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DESIGN, CONSTRUCTION, AND EVALUATION OF A LOW COST PANELIZED HOUSE
NEWMAN, J O. 1 OF 1

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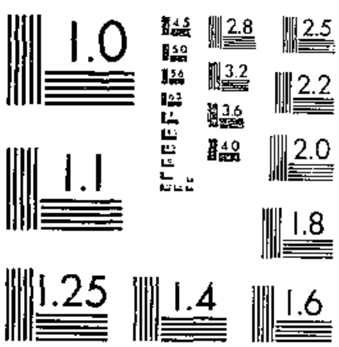

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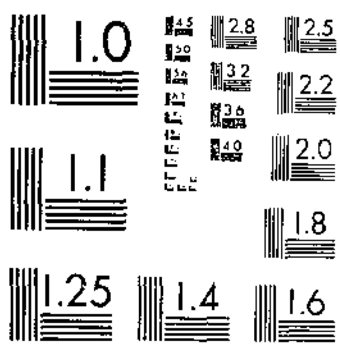

MICROCOPY RESOLUTION TEST CHART
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DESIGN, CONSTRUCTION, AND EVALUATION OF A LOW-COST PANELIZED HOUSE

Technical Bulletin No. 1544

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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DESIGN, CONSTRUCTION, AND EVALUATION OF A LOW-COST PANELIZED HOUSE

By JERRY O. NEWMAN, *research agricultural engineer, Agricultural Research Service, U.S. Department of Agriculture, Clemson, S.C.*

ABSTRACT

This bulletin presents the initial developmental design and step-by-step construction for the first generation of a modular house that can be economically remodeled to meet the changing needs of individual families and one that permits mass production of a variety of designs, shapes, and sizes. Premanufactured foundation panels, built in 2-, 4-, 6-, and 8-foot lengths, have telescoping joints that extend up to 10 inches for connection with nonmodular structures. A new dropped-chord truss increases structural rigidity and provides space for extra insulation. Split-frame wall panels allow the inside panels of the exterior walls to be altered, removed, or replaced without disturbing the outside panels. Moreover, wall thickness can be easily changed for adding insulation or hiding obstructions by shifting the interior panel. The interior walls or partitions are easily relocated, and prefabricated corner panels reduce onsite cutting and fitting to a minimum. **KEY WORDS: foundations, housing, mass production, modular construction, panels, partitions, roof trusses, self-help building, variable module.**

INTRODUCTION

The custom-built houses now being constructed have many shortcomings. They are permanent, expensive, and difficult to modify; they are also difficult and expensive to repair.

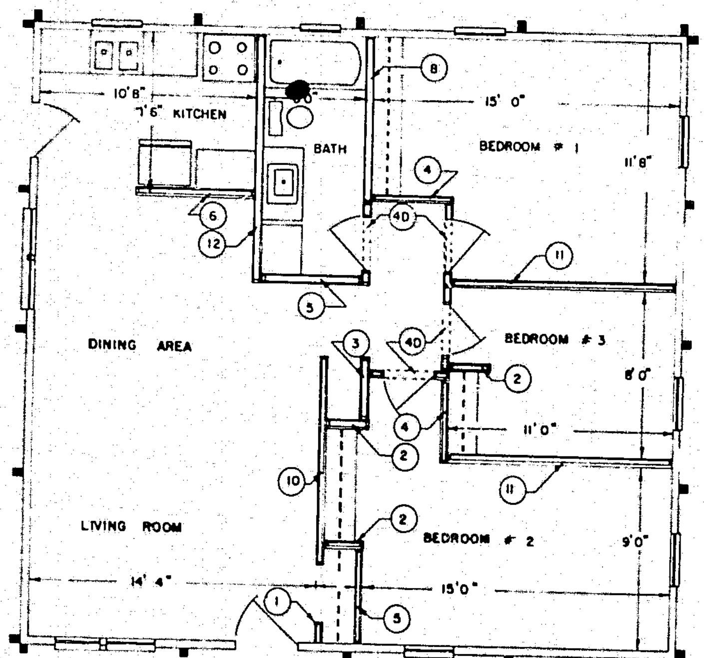
One of the major causes of family dissatisfaction with housing results from their constantly changing needs. The change in need may result from an increase or decrease in family size, a change in economic status, a change in social activities, or a change in the desires of those persons who occupy the house.

Custom-built houses cannot possess the inherent economic advantages gained from factory methods and equipment. The mobile-home industry has dramatically shown the economic advantages of factory techniques on house construction. Repairs in these houses are difficult and expensive because nondurable, short-lived parts or materials are installed behind permanent construction or in inaccessible spaces. A simple waterline or electrical repair may require the skills of several trades.

