr>
<td>Subflooring (1x6 diagonal)</td>
<td></td>
</tr>
<tr>
<td>855 + 20%</td>
<td>= 1026.0</td>
</tr>
</tbody>
</table>

\[ \frac{1026.0}{2263.3} \]
Rate = 65 bd. ft. per hour
Time = \frac{2263}{65} = 35.13 \text{ hrs.} \text{ or } 2108 \text{ minutes}
Time per 100 \text{ sq. ft.} = 247 \text{ man-minutes}

Production rates used were those published in Chapter III, Section V, of the Dealer Operating Guide published by the National Retail Lumber Dealers Association.

It can be seen from this data that the panel floor system does not show an advantage in total fabrication and erection time, but does transfer the major portion of the labor time to the shop.

Since the bulk of the time is consumed in the fabrication of the box beams, this item may offer the greatest possibility for saving. Obviously, the elimination of the care necessary to produce an excellent-appearing box beam (such as those used over the basement) would reduce the cost substantially.

In the bedroom wing, two 12-foot box beams in place of one 24-foot beam would be satisfactory from a structural point of view, and should result in a saving.

Structurally, a beam composed of either one 2 x 12 or two 2 x 10's is strong enough to function in place of the box beams of the bedroom wing; however, neither provide adequate bearing surface for the cross ribs of the floor panels. The use of 2 x 4 ledger strips nail-glued on each side of a 2 x 12 will provide adequate bearing, and will also eliminate the need for the 2 x 4 spline on top of the beam. This system would have the disadvantage of greater shrinkage problems than the box beam, but would also result in a reduced depth for the floor system. Although the system would not be as stiff as box beam system it would meet generally specified deflection standards.

The original specifications for the better ("custom") grade beams called for the use of 4d finish nails spaced 6" on center. These
nails were to be set and puttied. The SHC-BRC observer at the fabrication site called attention to the fact that the nails were not providing satisfactory clamping pressure and the nails were subsequently placed on 3-inch centers. Even at this spacing, the holding power of a small-headed nail is questionable. Fortunately, the gap-filling power of casein glue overcame this problem to some extent; nevertheless, a number of the box beams did not pass the inspection test established and performed by the Plywood Fabricators Service, Inc. Serious consideration should be given to the advisability of eliminating the use of finish nails for providing the clamping power needed in the nail-gluing technique.

The fabricator of the beams used only two men during the nail-gluing of the beams. The two men were unable to complete the beam in the "open" time of the casein glue, and therefore the glue bond was endangered in some degree. In order to eliminate this condition, additional personnel should be used in the nail-gluing operation, or the beam should be fabricated in distinct operations allowing full curing time between operations.
II. WALL SYSTEM

GENERAL DESCRIPTION

The wall system used throughout most of the house was the wall-panel framing system developed by the Small Homes Council-Building Research Council in a cooperative investigation with the Lumber Dealers Research Council. Integral nail-glued semi-box headers were used in the window and door panels, eliminating the need for the double 2 x 6 continuous header. A single 2 x 4 plate was fastened to the top of the panels in the field in order to tie the wall panels together.

The basic panel (Type A) was composed of a framework of a 2 x 4 stud at each edge of the panel with 2 x 4 horizontal nailers between (Figs. 7, 8). This framework was covered on the outside with 1/2" medium-density-overlay plywood 4'-0" wide by 8'-8" high. The extra length allowed an overlap of both the floor system and the top inch of the foundation wall. The plywood served as combined sheathing and siding for the house.

Window panels (Types C, D, and E) were based on a structural window unit in which the studs and cripples below the sill of the window were incorporated with the window frame, sash, and exterior trim. Medium-density-overlay plywood, 1/2" thick, was added to this structural window unit to form the window panels (Fig. 9).

The original drawings called for certain window panels (Type E) to be built with structural window units 39-5/8" wide incorporated in a 4-foot-wide panel. Since these units were not available to the fabricator, a structural window unit 48" wide was used. This change, in combination with the plan arrangement, required some variation in placement of the panels in order to accommodate interior partitions, and resulted in the fabrication of two 1-foot-wide units (Type B, modified), which were used in the bathroom area of the bedroom wing.* A number of special wall panels were required. Large sliding glass doors required extra-wide wall panels (Type J) in portions of the foyer.

*Plan 4 shows the layout of the panels as given by the original design. The rear wall of the bedroom was not built according to this plan. The panel sequence as actually constructed was as follows: From left to right, Bm, E, A, E, Bm, E, B, E, Bm; A, D, A.
Fig. 7. Frame for the solid wall panel

Fig. 8. Solid wall panel

Fig. 9. Window panel assembly

Fig. 10. Component assembly

Fig. 11. Truss erection

Fig. 12. Gable overhang placement
PLAN 4—SHOWING WALL PANELS
and the living room. Panel types M, N, and O were fabricated for the living room end wall. In these panels the stud lengths were varied so that the top of the panel matched the slope of the roof. A special triangular window panel was set above three regular wall panels in the living room. Also, at certain points in the house, wall panels of framing members only (Type F) were used.

FABRICATION OF PANELS

Solid Wall Panels

Fabrication times for 23 standard solid wall panels 4'-0" wide (Type A) were recorded (see Appendix, page A-19). The times included handling parts, cutting and stacking the studs and ribs, cutting the plywood lengths from 10-foot pieces, applying chalk lines, and assembling the panels in the wall panel jig. Two-inch aluminum nails were used to fasten the plywood to the framework. Care was taken to avoid denting the overlay.

23 Solid Panels (4'-0" x 8'-8")

\[
\text{Time per panel} = \text{308.2 man-minutes} \\
\]

Times for special solid wall panels are included in the Appendix.

Window Panels

Records were kept for the fabrication of 16 window panels of three different sizes as follows:

- 6 panels Type C  
  glass size 41-3/8" x 49" over 41-3/8" x 14"

- 6 panels Type D  
  glass size 41-3/8" x 30" over 41-3/8" x 18"

- 4 panels Type E  
  glass size 41-3/8" x 22"

The total time recorded was 504 man-minutes, which included 56 man-minutes for handling panels, 84 man-minutes for cutting plywood, 120 man-minutes for conferences and interpreting plans, and 244 man-minutes for nailing. (Actual nailing time varied from 10 to 26 man-minutes per panel.) The average total time per window panel was 31.5 man-minutes.
ERECTION OF PANELS

Since the bedroom wing offered the largest section of the house using a minimum number of non-standard panels, it was used as the basis for the wall erection study.

The bedroom wall sections were transported to the building site and assembly started at one corner. The panels were spiked to the floor, and nailed together as the walls progressed (Fig. 10). Five men worked on erecting and fastening the wall panels of the bedroom wing. A 2 x 4 plate nailed flat to the top of the panels tied the walls together, and special 26-gauge metal corner pieces were used at the corners. Average erection time for the panels included handling at the site, nailing together, temporary wall bracing, and applying the top 2 x 4 plate and metal corner pieces. The perimeter of the bedroom wing was erected in 271 man-minutes. Since two panels were omitted at the connection to the foyer, a total length of wall of 108 feet was involved. The average time of erection per lineal foot of wall was 2.51 man-minutes.

In the living room section, the non-standard panels mentioned previously increased the erection time. These panels included special panels (Types M, N, and O) with sloping tops, three door panels (Type J), and a special triangular window section panel (Type P) in the gable end wall of the living room wing. Total time for erecting 92 lineal feet of this wall was 275 man-minutes, or 3 man-minutes per lineal foot.

WALL PANELS – SUMMARY

The fabrication and erection times of the wall panels for the bedroom wing may be summarized as follows:
**Wall Panels - Bedroom Wing (108 Lineal Feet)**

### Fabrication Time

<table>
<thead>
<tr>
<th>Item</th>
<th>Man-Minutes Per Panel</th>
<th>Total Man-Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 window panels</td>
<td>31.5</td>
<td>315.0</td>
</tr>
<tr>
<td>12 solid panels (Type A)</td>
<td>13.4</td>
<td>160.8</td>
</tr>
<tr>
<td>3 solid panels (Type B)</td>
<td>19.7</td>
<td>59.1</td>
</tr>
<tr>
<td>2 solid panels (Type B modified)</td>
<td>19.7</td>
<td>39.4</td>
</tr>
<tr>
<td>3 framework panels (Type F)</td>
<td>6.5</td>
<td>19.5</td>
</tr>
</tbody>
</table>

**Erection Time**

108 lineal feet of panels 2.51 lineal foot

| Total Man-Minutes | 271.0               |

**Total time for fabricating and erecting walls of bedroom wing**

<table>
<thead>
<tr>
<th>Time per lineal foot of exterior wall</th>
<th>864.8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 man-minutes</td>
</tr>
</tbody>
</table>

### EVALUATION OF WALL SYSTEM

In order to evaluate the wall system more thoroughly, an effort was made to determine the times involved in the construction of a similar wall built by conventional methods. Information available on times involved in conventional wall construction procedures is insufficient to allow an entirely satisfactory comparison between the wall-panel system and conventional or tip up methods. In establishing a comparative structure, the number of studs (spaced 16 inches on center) which would be used in framing the bedroom wing walls conventionally was determined, and the time consumed in building the frame for the wall was estimated:

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>Board Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 Studs</td>
<td>2 x 4 x 8'</td>
<td>347</td>
</tr>
<tr>
<td>2 Plates</td>
<td>2 x 4 x 108'</td>
<td>144</td>
</tr>
<tr>
<td>1 Plate</td>
<td>2 x 4 x 68'</td>
<td>45</td>
</tr>
<tr>
<td>10 Headers</td>
<td>2 - 2 x 6 x 4'</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>616</td>
</tr>
</tbody>
</table>

**Production Rate** 40 bd.ft. per hour

**Total time for framing** 924 man-minutes

**Time per lineal foot of wall** 8.6 man-minutes
Time for applying the combined sliding-sheathing in the field was more difficult to estimate, as no data for the application of 1/2" overlaid plywood is available. Based on a study* of the installation of sheathing materials, a production rate of 50 man-minutes per 100 square feet was used.

The quantity of plywood was calculated as follows:

96 lineal feet** of covered panels x 8'-8" high = 832 sq. ft.

less window areas

<table>
<thead>
<tr>
<th>Windows Type</th>
<th>Number</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>7</td>
<td>112</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>24</td>
</tr>
</tbody>
</table>

Total Window area = 136 sq.ft.

Total area of plywood = 696 sq.ft.

Total Application Time = 6.96 x 50 = 348 man-minutes

Conventional Construction of Bedroom Wing (108 Lineal Feet)

Total time for exterior wall of bedroom wing = 1272 man-minutes

Time per lineal foot of wall = 11.8 man-minutes

It is apparent that the panel system shows a considerable advantage in the times involved. On the basis of the production rates used, the fabrication and erection of the conventional framing alone consumed more time than did the complete wall fabrication and erection of the panel system.

It should be noted that the hypothetical conventional wall construction used in the comparison was in reality a less complex wall than normal, since the structural window-wall unit was used. This eliminated all special framing required at openings, with the exception of the 2 x 6 headers. If normal double studs, cripples, and headers were used around non-modular windows, the framing time would be substantially increased.


The rate used was an average of 6 observations for 2' x 8' x 25/32" and 4' x 8' x 1/2" fiberboard sheathing applied in the field.

** 12 lineal feet of the wall were uncovered (Type F) panels.
The demonstration house showed that the wall-panel framing system incorporating a structural window unit with box-beam header is one of, if not the most, efficient methods of building wood frame walls. Comparison of the times involved in fabricating non-standard panels emphasizes the importance of using uniform construction if maximum savings are to be achieved.

ROOF SYSTEM — BEDROOM WING

The roof system of the bedroom wing was composed of 2 x 4 nail-glued king-post trusses which were built to the design of the Small Homes Council—Building Research Council. Gable ends were framed with modified trusses. Prefabricated gable-end ladder panels were used to extend the gable-end overhang. The roof was sheathed with 3/8" plywood stiffened at unsupported edges with patented aluminum "H" clips.

Description of Trusses

The nail-glued trusses were built to follow the latest design prepared by the Small Homes Council—Building Research Council. Top chords consisted of 2 x 4 x 16'-0"; the bottom chord was made up of one 2 x 4 12'-0" long and one 2 x 4 12'-0" long which was cut from a 16'-0" length. The king post was also cut from this length, leaving a waste of only 2 inches. Since the fabricator did not have the specified 3/8" plywood in stock, 1/2" plywood of C-D grade was used.

Fabrication of Trusses

Sixteen trusses were fabricated. Casein glue was applied to the 2 x 4 members, and the plywood gusset plates and splice plates were fastened.
III. ROOF SYSTEM

Three different roof systems were used in the house.

The bedroom wing was covered by truss system with plywood roof sheathing and a gypsum-board finish applied directly to the horizontal bottom chords of the trusses (See Plan 5).

Roof panels resting on cathedral beams shaped in a scissors form spanned the living-dining area, giving a sloped ceiling on the interior. The under surfaces of the roof panels, which were exposed to the room, were of medium-density-overlay plywood.

The entry and kitchen section were also roofed with panels, but in this instance the panels formed a flat roof.

ROOF SYSTEM — BEDROOM WING

The roof system of the bedroom wing was composed of 2 x 4 nail-glued king-post trusses which were built to the design of the Small Homes Council-Building Research Council. Gable ends were framed with modified trusses. Prebuilt gable-end ladder panels were used to extend the gable-end overhangs. The roof was sheathed with 3/8" plywood stiffened at unsupported edges with patented aluminum "H" clips.

Description of Trusses

The nail-glued truss was built to follow the latest designs prepared by the Small Homes Council-Building Research Council. Top chords consisted of 2 x 4 x 16'-0"; the bottom chord was made up of one 2 x 4 12'-0" long and one 2 x 4 12'-8" long which was cut from a 16'-0" length. The king post was also cut from this length, leaving a waste of only 2 inches. Since the fabricator did not have the specified 3/8" plywood in stock, 1/2" plywood of C-D grade was used.

Fabrication of Trusses

Sixteen trusses were fabricated. Casein glue was applied to the 2 x 4 members, and the plywood gusset plates and splice plates were fastened.
PLAN 5 — SHOWING ROOF PANELS

3/8" PLYSCORD SHEATHING

4X6  4X8
by the use of a pneumatic stapler. Fabrication time for the trusses included handling and cutting the members and plywood gussets, mixing the glue, spreading the glue, stapling, and stacking the trusses. Eight of the 16 trusses were fabricated in 16 man-minutes per truss at the time when the photographers were taking pictures and management was present. Later, when only the time-study recorder was present, production time increased to 21 man-minutes per truss.

**Description of Gable Ends**

The gable ends of the bedroom wing were king-post trusses modified by the addition of extra nailers. Gusset plates were omitted on one side of the truss and medium-density-overlay plywood was used as siding for the gable ends.

**Fabrication of Gable Ends**

Fabrication time for two gable ends was 80 man-minutes per unit.

**Erection of Trusses and Gable Ends**

Sixteen trusses and two gable ends were erected by five men in a total time of 217 man-minutes, or at the rate of approximately 12 man-minutes per unit.

**Description of Gable-End Overhang Ladder Panels**

Gable-end overhang ladder panels were built of two 2 x 4 x 16'-1" rails and 2 x 4 rungs at 2-foot centers. The soffit of the panel was finished with 1/2" medium-density-overlay plywood. Overall dimensions of each panel were 1'-7½" x 16'-1".

**Fabrication of Overhangs**

Four overhangs were fabricated in a total time of 192 man-minutes or 48 man-minutes per unit.

**Erection of Overhangs**

Gable-end overhangs were nailed to the gable-end trusses by four men in a total time of 128 man-minutes, or 32 man-minutes per unit.
Roof Sheathing

Roof sheathing was 3/8" C-D sheathing (plyscord) plywood (See Fig. 13). Sheathing was stapled to the trusses and aluminum "H" clips were used on the unsupported edges of the plywood. The total area of the plywood was 1216 square feet. Four men sheathed the roof in 203 man-minutes. Expressed in terms of 100 square feet of roof area the time was 16.7 man-minutes.

BEDROOM WING ROOF CONSTRUCTION - SUMMARY

(Floor Area = 855 Sq. Ft. Roof Area = 1216 Sq. Ft.)

<table>
<thead>
<tr>
<th>Task</th>
<th>Time (man-minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricate 16 trusses</td>
<td>296</td>
</tr>
<tr>
<td>Fabricate 2 gable ends</td>
<td>160</td>
</tr>
<tr>
<td>Erect 16 trusses and 2 gable ends</td>
<td>217</td>
</tr>
<tr>
<td>Fabricate 4 gable-end overhangs</td>
<td>192</td>
</tr>
<tr>
<td>Erect 4 gable-end overhangs</td>
<td>128</td>
</tr>
<tr>
<td>Sheath Roof</td>
<td>203</td>
</tr>
<tr>
<td><strong>Total time</strong></td>
<td><strong>1196 man-minutes</strong></td>
</tr>
</tbody>
</table>

Time per 100 square feet of roof area = 98 man-minutes
Time per 100 square feet of floor area = 140 man-minutes
Time exclusive of gable ends = 1012 man-minutes
Time per 100 square feet of roof area = 83 man-minutes
Time per 100 square feet of floor area = 118 man-minutes

ROOF SYSTEM - LIVING ROOM WING

The four-bay roof system of the living room consisted of roof panels finished both top and bottom with plywood. The panels were supported by three cathedral beams and the end-wall structures.

Description of Cathedral Beams

The main supporting members of the living room roof consisted of three cathedral-type beams which were placed 8 feet apart, and spanned a clear distance of 24 feet. The beams had a slope of 3/12 for the top chord, and approximately 1/12 for the bottom chord. The top chord consisted of two 2 x 4's spaced by a 1-5/8" x 2-7/8" lumber piece. The bottom chords...
were also of two 2 x 4's. Stiffeners were placed at intermediate points along the beam, and 5/16" and 5/8" plywood gussets were used at the critical points. The cathedral beams were constructed in two halves, and each of the two halves was surfaced on one face with an outer skin of 5/16" exterior-type B-C medium-density-overlay plywood with a printed pattern.