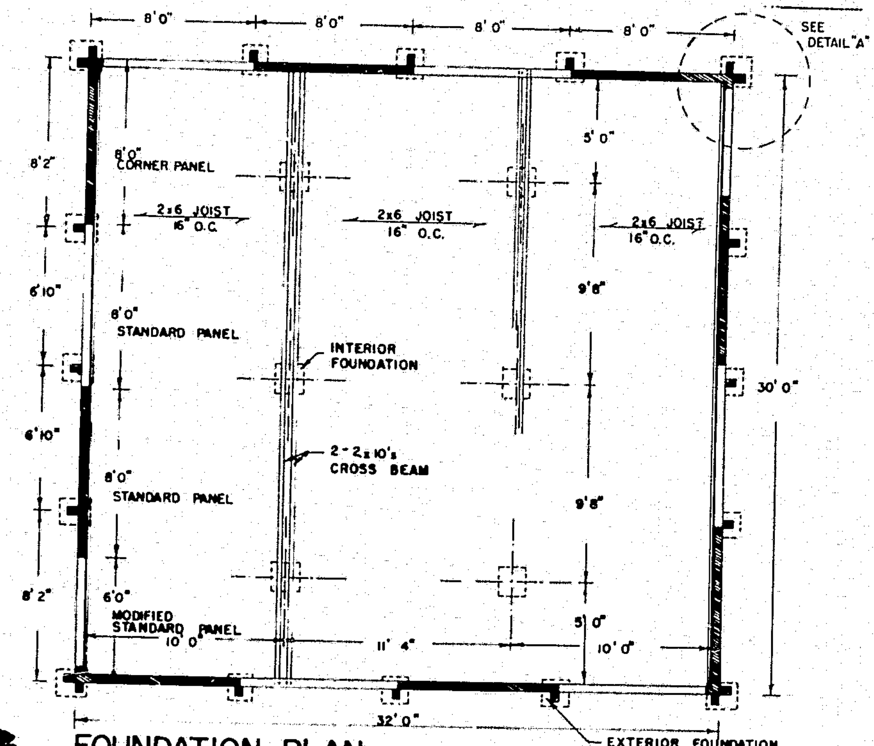
The purpose of this bulletin is to present the first and second generation of a modular construction design that (1) provides a house with the flexibility to allow major changes in floor plans without major structural change, (2) allows home repairing that approaches the simplicity of replacing TV tubes, and (3) provides a house that can be mass-produced without excessive uniformity. The developmental design of each module or panel and the individual steps involved in the construction of this prototype house are discussed in detail.

This house incorporates several features designed to overcome the disadvantages in present housing. The results from research on this house provide a basis for the design and development of future houses that will provide maximum flexibility to designers, assemblers, and homeowners. These houses will make maximum use of economic and time-saving equipment and procedures without creating the monotonous, repetitive creature of many present housing systems.

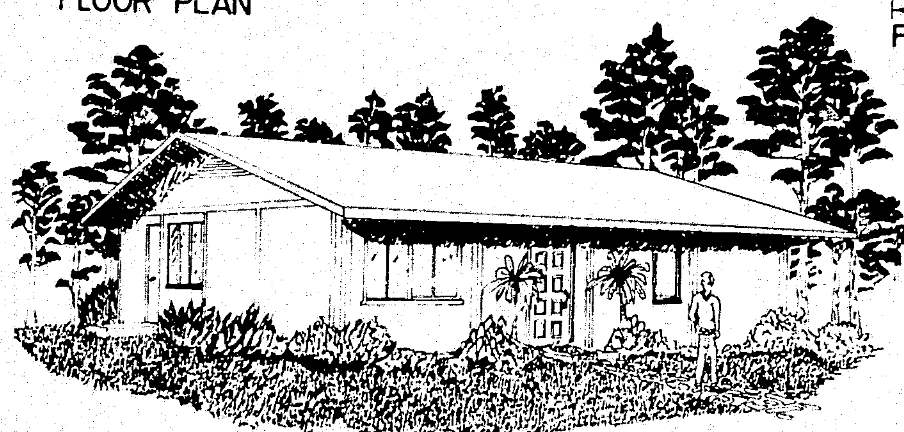
(Continued on page 4.)



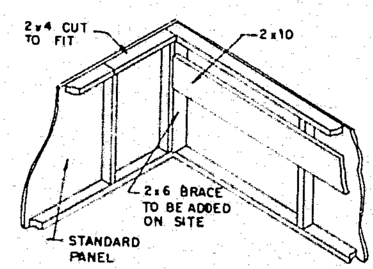
FLOOR PLAN



FOUNDATION PLAN



PERSPECTIVE



DETAIL "A"

PANEL SCHEDULE

MARK	SIZE	NO REQ.
1	1'0" x 8'0"	1
2	2'0" " "	3
3	3'0" " "	1
4	4'0" " "	2
4D	4'0" " "	4
5	5'0" " "	2
6	6'0" " "	1
7	7'0" " "	0
8	8'0" " "	1
9	9'0" " "	0
10	10'0" " "	1
11	11'0" " "	2
12	12'0" " "	1

FIGURE 1.—Perspective, floor plan, and foundation plan for first-generation house.