**Fabrication of Cathedral Beams**

Beams were fabricated in two sections, and then were tied together with plywood spacers in the field. The time study observer was able to time the fabrication of only two of the three beams. Two men were used in the fabrication of the beam sections. The total time required for fabricating the two sections of the first beam was 620 man-minutes. The second required 480 man-minutes to build. Following fabrication the cathedral beams were wrapped in heavy paper to prevent shipping damage of the printed walnut surface during handling and transportation.

**Erection of Cathedral Beams**

Some field work was required on these beams after they arrived at the site of construction. This involved such items as unwrapping, detailed cutting for better fitting, and spacer application. This work required a total of 120 man-minutes. Six men worked on the erection of the cathedral beams over the living room section, and a total time of 708 man-minutes was consumed in this operation. Thus a total time of 828 man-minutes was required for the field assembly and erection of the three cathedral beams.

**Description of Roof Panels**

The roof of the living room section consisted of pressure-glued roof panels with the basic dimensions of 4' x 8' or 4' x 10'. The structural elements of the stressed-skin panels were 2 x 4 ribs placed parallel to the length of the panel. These ribs were spaced approximately 16" on center, and were so located that a tongue-and-groove joint was formed by the ribs and the two skins. The ribs were ripped to a uniform depth of 3-1/2" in order to be certain of equal lumber dimensions. The upper face of the roof panels was composed of 3/8" exterior-type C-D sheathing.
plywood, while the interior skin was 5/16" medium-density-overlay plywood. Insulation was inserted during fabrication.

**Fabrication of Roof Panels**
The roof panels were pressure-glued in a specially-designed metal clamping system and allowed to cure. Several of the panels arrived at the site showing a considerable amount of unevenness of the bottom section. This resulted in a general "wavy" appearance of the exposed interior skin of the panels. Fabrication times for twenty-six 8-foot and 10-foot panels were recorded. The average number of man-minutes per panel was 52. Projecting these times for the entire roof (which consisted of sixteen 8-foot panels and sixteen 10-foot panels) the total fabrication time for the roof panels was 1664 man-minutes.

**Erection of Roof Panels**
Certain fabrication errors involved in the building of the cathedral beams and the roof panels, particularly the latter, resulted in additional time being required for the assembly of the roof system. A total of 2,220 man-minutes was required for this operation.

**SUMMARY OF LIVING ROOM WING ROOF CONSTRUCTION**

- **Roof** = 1152 sq. ft.; **Floor Area** = 806 sq. ft.
- Fabricate 3 cathedral beams\* 1440 man-minutes
- Erect 3 cathedral beams 828
- Fabricate 32 roof panels 1664
- Erect 32 roof panels 2220
- **Total** 6152
- Time per 100 square feet of roof area 534
- Time per 100 square feet of floor area 763

**ROOF SYSTEM --- ENTRY AND KITCHEN**
The number of panels involved in this section was too few to permit the collection of adequate data and therefore no summary is presented.

\* Fabrication time based on second beam
EVALUATION OF ROOF SYSTEM

It is extremely difficult to offer any precise comparison of the construction time involved in the two different roof systems: the cathedral-beam-and-panel system used in the living room wing and the roof-truss system used in the bedroom wing. Fabrication errors in the roof panels caused the time per 100 sq. ft. of floor area to be higher than might have been expected if the operation had gone smoothly and without difficulty. A comparison of the time per 100 sq. ft. of area of the living room wing (763 man-minutes) with the time for the bedroom wing (118 man-minutes) shows a wide discrepancy. Please note that in both instances the gable-end structure has been eliminated from the totals.

Since the panel structure of the living room presents a finished surface to the interior of the room, no additional work is required other than the painting and spotting of the panels. Therefore, to bring the two times to a more comparative basis, some labor time must be assigned to the bedroom wing for the process of installing and taping the drywall finish. This time varies, but will probably lie somewhere within the range of 2 to 4 hours per 100 sq. ft. of ceiling surface. Thus the total time per 100 sq. ft. of floor area involved in the construction of the bedroom ceiling should be increased from 120 to 240 man-minutes, depending upon which production factor is used for the drywall application. Even when the highest figure for drywall application is assumed, the total time involved for the construction of the bedroom roof and ceiling (358 man-minutes) is much less than the 763 man-minutes for the living room section, built with the cathedral beams and panels. The living room section requires more than twice the time necessary for the bedroom section when compared on the basis of 100 sq. ft. of floor area covered.

Obviously, the living room section results in a more architecturally pleasing section, and certain cost sacrifices would be made to achieve this effect. Nevertheless, it is questionable whether the cost sacrifices
as indicated would be acceptable under most circumstances. An improve-
ment in the production of the cathedral beams and roof panels would
clearly lower this time to some extent but a very great reduction is
required to bring it in line with more conventional truss-roof system.

Some problems occurred in the flat roof over the kitchen and entry sec-
tion. A hole was cut in the roof sheathing for a skylight and the roof
was covered by a layer of roofing felt. This was not sufficient to pro-
tect the roof during a two-day period of wet weather and, when the ceiling
plywood was cut out for the skylight at a later date, a considerable
amount of water drained out of the roof section. This water was suf-
ficient to cause damage to the glue bond and to the printed surface of
the ceiling plywood. Care should be used to apply roofing to flat
roof panels as soon as possible.

<table>
<thead>
<tr>
<th>Garage (Gross Floor Area = 592 Sq. Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 sections (half-frames)</td>
</tr>
<tr>
<td>Time per section</td>
</tr>
<tr>
<td>Time per frame</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross floor area</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross roof area</td>
</tr>
<tr>
<td>(592 sq. ft.)</td>
</tr>
</tbody>
</table>

Erection of Rigid Frames

The two half-frames were field assembled at the site by nailing gusset
plates at the back of the frame (Figure 17). Nails were driven through
the frame and two gusset plates and then clinched. Two men took 3.8
man-hours to perform this operation. Three men then erected the
frames in 3.3 man-hours. The frames were toenailed to a 2 x 8 plate
on the foundation wall (Figure 18).

<table>
<thead>
<tr>
<th>Garage (Field Assembly and Erection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 frames</td>
</tr>
<tr>
<td>Time per frame</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross floor area</td>
</tr>
<tr>
<td>(592 sq. ft.)</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross roof area</td>
</tr>
<tr>
<td>(592 sq. ft.)</td>
</tr>
</tbody>
</table>
The garage for the house was detached from the main house and was constructed with a rigid-frame system. Eleven rigid frames and two panelized gable-end walls carried the roof of the 24'-0" x 24'-8" garage. The 16-foot garage door was located in one of the gable-end walls.

Description of Rigid Frames

The rigid frames were composed of 2 x 8 vertical legs eight feet high rigidly connected by nail-glued plywood gussets to a 16-foot 2 x 8 rafter set at a slope of 3/12. Where the rafters extended to form the overhangs, they were cut to the size of 2 x 4 members (Fig. 16). The span of the completed frame from outside to outside of the vertical legs was 24'-0".

Fabrication of Rigid Frames

Rigid frames were fabricated in sections (half-frames) consisting of one leg and one rafter and were shipped to the site in this form.

<table>
<thead>
<tr>
<th>Garage (Gross Floor Area = 592 Sq. Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 sections (half-frames)</td>
</tr>
<tr>
<td>Time per section</td>
</tr>
<tr>
<td>Time per frame</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross floor area</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross roof area</td>
</tr>
<tr>
<td>(896 sq. ft.)</td>
</tr>
</tbody>
</table>

Erection of Rigid Frames

The two half-frames were field assembled at the site by nailing gusset plates at the peak of the frame (Figure 17.) Nails were driven through the frame and two gusset plates and then clinched. Two men took 3.5 man-hours to perform this operation. Three men then erected the frames in 3.3 man-hours. The frames were toenailed to a 2 x 8 plate on the foundation wall (Figure 18).

<table>
<thead>
<tr>
<th>Garage (Field Assembly and Erection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 frames</td>
</tr>
<tr>
<td>Time per frame</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross floor area</td>
</tr>
<tr>
<td>(592 sq. ft.)</td>
</tr>
<tr>
<td>Time per 100 sq. ft. of gross roof area</td>
</tr>
<tr>
<td>(896 sq. ft.)</td>
</tr>
</tbody>
</table>
Fig. 13. Roof sheathing

Fig. 14. Living room box beam placement

Fig. 15. 4d casing nails, 3" o.c.

Fig. 16. Rigid frames

Fig. 17. Frames completed on driveway

Fig. 18. Rigid frames toenailed to plate
EVALUATION OF RIGID FRAMES

In order to evaluate the comparative economy of the rigid frames with a truss and panel system for a typical bay 4 feet long and 24 feet wide, the following tables were made:

<table>
<thead>
<tr>
<th>Rigid Frames* (2)</th>
<th>Panel and Truss* (2 each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sill plate 2 - 2 x 8 x 4'-0&quot;</td>
<td>Plates 6 - 2 x 4 x 4'-0&quot;</td>
</tr>
<tr>
<td>Leg 4 - 2 x 8 x 8'-0&quot;</td>
<td>Studs 6 - 2 x 4 x 8'-0&quot;</td>
</tr>
<tr>
<td>Rafters 4 - 2 x 8 x 16'-0&quot;</td>
<td>Rafters 4 - 2 x 4 x 16'-0&quot;</td>
</tr>
<tr>
<td>Total Material 139 bd. ft.</td>
<td>L. Chord 2 - 2 x 4 x 12'-0&quot;</td>
</tr>
<tr>
<td></td>
<td>and Strut 2 - 2 x 4 x 16'-0&quot;</td>
</tr>
<tr>
<td></td>
<td>Total Material 128 bd. ft.</td>
</tr>
</tbody>
</table>

Comparison of Time

<table>
<thead>
<tr>
<th>Rigid Frames (2)</th>
<th>Panel and Truss (2 each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabrication 124 man-minutes</td>
<td>Panel fabrication 27 man-minutes</td>
</tr>
<tr>
<td>Erection 74 &quot; &quot;</td>
<td>Panel erection 20 &quot; &quot;</td>
</tr>
<tr>
<td>Wall siding application 32 &quot; &quot;</td>
<td>Truss fabrication 40 &quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>Truss erection 24 &quot; &quot;</td>
</tr>
<tr>
<td>230 man-minutes</td>
<td>111 man-minute</td>
</tr>
</tbody>
</table>

The tables indicate that the panel-truss system represents a saving in materials required, and is considerably less costly in the labor involved. It seems likely that a substantial portion of the fabrication time for the rigid frames was involved in the cutting of the overhang extensions, and it may be assumed that approximately a half hour per frame might be saved by eliminating this operation. However, this reduction is not sufficient to bring the labor times into line with the panel-truss system.

One further limitation of the rigid frame system must be mentioned. When rigid frames are placed 2'-0" on center, special provisions must be made for window and door openings. Usually it will be necessary to cut the leg of the frame short and to rest the leg upon a header over the opening. Care must be used in fastening the shortened legs of the frame to header and the header must be designed for horizontal thrust as well as vertical load.

* Materials do not include gusset plates.
### TABLE 1
**TIME SUMMARY - COMPONENT UNITS**

<table>
<thead>
<tr>
<th>COMPONENT OR UNIT</th>
<th>SHOP FABRICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMPONENT</strong></td>
<td><strong>No.</strong></td>
</tr>
<tr>
<td>7 - Box beams (B8)</td>
<td>2</td>
</tr>
<tr>
<td>(168 lin. ft.)</td>
<td></td>
</tr>
<tr>
<td>23 - Solid wall panels</td>
<td>2</td>
</tr>
<tr>
<td>16 - Window panels</td>
<td>2</td>
</tr>
<tr>
<td>26 - Roof panels</td>
<td>2</td>
</tr>
<tr>
<td>12 - 4' x 10'</td>
<td></td>
</tr>
<tr>
<td>14 - 4' x 8'</td>
<td></td>
</tr>
<tr>
<td>8 - Gable overhangs</td>
<td>2</td>
</tr>
<tr>
<td>1 - Cathedral beam</td>
<td>2</td>
</tr>
<tr>
<td>1 - Cathedral beam</td>
<td>2</td>
</tr>
</tbody>
</table>

(1) Components not shown here are given in the following tables, the text, or in the Appendix.
## TABLE 2
TIME SUMMARY - ENTIRE HOUSE
(gross floor area = 2052 sq. ft.)

<table>
<thead>
<tr>
<th>COMPONENT OR UNIT</th>
<th>SHOP FABRICATION</th>
<th>FIELD ASSEMBLY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Men</td>
<td>Total Man-Min.</td>
</tr>
<tr>
<td>23 - Floor box bms. (431.5 lin. ft.)</td>
<td>2</td>
<td>6878</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor Splines (approx. 875 lin. ft.)</td>
<td>3</td>
<td>239</td>
</tr>
<tr>
<td>66 - Floor panels 27 - Plywood filler</td>
<td>2</td>
<td>301.6</td>
</tr>
<tr>
<td>16 - Trusses</td>
<td>2</td>
<td>286</td>
</tr>
<tr>
<td>2 - Gable ends</td>
<td>2</td>
<td>160</td>
</tr>
<tr>
<td>4 - Gable overhangs</td>
<td>2</td>
<td>192</td>
</tr>
<tr>
<td>Roof sheathing (1216 sq. ft.)</td>
<td>4</td>
<td>203</td>
</tr>
<tr>
<td>16.7/100 sq. ft. of roof</td>
<td><strong>(1)</strong> Based on Table 1</td>
<td><strong>(2)</strong> Based on Table 2</td>
</tr>
</tbody>
</table>
### TABLE 3
TIME SUMMARY - BEDROOM WING
(gross floor area = 855 sq. ft.) (roof area = 1216 sq. ft.)

<table>
<thead>
<tr>
<th>COMPONENT OR UNIT</th>
<th>SHOP FABRICATION</th>
<th>FIELD ASSEMBLY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Men</td>
<td>Total Man-Min.</td>
</tr>
<tr>
<td>8 - Box beams (B8)</td>
<td>2</td>
<td>1577</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splines</td>
<td>3</td>
<td>99</td>
</tr>
<tr>
<td>Floor panels</td>
<td>2</td>
<td>126</td>
</tr>
<tr>
<td>Wall panels</td>
<td>2</td>
<td>594</td>
</tr>
<tr>
<td>(108 lin. ft.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 - Trusses</td>
<td>2</td>
<td>296</td>
</tr>
<tr>
<td>2 - Gable ends</td>
<td>2</td>
<td>160</td>
</tr>
<tr>
<td>4 - Gable overhangs</td>
<td>2</td>
<td>192</td>
</tr>
<tr>
<td>Roof sheathing</td>
<td>4</td>
<td>203</td>
</tr>
<tr>
<td>(1216 sq. ft)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Based on Table 1
(2) Based on Table 2

Note: All rates are recorded at 400 man-minutes; see Table 1 for combined living room and kitchen entry areas of 950 sq. ft.
<table>
<thead>
<tr>
<th>UNIT</th>
<th>SHOP FABRICATION</th>
<th>FIELD ASSEMBLY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Total Min.</td>
</tr>
<tr>
<td>10 - Floor box beams (178.5 lin. ft.)</td>
<td>2</td>
<td>3272</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.3/lin. ft.</td>
</tr>
<tr>
<td>Splines</td>
<td>3</td>
<td>94</td>
</tr>
<tr>
<td>Floor panels</td>
<td>2</td>
<td>118</td>
</tr>
<tr>
<td>Wall panels (92 lin. ft.)</td>
<td>2</td>
<td>275</td>
</tr>
<tr>
<td>3 - Cathedral beams (3)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>32 - Roof panels (1152 sq. ft.)</td>
<td>1664</td>
<td>52/panel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>193/100 sq. ft. roof area</td>
</tr>
</tbody>
</table>

(1) From Table 2
(2) Many different panels; data incomplete. See Appendix
(3) Gable-end structure included as part of walls
(4) Based on one beam recorded at 480 man-minutes. See Table 1
(5) This rate based on rate for combined living room and kitchen entry areas of 930 sq. ft.
<table>
<thead>
<tr>
<th>UNIT</th>
<th>No. Men</th>
<th>Total Man-Min.</th>
<th>Rate (Man-Minutes)</th>
<th>No. Men</th>
<th>Total Man-Min.</th>
<th>Rate (Man-Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 Rigid frames</td>
<td>2</td>
<td>686</td>
<td>62/frame</td>
<td>2</td>
<td>37/frame</td>
<td>69/100 sq. ft. of floor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>116/100 sq. ft. of floor and</td>
<td></td>
<td></td>
<td>69/100 sq. ft. of floor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>77/100 sq. ft. of roof</td>
<td>3</td>
<td>46/100 sq. ft. of roof</td>
<td></td>
</tr>
</tbody>
</table>
A. BOX BEAM FABRICATION

Beam #1 (BR) - 23'-11" x 11 5/8"

Men: Three men

Steps and time:

1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material, 24' long. 4 pieces. 16 minutes

2) Nail together, run through planer, both edges to 3 1/3" wide flanges. 10 pieces. 20 minutes

3) Staple-glue stiffeners, cutting and planing 3 x 4, cutting plywood, applying glue and stapling. 7 pieces. 28 minutes

4) Place flanges and stiffeners in jig and nail. 3 minutes

5) Squaring flanges and stiffeners. 1 hour 45 minutes

6) Cut plywood web members. 1 hour

7) Spread glue, apply plywood and staple. 1 hour

8) Scrape glue off flanges and set aside. 20 minutes

9) Plane each flange edge. 6 minutes

Total man hours: 12 hours 45 minutes 768 man minutes

Beam #2 (BR) - 23'-11" x 15 5/8"