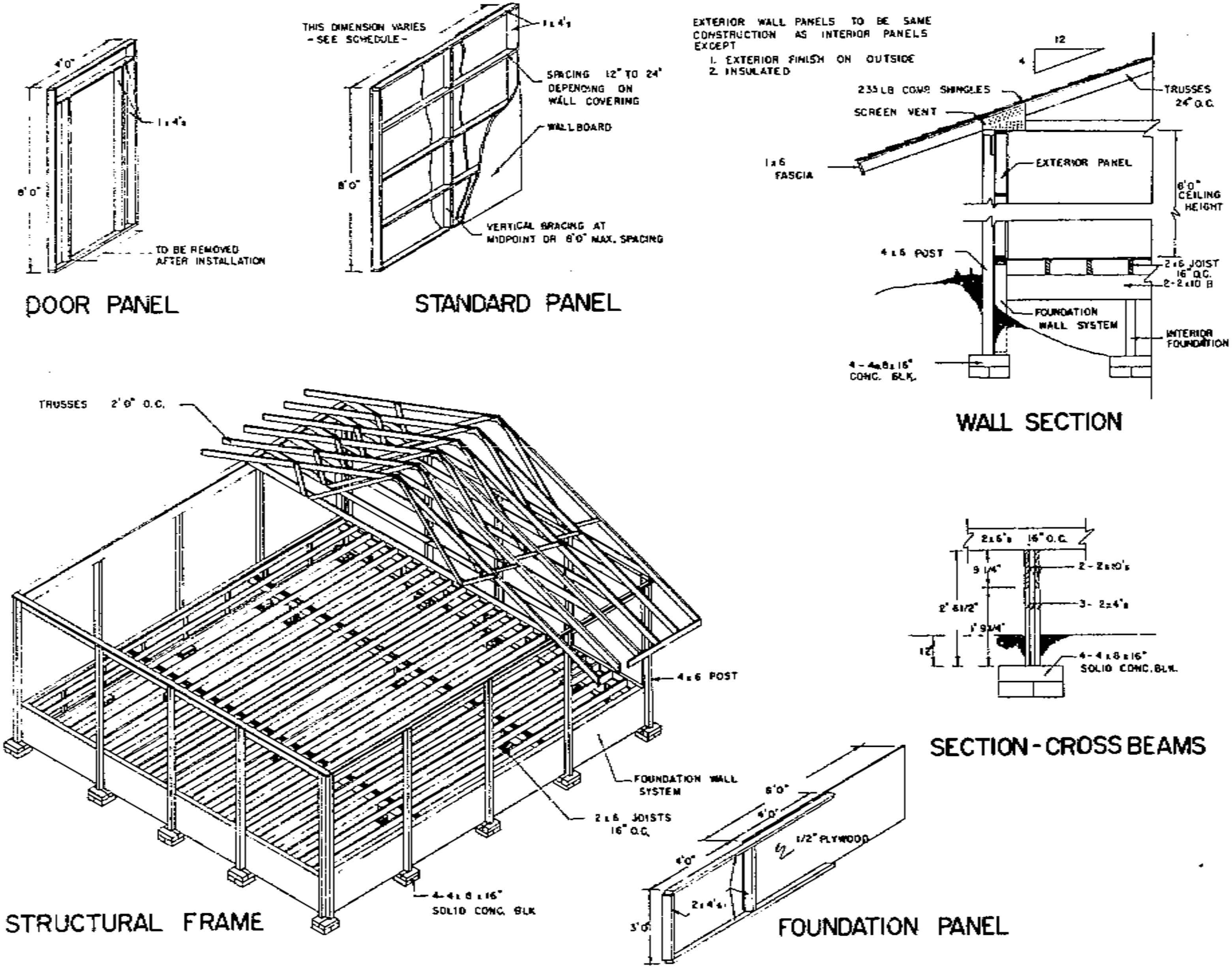


FIGURE 2.—Structural frame, exterior-wall section, cross-beam section, and various panels for first-generation house.

DESIGN AND CONSTRUCTION OF FIRST-GENERATION HOUSE

Only about 50 percent of this house was built of standard premanufactured parts, including the footings, foundation panels, roof trusses, exterior wall panels, and the interior partitions. Complete plans for this house are shown in figures 1 and 2.

Foundation and Framing

Footings

A continuous ditch around the perimeter of the house (fig. 3) provides a base for the pole footings, which were easily leveled with a simple 8-foot level. The footings are solid concrete blocks, which were set at the bottom of the ditch and leveled in a bed of mortar. Crushed rock added to the ditch forms a perimeter drain.

Foundation panels

The foundation panels are 8-foot modules. Each module consists of a pressure-treated, ½-inch-plywood skin and an 8-foot frame of 2 by 4's that supports one-half of the attached plywood skin and projects to support one-half of the skin of the adjacent panel (fig. 4). This frame joins the modules and provides structural continuity from panel to panel. The panels, which were fastened together and properly alined on the leveled footings, form a continuous wall around the structure.

The concrete footings and panels were installed with little difficulty, except for panels that were not square. It was obvious that panels must be built to quite close tolerances because panels with flaws project irregularities to other panels.

It was apparent that corner panels were needed and that straight panels were needed in several lengths. Also, a more positive method of connecting and disconnecting the panels was needed. In addition, it was necessary to devise a method of preventing water from seeping into the cracks at the tops of the foundation panels. The design and development of these features is discussed under "Design Features of Second-Generation House."

Pole frame

The pole frame (which could be precut at the factory) was assembled on the ground at the building site and tilted into place on the footings in three- to five-pole sections (fig. 5). After each section was tilted into place the sections were joined together, and a plate of 2- by 8-inch lumber was attached to the perimeter beam to stiffen and straighten the walls (fig. 6). The pole frame was then custom-fitted and fastened to the foundation wall with two ½-inch bolts at each pole.

The pole frame was easily installed, but a perimeter-beam projection of 7½ inches below the ceil-

FIGURE 3.—Continuous ditch around perimeter of house.

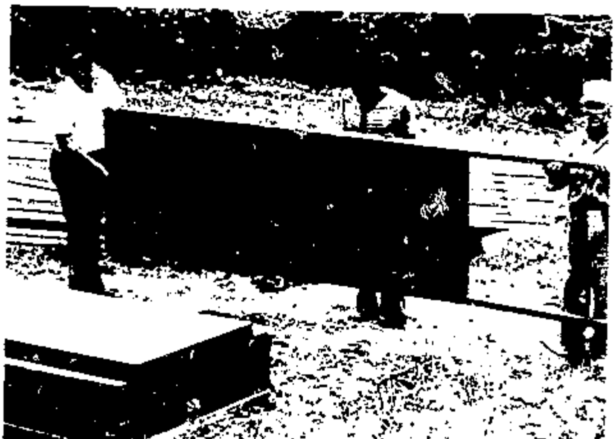


FIGURE 4.—Premanufactured, pressure-treated-plywood foundation panels for first-generation house.

ing line in the finished structure created an obstruction to movement of tall panels or modular units into and out of the structure. The modification to correct this flaw is discussed under "Design Features of Second-Generation House."