Men: Two men

Steps and time:

1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 4 pieces. 16 minutes

2)uck 28' standard grade 2 x 4 to each top flange member, 4 pieces. 16 minutes

3) Run thru A-1 planer. 4 pieces. 20 minutes

4) Separate, apply glue and place in jig. 10 minutes

APPENDIX

BOX BEAMS
A. BOX BEAM FABRICATION

Beam #1 (B8) - 23'-11" x 11 5/8"

Men: Three men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material, 24' long. 4 pieces. 16 minutes
2) Nail together, run through planer, both edges to 3 1/2" wide flanges. 10 pieces. 10 minutes
3) Staple-glue stiffeners, cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 7 pieces. 28 minutes
4) Place flanges and stiffeners in jig and nail. 3 minutes
5) Squaring flanges and stiffeners. 1 hour 45 minutes
6) Cut plywood web members. 8 minutes
7) Spread glue, apply plywood and staple. 1 hour
8) Scrape glue off flanges and set aside. 20 minutes
9) Plane each flange edge. 6 minutes

Elapsed time: 4 hours 16 minutes

Total man hours: 12 hours 48 minutes 768 man minutes

Beam #2 (Bl) - 23'-11" x 15 5/8"

Men: Two men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 4 pieces. 16 minutes
2) Tack 16' standard grade 2 x 4 to each top flange member. 4 pieces. 16 minutes
3) Run through planer. 4 pieces. 20 minutes
4) Separate, apply glue and place in jig. 10 minutes
5) Run through planer. Close tolerance necessary. 2 pieces. Make stiffeners.
6) Place flanges in jig, place stiffeners, squaring.
7) Cut plywood.
8) Apply glue and plywood webs, one side.
9) Nail with 4d casing nails (much care to prevent indenting wood).
10) Set nails.
11) Router on edges to square plywood.
12) Turn beam over, apply glue and plywood.
13) Nail with 4d casing nails
14) Set nails.
15) Scrape glue off flanges.
16) Router on edges to square plywood.
17) Fill holes, use belt sander, plane edges of flanges.

Elapsed time: 4 hours
Total man hours: 8 hours

Beam #3 (B5) - 12'-6 1/2" x 11 5/8"

Men: Two men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 12' long. 2 pieces.
2) Nail together, run through planer, both edges to 3 1/2" wide.
3) Staple-glue stiffeners; cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 5 pieces.
4) Place flanges and stiffeners in jig and nail together.
5) Squaring flanges and stiffeners.
6) Cut plywood web members.
7) Spread glue, apply plywood.
8) Nail with 4d casing nails.
9) Set nails. 8 minutes
10) Scrape off glue. 10 minutes
11) Router on edges to square edges. 3 minutes
12) Turn beam over, apply glue and plywood. 3 minutes
13) Nail with 4d casing nails. 13 minutes
14) Set nails. 8 minutes
15) Scrape off glue excess. 10 minutes
16) Router on edges to square edges. 3 minutes
17) Fill holes, use belt sander, plane edges of flanges. 13 minutes

Elapsed time: 2 hours 23 minutes
Total man hours: 4 hours 46 minutes, 286 man minutes

Beam #4 (B5) - 12'-6 1/2" x 11 5/8"

Men: Two men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material, 12' long. 2 minutes per piece, 4 pieces. 8 minutes
2) Nail together, run through planer, both edges to 3 1/2" wide. 7 minutes
3) Staple-glue stiffeners, cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 5 pieces. 20 minutes
4) Place flanges and stiffeners in jig and nail together. 4 minutes
5) Squaring flanges and stiffeners. 14 minutes
6) Cut plywood web members. 4 minutes
7) Spread glue, apply plywood. 5 minutes
8) Nail with 4d casing nails 3" o.c. 12 minutes
9) Set nails. 9 minutes
10) Scrape glue off flanges. 7 minutes
11) Router on edges for squaring. 4 minutes
12) Turn beam over, apply glue and plywood. 5 minutes
13) Nail with 4d casing nails. 14 minutes
14) Set nails. 9 minutes
15) Scrape off glue. 7 minutes
16) Router on edges. 5 minutes
17) Fill Holes, use belt sander, plane edges of flanges 14 minutes

Elapsed time: 2 hours 28 minutes
Total man hours: 4 hours 56 minutes, 296 man minutes
Beam #5 (B6) - 12'-6 1/2" x 11 5/8"

Men: Two men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 16' long. 4 pieces. 12 minutes
2) Nail together, run through planer, both edges to 3 1/2" wide. 10 minutes
3) Separate, apply glue and place two flanges sets in jigs. 16 minutes
4) Staple-glue stiffeners; cutting, planing 2 x 4, cutting plywood, applying glue and stapling, 5 pieces. 20 minutes
5) Run flanges through planer. 8 minutes
6) Place flanges and stiffeners in jig and nail together. 8 minutes
7) Squaring flanges and stiffeners. 15 minutes
8) Cut plywood web members. 6 minutes
9) Apply plywood web, one side. 7 minutes
10) Nail with 4d casing nails. 18 minutes
11) Set nails. 11 minutes
12) Scrape off glue. 7 minutes
13) Router the edges. 6 minutes
14) Turn beam over, apply glue and plywood. 8 minutes
15) Nail 4d casing. 17 minutes
16) Set nails. 12 minutes
17) Router on edges. 6 minutes
18) Fill holes, use belt sander, plane edges of flanges. 18 minutes

Elapsed time: 3 hours 25 minutes
Total man hours: 6 hours 50 minutes 410 man minutes

Beam #6 (B7) - 9'-11" x 11 5/8"

Men: Two men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 10' long. 12 minutes
2) Nail together, run through the planer both edges to 3 1/2" wide. 6 minutes
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rip 3 5/8&quot; flanges from 2 x 12 scaffolding grade material 10' long.</td>
<td>6 min</td>
</tr>
<tr>
<td>2</td>
<td>Nail together, run through the planer both edges to 3 1/2&quot; wide.</td>
<td>6 min</td>
</tr>
<tr>
<td>3</td>
<td>Staple-glue stiffeners; cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 5 pieces.</td>
<td>20 min</td>
</tr>
<tr>
<td>4</td>
<td>Place flanges and stiffeners in jig and nail together.</td>
<td>5 min</td>
</tr>
<tr>
<td>5</td>
<td>Squaring flanges and stiffeners.</td>
<td>14 min</td>
</tr>
<tr>
<td>6</td>
<td>Cut plywood web members.</td>
<td>4 min</td>
</tr>
<tr>
<td>7</td>
<td>Apply glue and plywood web members.</td>
<td>5 min</td>
</tr>
<tr>
<td>8</td>
<td>Nail with 4d casing.</td>
<td>12 min</td>
</tr>
<tr>
<td>9</td>
<td>Set nails.</td>
<td>7 min</td>
</tr>
<tr>
<td>10</td>
<td>Scrape off glue.</td>
<td>5 min</td>
</tr>
<tr>
<td>11</td>
<td>Turn beam over, apply glue and plywood.</td>
<td>12 min</td>
</tr>
<tr>
<td>12</td>
<td>Nail.</td>
<td>7 min</td>
</tr>
<tr>
<td>13</td>
<td>Set nails.</td>
<td>4 min</td>
</tr>
<tr>
<td>14</td>
<td>Scrape off glue.</td>
<td>6 min</td>
</tr>
</tbody>
</table>

**Elapsed time:** 1 hour 59 minutes

**Total man hours:** 3 hours 58 minutes

---

**Beam #7 (B7) - 9'-11" x 11 5/8"**

<table>
<thead>
<tr>
<th>Men:</th>
<th>Two men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steps and time:</td>
<td></td>
</tr>
<tr>
<td>1) Rip 3 5/8&quot; flanges from 2 x 12 scaffolding grade material 10' long.</td>
<td>6 min</td>
</tr>
<tr>
<td>2) Nail together, run through the planer both edges to 3 1/2&quot; wide.</td>
<td>6 min</td>
</tr>
<tr>
<td>3) Staple-glue stiffeners; cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 5 pieces.</td>
<td>20 min</td>
</tr>
<tr>
<td>4) Place flanges and stiffeners in jig and nail together.</td>
<td>5 min</td>
</tr>
<tr>
<td>5) Squaring flanges and stiffeners.</td>
<td>14 min</td>
</tr>
<tr>
<td>6) Cut plywood web members.</td>
<td>4 min</td>
</tr>
<tr>
<td>7) Apply glue and plywood web members.</td>
<td>5 min</td>
</tr>
<tr>
<td>8) Nail with 4d casing.</td>
<td>12 min</td>
</tr>
<tr>
<td>9) Set nails.</td>
<td>7 min</td>
</tr>
<tr>
<td>10) Scrape off glue.</td>
<td>5 min</td>
</tr>
<tr>
<td>11) Turn beam over, apply glue and plywood.</td>
<td>6 min</td>
</tr>
<tr>
<td>12) Nail.</td>
<td>12 min</td>
</tr>
</tbody>
</table>
13) Set nails.  
14) Scrape off glue.

Elapsed time: 1 hour 54 minutes
Total man hours: 3 hours 48 minutes

Bean #8 (B9) - 7'-11" x 15 5/8"

Men: Two men
Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 8' long. 5 minutes
2) Nail together, run through the planer both edges to 3 1/2" wide. 5 minutes
3) Stiffeners, cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 3 pieces. 12 minutes
4) Place flanges and stiffeners in jig and nail together. 3 minutes
5) Square flanges and stiffeners. 10 minutes
6) Cut plywood web members. 3 minutes
7) Apply glue and plywood. 4 minutes
8) Nail with 4d casing nails, 3" o.c. 9 minutes
9) Scrape off glue. 5 minutes
10) Turn beam over, apply glue and plywood. 4 minutes
11) Nail. 9 minutes
12) Scrape off glue. 5 minutes

Elapsed time: 1 hour 14 minutes
Total man hours: 2 hours 28 minutes 148 man minutes

Bean #9 (B4) - 7'-7 3/4" x 15 5/8"

Men: Two men
Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 8' long. 5 minutes
2) Run through planer both edges to 3 1/2" wide. 5 minutes
3) Stiffeners; cutting and planing 2 x 4 cutting plywood, applying glue and stapling. 5 pieces. 20 minutes

Elapsed time: 1 hour 14 minutes
Total man hours: 2 hours 28 minutes 148 man minutes
4) Place flanges and stiffeners in jig, secure.  
5) Square flanges and stiffeners.  
6) Cut plywood.  
7) Apply glue and plywood.  
8) Nail 4d casing.  
9) Set nails.  
10) Scrape off glue.  
11) Turn beam over, apply glue and plywood.  
12) Nail.  
13) Set nails.  
14) Scrape off glue.  
15) Router on edges.  
16) Fill holes, belt sander, plane both flanges.

Elapsed time: 1 hour 53 minutes

Total man hours: 3 hours 46 minutes

Beam #10 (B4) - 7'-7 3/4" x 15 5/8"

Men: Two men

Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 9' long.  
2) Run through planer both edges to 3 1/2" wide.  
3) Stiffeners, cutting and planing 2 x 4 cutting plywood, applying glue and stapling. 5 pieces.
4) Place flanges and stiffeners.  
5) Square set-up.  
6) Cut plywood webs.  
7) Apply glue and plywood.  
8) Nail with 4d casing nail.  
9) Set nails.  
10) Scrape off glue.  
11) Router on edges.  
12) Turn beam over, apply glue and plywood.  
13) Nail.  
14) Set nails.  
15) Scrape off glue.  
16) Router on edges.  
17) Fill holes, belt sander and plane flanges.

Elapsed time: 1 hour 59 minutes

Total man hours: 3 hours 58 minutes

226 man minutes
Beam #11 (B3) - 8'-11 1/4" x 15 5/8"

Men: Two men

Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 12' long. 5 minutes
2) Run through planer both edges to 3 1/2" wide. 5 minutes
3) Stiffeners; cutting and planing 2 x 4, cutting plywood, applying glue and stapling, 5 pieces. 20 minutes
4) Place flanges and stiffeners. 3 minutes
5) Square set-up. 6 minutes
6) Cut plywood webs. 6 minutes
7) Apply glue and plywood. 5 minutes
8) Nail with 4d casing nails. 14 minutes
9) Set nails. 8 minutes
10) Scrape off glue. 3 minutes
11) Router on edges. 5 minutes
12) Turn over the beam, apply glue and plywood. 4 minutes
13) Nail. 10 minutes
14) Set nails. 7 minutes
15) Scrape off glue. 3 minutes
16) Router on edges. 5 minutes
17) Fill holes, belt sander and plane flanges. 10 minutes

Elapsed time: 1 hour 59 minutes

Total man hours: 3 hours 58 minutes 238 man minutes

Beam #12 (B2) - 10'-3 1/4" x 15 5/8"

Men: Two men

Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 11' long. 5 minutes
2) Run through planer both edges to 3 1/2" wide. 5 minutes
3) Stiffeners; cutting and planing 2 x 4 and 4 x 4 material, applying glue and stapling, 5 pieces. 20 minutes
4) Place flanges and stiffeners. 5 minutes
5) Square the set-up. 7 minutes
6) Cut plywood webs. 4 minutes
7) Apply glue and plywood. 2 minutes
8) Nail 4d casing. 17 minutes
9) Set nails. 7 minutes
10) Turn beam over, apply glue and plywood. 5 minutes

A-9
11) Nail. 10 minutes
12) Set nails. 6 minutes
13) Scrape off glue. 6 minutes
14) Fill holes, belt sander and plane edges of flanges. 20 minutes

Elapsed time: 1 hour 59 minutes

Total man hours: 3 hours 58 minutes 238 man minutes

Beam #13 (BlA) - 23'-11" x 15 5/8"

Men: Two men

Steps and time: 1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 8 minutes
2) Run through planer, both edges to 3 1/2" wide. 8 minutes
3) Stiffeners; cutting, planing 2 x 4 and 2 x 6 material, cutting plywood, applying glue and stapling. 40 minutes
4) Place flanges and stiffeners in jig. 8 minutes
5) Apply glue, plywood plates. 6 minutes
6) Nail with 4d casing. 18 minutes
7) Set nails. 9 minutes
8) Scrape off glue. 5 minutes
9) Turn beam over, apply glue and plywood. 6 minutes
10) Nail. 17 minutes
11) Set nails. 8 minutes
12) Scrape glue. 5 minutes
13) Fill holes, belt sander and plane edges of flanges. 24 minutes

Elapsed time: 2 hours 42 minutes

Total man hours: 5 hours 24 minutes 324 man minutes

Beam #14 (BlA) - 24'-11" x 15 5/8"

Men: Two men

Steps and time: 1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 8 minutes
2) Run through planer, both edges to 3 1/2" wide. 8 minutes
3) Stiffeners; cutting, planing 2 x 4 and 2 x 6 materials, cutting plywood, applying glue and stapling. 10 pieces.

4) Place flanges and stiffeners in jig and square up.

5) Apply glue, plywood plates.

6) Nail with 4d casing.

7) Set nails.

8) Scrape off glue.

9) Turn beam over, apply glue and plywood.

10) Nail.

11) Set nails.

12) Scrape glue.

13) Fill holes, belt sander and plane edges of flanges.

Elapsed time: 2 hours 39 minutes

Total man hours: 5 hours 18 minutes

318 man minutes

Beam #15 (B1C) - 23'-11" x 15 5/8"

Men: Two men

Steps and time: 1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 17 minutes
2) Plane pieces to 3 1/2" wide. 8 minutes
3) Apply glue between flanges and place in jig for curing. 20 minutes
4) Stiffeners; cutting and planing stiffeners 2 x 4, cutting plywood, applying glue and stapling. 7 pieces. 28 minutes
5) Remove flanges from jig and run through planer to remove glue. 10 minutes
6) Place flanges in jig and insert stiffeners and tack together. 6 minutes
7) Set jig for camber. 10 minutes
8) Apply glue and plywood plates. 5 minutes
9) Nail with 4d casing. 19 minutes
10) Set nails. 15 minutes
11) Scrape glue off sides. 5 minutes
12) Turn beam over and apply glue and plywood. 6 minutes
13) Nail. 17 minutes
14) Set nails. 7 minutes

A-11
15) Scrape off glue. 8 minutes
16) Fill holes, belt sander, plane edges. 28 minutes

Elapsed time: 3 hours 29 minutes
Total man hours: 6 hours 58 minutes 418 man minutes

Beam #16 (B1C) - 23'-11" x 15 5/8"

Men: Two men

Steps and time: 1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 17 minutes
2) Plane pieces to 3 1/2" wide. 8 minutes
3) Apply glue between flanges and place in jig for curing. 20 minutes
4) Stiffeners; cutting and planing stiffeners 2 x 4, cutting plywood, applying glue and stapling. 7 pieces. 28 minutes
5) Remove flanges from jig and run through planer to remove glue. 10 minutes
6) Set jig for 1/4" camber. 10 minutes
7) Apply glue and plywood plates. 5 minutes
8) Nail 4d casing. 17 minutes
9) Set nails. 13 minutes
10) Scrape off glue. 4 minutes
11) Turn beam over, apply glue and plywood plates. 6 minutes
12) Nail. 17 minutes
13) Set nails. 14 minutes
14) Scrape off glue. 3 minutes
15) Fill holes, belt sander, plane edges of beam. 24 minutes

Elapsed time: 3 hours 16 minutes
Total man hours: 6 hours 32 minutes 392 man minutes

Beam #17 (B1C) - 23'-11" x 15 5/8"

Men: Two men

Steps and time: 1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 18 minutes
2) Plane edges to 3 1/2" wide. 9 minutes
3) Apply glue to faces and place in clamps. 20 minutes
4) Stiffeners; cutting and planing stiffeners, cutting plywood, applying glue and stapling, 4 min. per piece, 7 pieces.
5) Remove flanges from jig and run through planer to remove glue.
6) Place flanges and stiffeners in jig with camber.
7) Apply glue and plywood plates.
8) Nail with 4d casing.
9) Set nails.
10) Scrape off glue.
11) Turn beam over, apply glue and plywood plates.
12) Nail.
13) Set nails.
14) Scrape off glue.
15) Fill holes, belt sander, plane edges.