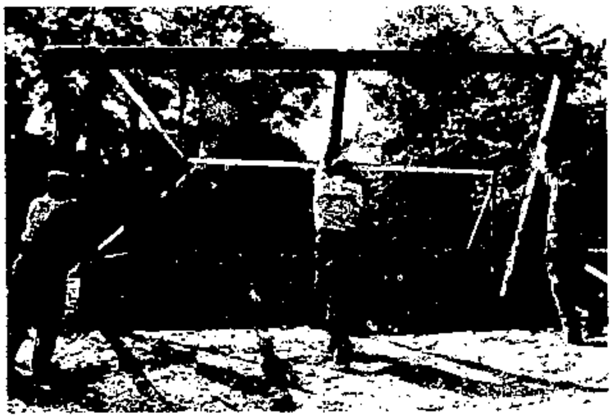


FIGURE 5.—Tilting pole-frame assembly into place.

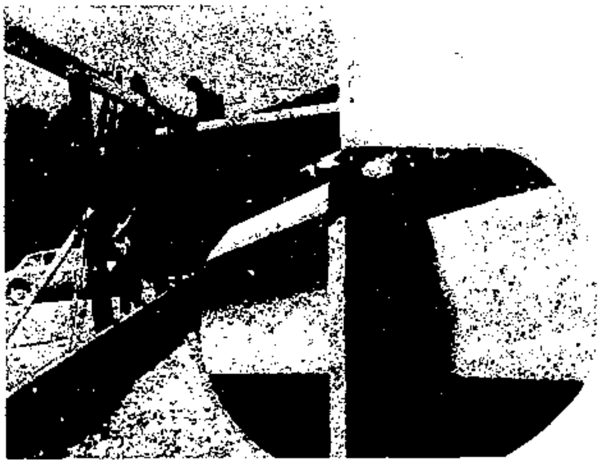


FIGURE 6.—Plate of 2- by 8-inch lumber attached to perimeter beam.

FIGURE 7.—Floor joists (2 by 6's) placed 16 inches on center.

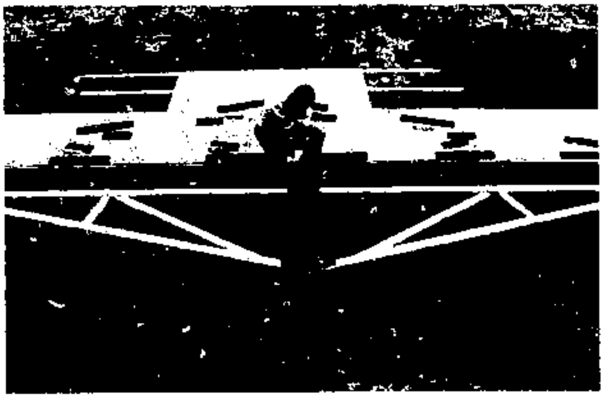


FIGURE 8.—Homemade jig for building trusses.

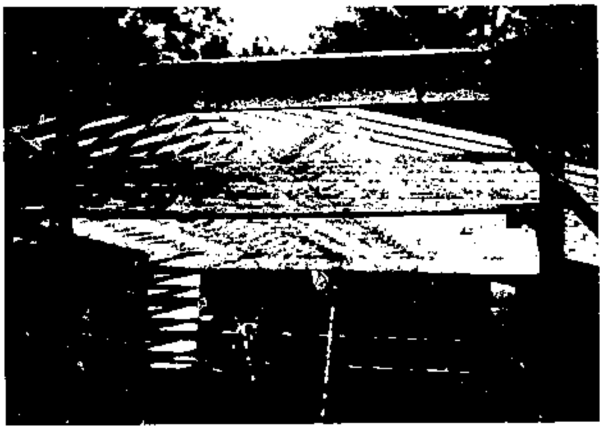


FIGURE 9.—Truss placement on structure.