Elapsed time: 3 hours 20 minutes
Total man hours: 6 hours 40 minutes

Beam #18 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long.
2) Plane edges to 3 1/2" wide.
3) Staple glue stiffeners; cutting and planing stiffeners, cutting plywood, applying glue and stapling. 7 pieces.
4) Place flanges and stiffeners in jig and square.
5) Cutting plywood.
6) Apply glue and plywood.
7) Nail with 1 1/2" ring-shanked nails, 3" o.c.
8) Scrape off glue.
9) Turn beam over, apply glue and plywood plates.
10) Nail.
11) Scrape off glue.
12) Plane edges of beam.

Elapsed time: 1 hour 48 minutes
Total man hours: 3 hours 36 minutes

400 man minutes

216 man minutes
Beam #19 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 7 minutes
2) Plane flange edges to 3 1/2". 7 minutes
3) Stiffeners; cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 7 pieces. 28 minutes
4) Place flanges and stiffeners in jig and square. 9 minutes
5) Cutting plywood. 7 minutes
6) Apply plywood and glue. 7 minutes
7) Nail with 1 1/2" ring-shanked nails, 3" o.c. 14 minutes
8) Scrape off glue. 4 minutes
9) Turn beam over, apply glue and plywood. 6 minutes
10) Nail. 14 minutes
11) Scrape off glue. 3 minutes
12) Plane edges of beam. 8 minutes

Elapsed time: 1 hour 54 minutes

Total man hours: 3 hours 48 minutes 228 man minutes

Beam #20 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:  
1) Rip 3 5/8" flanges from 2 x 12 scaffolding grade material 24' long. 8 minutes
2) Plane flange edges to 3 1/2". 7 minutes
3) Stiffeners; cutting and planing 2 x 4, cutting plywood, applying glue and stapling. 7 pieces. 28 minutes
4) Place flanges and stiffeners in jig and square. 8 minutes
5) Cutting plywood. 7 minutes
6) Apply plywood and glue. 6 minutes
7) Nail with 1 1/2" ring-shanked nails 8" o.c. and staple two staples equally spaced between the nails. 10 minutes
8) Scrape glue off beam. 3 minutes
9) Turn beam over, apply glue and plywood. 6 minutes
10) Nail the same as other side. 9 minutes
11) Scrape off glue.
12) Plane edges of beam.

Elapsed time: 1 hour 40 minutes
Total man hours: 3 hours 20 minutes

Beam #21 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:
1) Rip flange material.
2) Plane flange material.
3) Fabricate stiffeners.
   7 pieces.
4) Place materials in jig and square.
5) Cutting plywood.
6) Apply glue and plywood.
7) Nail with 1 1/2" ring-shanked nails 8" o.c. and staple two staples between
   nails.
8) Scrape off glue.
9) Turn beam over, apply glue and plywood.
10) Nail as above.
11) Scrape glue off.
12) Plane flange edges.

Elapsed time: 1 hour 47 minutes
Total man hours: 3 hours 34 minutes

Beam #22 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:
1) Rip flange material.
2) Plane flange material.
3) Fabricate stiffeners.
   7 pieces.
4) Place materials in jig and square.
5) Cutting plywood.
6) Apply glue and plywood.
7) Nail with 1 1/2" ring-shanked nails 8" o.c. and staple with two staples
   between nails.
8) Scrape off glue.
9) Turn beam over, apply glue and plywood.

A-15
10) Nail as before.
11) Scrape off glue.
12) Plane flange edges.

Elapsed time: 1 hour 26 minutes
Total man hours: 2 hours 52 minutes

Beam #23 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:
1) Rip flange material.
2) Plane flange edges.
3) Fabricate stiffeners, 7 pieces.
4) Place materials in jig and square.
5) Cutting plywood.
6) Apply glue and plywood.
7) Nail with 1 1/2" ring-shanked nails 8" o.c. and staple with two staples between nails.
8) Scrape off glue.
9) Turn beam over, apply glue and plywood.
10) Nail as before.
11) Scrape off glue.
12) Plane beam flanges.

Elapsed time: 1 hour 27 minutes
Total man hours: 2 hours 54 minutes
174 man minutes

Beam #24 (B8) - 23'-11" x 11 7/8"

Men: Two men

Steps and time:
1) Rip flange material.
2) Plane flange edges.
3) Fabricate stiffeners, 7 pieces.
4) Place materials in jig and square.
5) Cutting plywood.
6) Apply glue and plywood.
7) Nail with 1 1/2" ring-shanked nails 8" o.c. and staple with two staples between nails.
8) Scrape off glue.

10 minutes
3 minutes
6 minutes
14 minutes
8 minutes
7 minutes
14 minutes
9 minutes
6 minutes
10 minutes
2 minutes
7 minutes
9 minutes
3 minutes

A-16
9) Turn beam over, apply glue and plywood. 6 minutes
10) Nail as before. 10 minutes
11) Scrape off glue. 3 minutes
12) Plane beam flanges. 8 minutes

Elapsed time: 1 hour 28 minutes
Total man hours: 2 hours 56 minutes 176 man minutes
B. FLOOR PANELS

I. Floor panels (F-1, 53 panels) 4'-0" x 8'-0"

1) Cut and stack 2 x 4 x 46 1/4" ribs
2) Assemble and attach plywood with 1 7/8" staples
   Two men
   Elapsed time per panel: 2 minutes 16 seconds
   Average man hours per panel: 4 minutes 32 seconds

II. Floor panels (F-3, 2 panels) 4'-0" x 1'-8"

Same procedure
Two men
Elapsed time per panel: 1 minute 45 seconds
Average man minutes per panel: 3 minutes 30 seconds

III. Floor panels (F-6, 3 panels) 4'-0" x 5'-4"

Same procedure
Two men
Elapsed time per panel: 2 minutes
Average man minutes per panel: 4 minutes

IV. Floor panels (F-4, 2 panels) 4'-0" x 3'-0"

Same procedure
Two men
Elapsed time per panel: 2 minutes
Average man minutes per panel: 4 minutes

V. Floor panels (F-5, 3 panels) 4'-0" x 2'-4"

Same procedure
Two men
Elapsed time per panel: 1 minute 50 seconds
Average man minutes per panel: 3 minutes 40 seconds

VI. Floor panels (F-2, 3 panels) 2'-4" x 8'-0"

Same procedure
Two men
Elapsed time per panel: 2 minutes 25 seconds
Average man minutes per panel: 4 minutes 50 seconds

VII. Plywood spacers for floor panels

Cutting, stacking plywood
Two men
Elapsed time for 27 pieces: 60 seconds
Average man minutes for 27 pieces: 2 minutes
C. WALL PANELS

I. 23 solid wall panels (Type A) 4'-0" x 7'-11" frame
   Men: two men
   Time Included:
   1) Cutting plywood from 4' x 10' sheets to 4'-0" x 8'-8"
   2) Cutting and stacking ribs
   3) Fabrication of panels
   Elapsed time per panel: 6.7 minutes
   Average man minutes per panel: 13.4 man minutes

II. 5 solid wall panels (Type B) 2'-0" x 7'-11" frame
   2 solid wall panels (Type B modified) 1'-0" x 7'-11" frame
   Men: two men
   Time included:
   1) Cutting plywood
   2) Sorting and cutting 2 x 4 members
   3) Fabrication of panels
   Elapsed time per panel: 9.85 minutes
   Average man minutes per panel: 19.7 man minutes

III. 5 framework panels (Type F) 4'-0" x 7'-11" frame
    Men: two men
    Elapsed time per panel: 3.25 minutes
    Average man minutes per panel: 6.5 man minutes

*IV. 1 sloped top panel (Type M) 4'-0" x 9'-6 3/4" frame
    Men: two men
    Elapsed time per panel: 98 minutes
    Average man minutes per panel: 196 man minutes

*V. 1 sloped top panel (Type N) 4'-0" x 10'-6 3/4" frame
    Men: two men
    Elapsed time per panel: 27 minutes
    Average man minutes per panel: 54 man minutes

*VI. 1 sloped top panel (Type O) 4'-0" x 11'-6 3/4" frame
    Men: two men
    Elapsed time per panel: 36 minutes
    Average man minutes per panel: 72 man minutes

*Plans for these panels were misread and a total of 3 hours and 56 man minutes were required to correct the panels.

A-19
D. WINDOW AND DOOR PANELS

1) Cut 10'-2" x 3'-4" for part of bottom chord and post.
2) Cut 44 heel gussets, 32 post gussets, 32 peak gussets.
3) Men: two men
    Elapsed time per panel: 105 minutes
    Man minutes per panel: 210 man minutes

1 triangular clerestory fixed glass window panel (Type P)
12'-0" x 3'-7 3/4" frame
    Men: two men
    Elapsed time per panel: 105 minutes
    Man minutes per panel: 210 man minutes

1 door panel (Type G) 4'-0" x 7'-11" frame
    Men: two men
    Elapsed time per panel: 30 minutes
    Man minutes per panel: 60 man minutes
I. King-post trusses - 24'-8", 3/12 slope. 1/2" plywood, 2 x 4.

1) Cut 16' - 2" x 4" for part of bottom chord and post.
2) Cut 64 heel gussets, 32 post gussets, 32 peak gussets.
3) Mix glue.
4) Fabricate 16 trusses, carry to stack.

Men: two men
Elapsed time per truss: 8 minutes (with photographers)
Average man hour per truss: 16 man minutes (with photographers)

Men: two men
Elapsed time per truss: 10 minutes 30 seconds (no photographers)
Average man hour per truss: 21 man minutes (no photographers)
F. GABLE FRAMING (BEDROOM)

I. Gable ends (two) - 24' - 8" (3/12 slope)

   Modified truss with nails

   Two men
   Elapsed time for two ends: 1 hour 20 minutes
   Man hours for two ends: 2 hours 40 minutes

II. Gable ends - over-hang - 16' - 1" x 1' - 1\(\frac{1}{2}\)"

   Eight separate ladders

   Two men
   Elapsed time for 8 ladders: 3 hours 12 minutes
   Man hours for 8 ladders: 6 hours 24 minutes
Beam #1 (Construction grade 2 x 4 and 2 x 6 plywood)

Men: Two men

Steps and time: Jig assembly and adjusting not included

1) Place 2 x 4 members in jig. Bevel cut one member of bottom chord. 10 minutes
2) Place angled cut 2 x 4 in position, apply glue and plywood, nail with 6d cement coated smooth box nails, 4" o.c. 1 hour 45 minutes
3) Discussion with foreman on drawings 45 minutes
4) Screw plywood and stack (over time for handling nail-glued units). 10 minutes
5) Start second part of the beam, place members, blocks, fit bottom chords. 30 minutes
6) Apply glue, plywood plates, nail-glue. 30 minutes
7) Scrape glue and stack. 10 minutes
8) Cut printed plywood, spread glue and put in press for curing. 30 minutes
9) Wrap individual sections with heavy paper. 15 minutes

Elapsed time: 5 hours 10 minutes (time for one beam = two sections)

Total man-hours: 10 hours 30 minutes (time for one beam = two sections)

Beam #2 (See Above)

Men: Two men

Steps and time:
1) Place 2 x 4 members in jig. Bevel cut one member of bottom chord. 10 minutes
2) Cut and place angled cut 2 x 4 interior members, apply glue and plywood, nail with 6d cement coated smooth box nails, 4" o.c. 1 hour 30 minutes

Fabricated in Chesterton, Indiana
G. CATHEDRAL BEAMS*

(Span 24' - 8" - 3/12 Roof; 1/12 Ceiling)

Beam #1 (Construction grade 2 x 4 and 5/8" plyscord)

Men: Two men

Steps and time: (Jig assembly and adjusting not included)

1) Place 2 x 4 members in jig. Bevel cut one member of bottom chord. 10 minutes
2) Place angled cut 2 x 4 in position, apply glue and plywood, nail with 6d cement coated smooth box nails. 4" o.c. 1 hour 45 minutes
3) Discussion with foreman on drawings. 45 minutes
4) Scrape off glue and stack (over time for handling nail-glued units). 10 minutes
5) Start second part of the beam, place members, blocks, fit bottom chords. 33 minutes
6) Apply glue, plywood plates, nail-glue. 47 minutes
7) Scrape glue and stack. 10 minutes
8) Cut printed plywood, spread glue and put in press for curing. 35 minutes
9) Wrap individual sections with heavy paper. 15 minutes

Elapsed time: 5 hours 10 minutes (time for one beam = two sections)

Total man hours: 10 hours 20 minutes (time for one beam = two sections)

Beam #2 (See Above)

Men: Two men

Steps and time: 1) Place 2 x 4 members in jig, bevel cut one member of bottom chord. 10 minutes
2) Cut and place angled cut 2 x 4 interior members, apply glue and plywood, nail with 6d cement coated smooth box nails, 4" o.c. 1 hour 30 minutes

*Fabricated in Chesterton, Indiana

A-24
3) Scrape off glue and stack 10 minutes
4) Start second part of the beam. Place members, cut blocks, fit bottom chord and interior members. 30 minutes
5) Apply glue plywood and nail-glue as before. 45 minutes
6) Scrape off glue, and stack. 10 minutes
7) Cut printed plywood, spread glue and put in press for curing. 30 minutes
8) Wrap individual sections with heavy paper. 15 minutes

Elapsed time: 4 hours (time for two sections, one beam)

Total man hours: 8 hours

Beam #3

Did not get data
II. ROOF PANELS

Panels B2 and B2A
12 panels - 4'-0" x 10'-0"

Materials: Ungraded 2" x 4" 1/4" plywood with ext. glue (not considered exterior grade plywood.) Inside face of panel - 5/16" MDOP. All plywood was 10' lengths.

Men: Two men

Steps and time:
1) All 2 x 4 ripped to 3 1/2" in width. Includes handling material for 12 panels. 48 pieces. (1" cut from 10' - 2 x 4) 1 man 30 minutes
2) Cutting and handling 2 x 4) stiffeners. 30 minutes
3) Inserting insulation, applying glue, tacking plywood and placing in clamps. Operation per panel, 15 minutes, 12 panels 3 hours

Elapsed time: 5 hours 6 minutes

Total man hours: 10 hours

Average time per panel: 50 man minutes

Panel A1 and A1A
14 panels - 4'-0" x 8'-0"

Materials: 5/16" 8' MDOP, unmarked 3 x 4 3/8" 8' ext. glue plywood

Steps and time:
1) 8' - 2 x 4 cut to 7' 10" and ripped to 3 1/2". 36 pieces, includes stiffeners and handling 2 minutes per piece. 1 hour 45 minutes
2) Inserting insulation, applying glue, tacking plywood and placing in clamps. Operation per panel, 18 minutes. 14 panels, 3 hours 30 minutes

Elapsed time: 6 hours 15 minutes

Total man hours: 12 hours 30 minutes

Panel A1 3 panels - 4'-0" x 12'-0"

Materials: Unmarked 2" x 4" C-D plywood, ext. glue, printed MDOP as bottom skin.

A-26
### H. ROOF PANELS

**Panels R2 and R2A**  
12 panels - 4'-0" x 10'-0"

| Materials: | Ungraded 2 x 4 3/8" plyscord with ext. glue (not considered exterior grade plywood.) Inside face of panel - 5/16" MDOP. All plywood was 10' lengths. |
| Men: | Two men |
| Steps and time: | 1) All 2 x 4 ripped to 3 1/2" in width. Includes handling material for 12 panels. 48 pieces. (1" cut from 10' - 2 x 4) 1 hour 36 minutes  
2) Cutting and handling 2 x 4) stiffeners. 30 minutes  
3) Inserting insulation, applying glue, tacking plywood and placing in clamps. Operation per panel, 15 minutes. 12 panels 3 hours |
| Elapsed time: | 5 hours 6 minutes |
| Total man hours: | 10 hours 12 minutes |
| Average time per panel: | 50 man minutes |

**Panel R1 and R1A**  
14 panels - 4'-0" x 8'-0"

| Materials: | 5/16" 8' MDOP, unmarked 2 x 4 3/8" 8' ext. glue plywood |
| Steps and time: | 1) 8' - 2 x 4 cut to 7' 10" and ripped to 3 1/2"/ 56 pieces. Includes stiffeners and handling 2 minutes per piece. 1 hour 45 minutes  
2) Inserting insulation, applying glue, tacking plywood and placing in clamps. Operation per panel, 15 minutes. 14 panels. 3 hours 30 minutes |
| Elapsed time: | 6 hours 15 minutes |
| Total man hours: | 12 hours 30 minutes |

**Panel R4**  
3 panels - 4'-0" x 13'-6"

| Materials: | Unmarked 2 x 4, 3/8" C-D plywood, ext. glue, printed MDOP as bottom skin. |

A-27
Steps and time:

1) Cut 14' - 2x4's to 13' 4" and rip to 3 1/2" wide. 12 pieces. Handling, stacking, etc., 3 minutes per piece. 48 minutes

2) Inserting members in jig, inserting insulation, applying glue, tacking and placing in clamps, operation per panel, cutting printed plywood, 35 minutes each. 105 minutes

Elapsed time: 2 hours 32 minutes

Total man hours: 5 hours 4 minutes

Average time per panel: 1 hour 55 minutes

Rest of roof panels were not included in time study. The remaining panels were of various designs and members and did not offer representative data.