FIGURE 10.—Installation of ceiling and carpet before interior wall placement

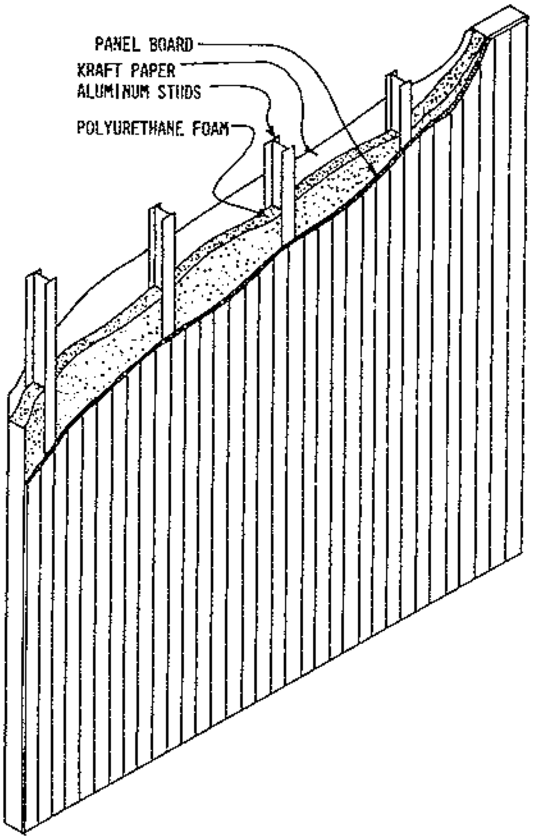


FIGURE 11.—Extruded polyurethane panel with 2- by 4-inch aluminum studs

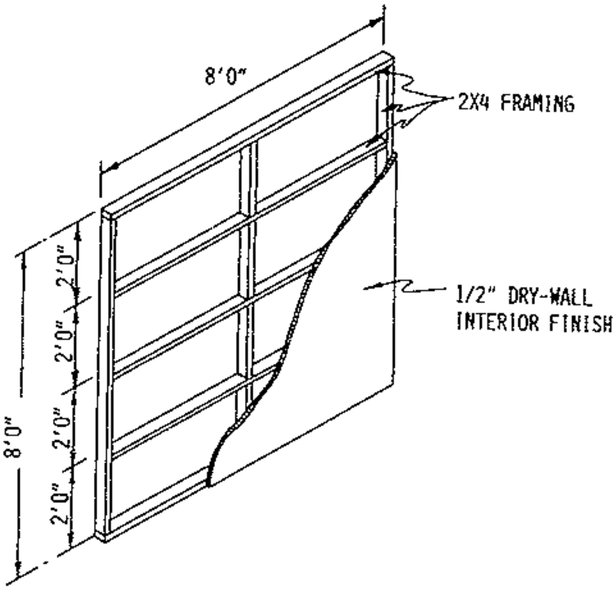


FIGURE 12.—Framed wall panel with horizontal 2 by 4's spaced 2 feet on center.

Floor

The ½-inch-plywood floor is supported on 2- by 6-inch floor joists placed 16 inches on center (fig. 7). The 2 by 6's are continuous for the entire length of the house. The floor joists are supported by four main beams that extend across the width of the house. These main beams, built of 2 by 10's, are also structurally spliced to be continuous. The two end beams are supported on the foundation wall, and the two center beams are supported on posts. The posts were custom-fitted to hold the main beams level. Joints between adjacent sheets of plywood are supported by 2- by 4-inch splicing blocks, which were placed between the floor joists and nailed in place to prevent differential deflection between plywood sheets. The entire floor was custom-built onsite.

Roof trusses

The roof trusses were constructed in a simple homemade jig (fig. 8) by unskilled labor. Each

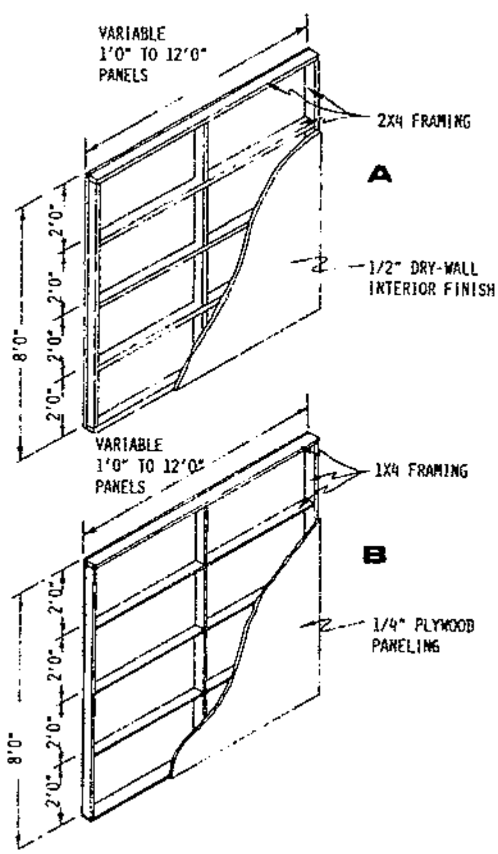


FIGURE 13.—Original and redesigned interior wall panels. *A*, Original panel with 2- by 4-inch framing and ½-inch dry-wall finish. *B*, Redesigned panel with 1- by 4-inch framing and ¼-inch plywood finish.

truss was carried into the structure upside down, set on the perimeter plate beam, and tilted into an upright position (fig. 9). Next, the truss was moved into place along the length of the structure and adjusted for proper overhang on each side. The truss was toenailed in place and then tied down with plumber's strap. The ends of all trusses were marked with a chalk line and cut off square. A 2 by 4 across the ends of the trusses maintained uniform spacing 2 feet on center, supported the edge of the roof, and provided a solid base for attaching gutters and trim.

The roof trusses were installed with no serious problems. However, some improvements were apparently necessary. Positive truss placement was needed to provide uniform spacing of the side walls of the house, and an improved method of fastening the trusses in place was needed to avoid the toenailing and metal-strapping techniques that were used. Moreover, the truss needed to be modified to drop the ceiling below the perimeter beam and thus create more attic space. The design and development of a new roof truss is discussed under "Design Features of Second-Generation House."

Roof

The roof was installed in the conventional manner with ½-inch plywood and standard 235-pound, three-tab shingles. A power nailer was used for fastening the plywood in place, but the shingles were hand-nailed.

With the roof installed, the complete frame is a clear-span structure with pole supports around the perimeter at approximately 8-foot intervals.

FIGURE 14.—Window installation without special framing.

Walls, Partitions, and Interior Finish

Ceiling

The entire ceiling was installed (fig. 10) on the bottom chords of the trusses before any panels or other materials were carried into the house, thus allowing full sheets of dry wall to be used with a minimum of cutting, fitting, and framing. Blocking, framing, and fitting are required around the perimeter of each room when individual rooms are ceiled separately.

Three basic exterior walls were built and installed in this house. The first wall is an extruded polyurethane panel 8 feet tall and 4 inches thick, which is surfaced with panel board on the interior and heavy kraft paper on the exterior (fig. 11). Any length of panel was available, but the panels in this house are 8 feet or 16 feet long. The wall is extruded and it contains 2- by 4-inch aluminum studs (8 feet long) at 2-foot intervals. The second wall panel is a frame built of 2 by 4's placed horizontally and spaced vertically at 2-foot intervals (fig. 12). The interior finish of ½-inch dry wall was attached to the frame at the time of construction, but the exterior covering and insulation were omitted until after the walls were in place. The third wall panel is very similar to the second, except the 2 by 4's are vertical studs.

All exterior panels were cut one-fourth inch

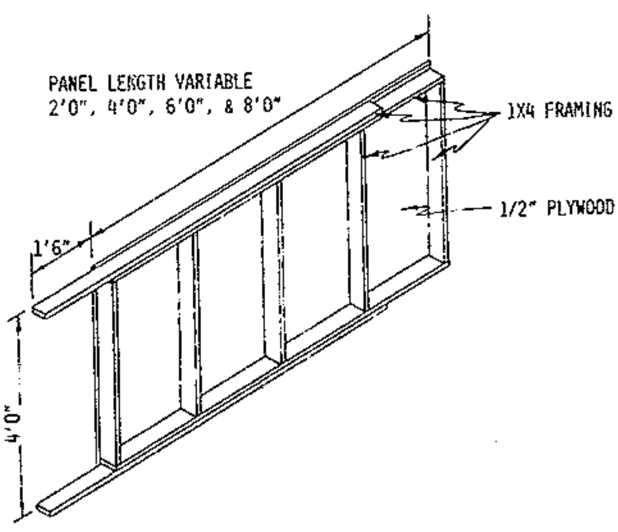


FIGURE 15.—Redesigned foundation panel.

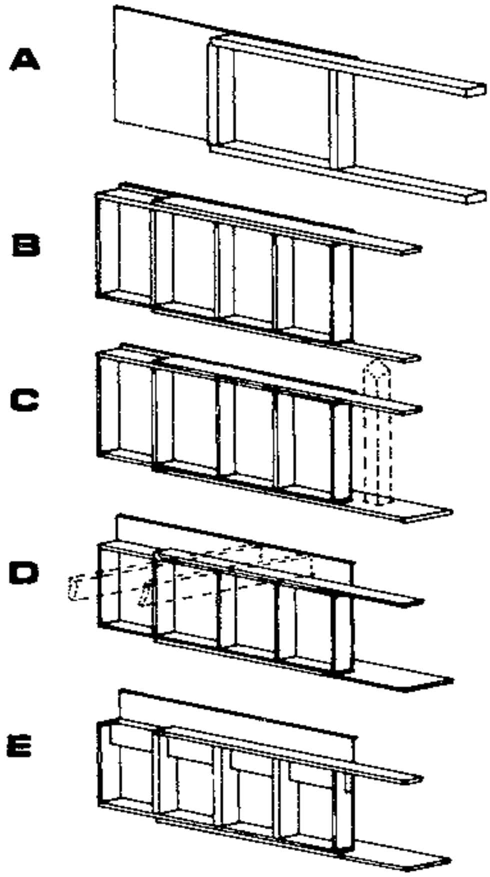


FIGURE 16.—Progressive development in foundation panel design. *A*, First generation panel with 2- by 4-inch framing and ½-inch plywood. *B*, Panel with redesigned frame of 1 by 4's for full skin support and for overlap of framing members. *C*, Panel with wider bearing plate for supporting poles and eliminating concrete footings. *D*, Panel with dropped top plate for providing slot for floor joists. *E*, Panel with 2- by 6-inch top bearing plate for carrying roof and floor loads.

shorter than ceiling height and were fitted into place and secured with wedges, which forced them against the ceiling. The panels were attached to the pole frame with two 8-inch lag bolts at each pole. A special molding was required to cover and hide the undesirable appearance of the lag bolts.

The panels were finished on only one side before being set in place. They were nailed to the floor and ceiling and thus cannot be easily moved. More positive placement and more versatile fastening methods were needed to improve appearance, reduce labor and construction time, and provide more strength for resisting wind load. The design and development of a new exterior wall is discussed under "Design Features of Second-Generation House."

Interior partitions

The interior partitions are constructed of standard panels built in 1-foot lengths up to 12 feet (fig. 13). A special 4-foot door panel was built for a standard 3-foot door. All panel frames are constructed of 2 by 4's (similar to the second exterior wall panels) with dry-wall finish on both sides (fig. 13*A*). Because of their excessive weight, these partitions were dismantled, and new panels were built with 1 by 4's, using the same horizontal framing pattern (fig. 13*B*). To further reduce weight, ¼-inch-plywood paneling was used as the finished surface on both sides. Before any partitions were installed, all carpet, pads, and floor tile were installed. Interior-partition panels were built one-fourth of an inch shorter than ceiling height. The partition panels were tilted into place, forming the walls for all rooms and closets. Each panel was held securely by friction

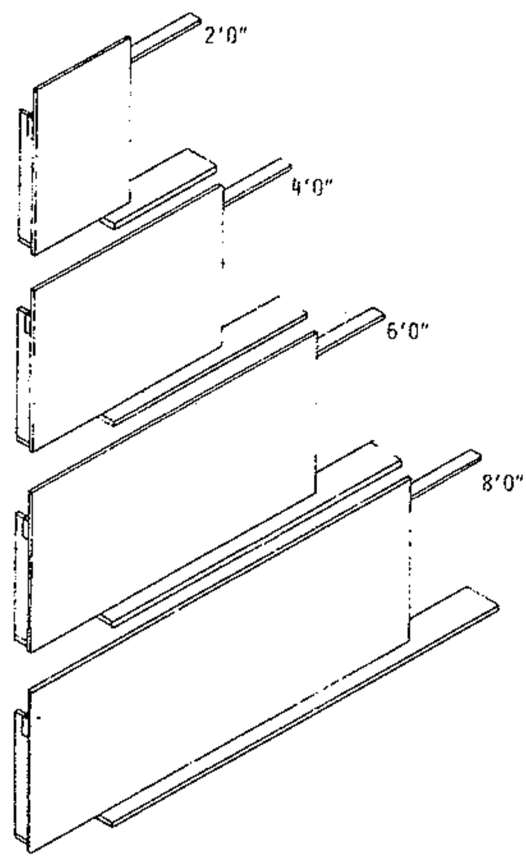


FIGURE 17.—Redesigned foundation panels built in four different lengths.

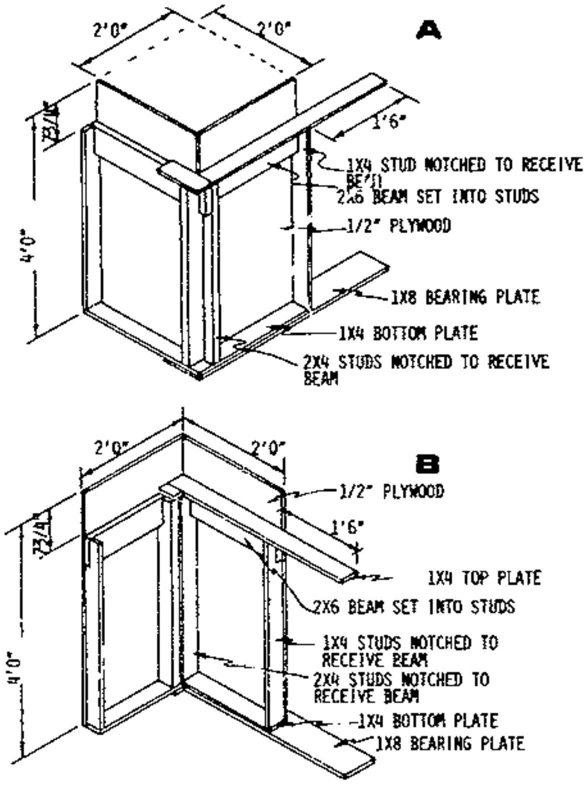


FIGURE 18.—Corner panel design. *A*, Obtuse corner panel. *B*, Standard corner panel.

between the panel and the ceiling by wedges placed under the panels. Most walls also received some lateral support from other panels placed at right angles to them. End caps were custom-fitted over all exposed ends of panels after they were in place.

The interior panels were easily assembled and installed. However, a more positive means of interlocking the panels was needed. The panels can be easily moved to relocate walls.

Doors and windows

No special framing was required for the installation of doors and windows because all exterior walls are non-load-bearing curtain walls. Proper size holes were cut in the polyurethane panels, and the window units were inserted into the openings. The interior trim was then attached to secure the window units and to decorate the perimeter of the openings (fig. 14). The doors and frames were installed in a similar fashion.

Utilities

The wiring in this house is a surface-mounted complex contained in a two-piece steel baseboard ½ inch by 2 inches in size. A prewired harness was installed in prestamped outlet openings at 30-inch intervals. The feeder wires enter the house through a standard custom-wired, 200-amp service entrance equipped with circuit breakers.

The standard custom-installed plumbing system is supplied with city water, and the sewage system is connected to a central aeration plant.

BREAKDOWN OF COSTS BY FUNCTIONAL UNIT

Since one of the primary concerns of this project was to reduce costs of housing for low-income persons, a complete record of all costs for this house was maintained. Table 1 is basically an actual cost record except for a few items that were used from stock purchased at an earlier date. Estimated costs for these items are listed. Also, the costs of some items that were left over, wasted, or lost are included. This cost record breaks down the costs by functional items, but more important, it provides a basis for comparison of costs for future generations of this house. It also provides a basis for evaluation cost savings on functional items as they are changed or improved in future designs.

TABLE 1.—*Cost breakdown for prototype house*

Item	Cost
Footings and site work:	
Grading and digging	$191.00
Stone fill and drive	26.38
Other	23.92
Solid concrete block	26.40
Total	267.70
Foundation (pressure-treated wood):	
Standard panels, 3- by 8-ft (8 @ $20.60)	164.80
Corner panels (4 @ $31.29)	125.16
Rigid urethane insulation (2 in by 1 ft by 124 ft)	124.00
Vapor barrier, 4 mil, (3- by 124-ft)	2.39
Total	416.35
Floor framing and deck:	
Cross beams	86.89
Cross-beam supports (treated)	11.44
Floor joists	133.76
Subflooring	234.56
Building paper	1.48
Total	468.13
Floor finish:	
Vinyl asbestos (198 ft² @ $0.45)	126.70

TABLE 1.—*Cost breakdown for prototype house*—Continued

Item	Cost
Floor finish—Continued:	
Carpet (762 ft² @ $0.53)	403.86
Total	530.56
Pole frame:	
Posts	192.00
Bolts	15.44
Perimeter beams	42.41
Cap plates	42.41
Total	292.26
Roof truss assembly:	
Standard trusses (15 @ $12.33)	184.95
Gable ends (2 @ $18.54)	37.08
Total	222.03
Roof deck and covering:	
Plywood, ½-in, 4- by 8-ft (39 panels @ $10.15)	396.00
Felt, 15-lb (1,224 ft²)	9.18
Shingles, 235-lb (30 sq)	172.00
Other	25.56
Total	602.74
Ceiling:	
Gypsum board, ½-in, 4- by 8-ft (32 sheets @ $1.60)	51.20
Insulation	138.09
Labor-ceiling finish	140.00
Total	329.29
Exterior wall No. 1:	
Polyurethane foam panels (124 ft @ $6.00)	744.00
Windows (8 @ $39.00)	312.00
Exterior doors (2) and frame	175.00
Prime siding (32 sheets @ $8.80)	281.60
Furring strips and lag bolts	20.40
Total	1,533.00
Exterior wall No. 2:	
Framed wall (2-by 4-in lumber)	
Frame	89.60
Gypsum board (interior)	51.20
Prime siding (exterior)	281.60
Insulation	100.00
T-molding	12.88
Windows (8 @ $39.00)	312.00
Exterior doors (2) and frame	175.00
Total	1,022.28
Gable ends and eaves:	
Vents	16.64
Lumber	61.28
Prime siding	5.10
Thermoply	30.00
Total	166.78
Exterior finish:	
Calking, molding, and paint	69.67
Interior partition:	
1-ft panel (1 @ $3.10)	3.10

TABLE 1.—*Cost Breakdown for prototype house*—Continued

Item	Cost
Interior partitions—Continued:	
2-ft panel (3 @ $6.08)	18.24
3-ft panel (1 @ $9.36)	9.36
4-ft door panel (4 @ $12.64)	50.56
4-ft panel (2 @ $12.16)	24.32
5-ft panel (1 @ $14.96)	14.96
6-ft panel (1 @ $17.76)	17.76
8-ft panel (1 @ $23.36)	23.36
10-ft panel (2 @ $29.44)	58.88
11-ft panel (1 @ $32.24)	32.24
12-ft panel (1 @ $35.04)	35.04
Total	287.82
Interior finish:	
Doors and frames	139.10
Dry-wall	81.00
Molding, calk, paint, nails, etc.	156.88
Total	376.98
Plumbing	444.27
Electrical:	
Potomac Edison	28.00
L & T contractor	150.00
Wire mold	100.00
Install wire mold	150.00
Fan vent (bath)	39.95
Total	467.95
Heating:	
Coal stove	100.00
Registers	23.50
Pipe	16.00
Bath heater	108.00
Vents and grills	41.90
Total	289.40
Cabinets	558.65
Total, materials:	
For exterior wall No. 1	7,323.58
For exterior wall No. 2	6,812.86
Miscellaneous	455.46
Labor (651 hours)	1,898.20
Water hookup	125.00
Lot	1,200.00
Grand total:	
For exterior wall No. 1	11,002.24
For exterior wall No. 2	10,491.52

DESIGN FEATURES OF SECOND-GENERATION HOUSE

The first-generation house provided reassurance of the overall concept of a house built from standardized panels, and it unveiled features that needed improvement. On this basis, a second-generation house was designed, incorporating several improvements and increasing the degree of panelization.

Foundation and Framing

Foundation panels

Several improvements were made in the basic foundation panel.[1] The new foundation panel has a full-perimeter frame that supports the entire plywood skin and features 1- by 4-inch double plates with staggered joints that overlap with the adjacent panel to form a telescoping joint (fig. 15). Figure 16 shows several panel modifications that can be incorporated for special uses.

The redesigned foundation is made up of six standard panels that can be assembled to fit houses of almost any shape. Straight panels are built in 2-, 4-, 6-, and 8-foot lengths (fig. 17). A standard corner panel and an outside or obtuse corner panel reduce onsite cutting and fitting and improve the structural stability of the corner joint (fig. 18). The two corner panels allow the fitting of standard panels with other than rectangular floor plans. All panels are joined by a telescoping connection, which allows a panel to slide into its precise location. The telescoping joint can be expanded up to 10 inches for structures not modular in length (fig. 19).

[1] Newman, J. O. 1976. Standard modular foundation panels for houses of all shapes. U. S. Dep. Agric. Tech. Bull. No. 1541.

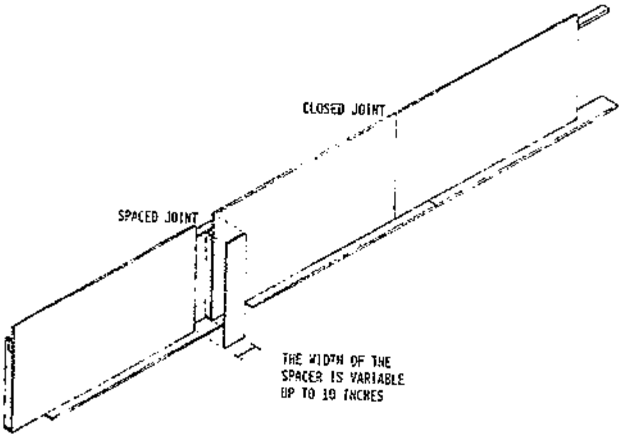


FIGURE 19.—Standard foundation panel with telescoping joints.

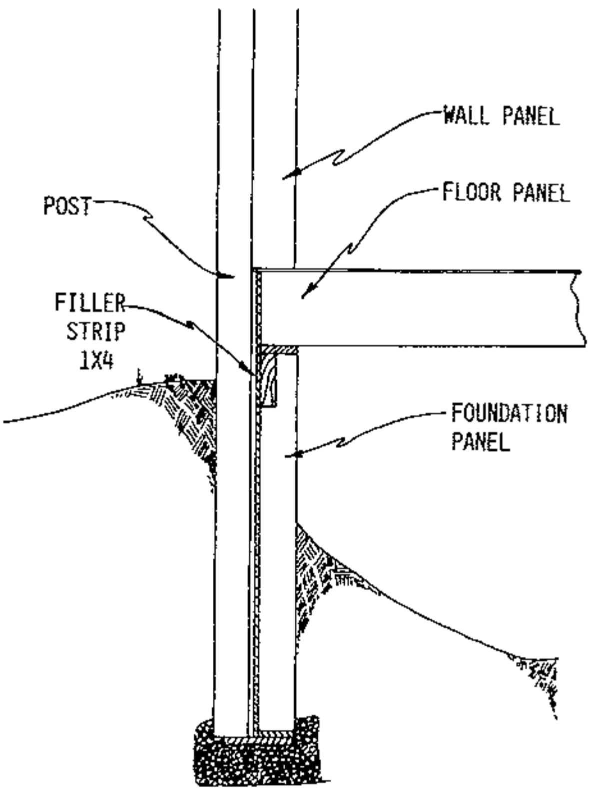


FIGURE 20.—Foundation wall section with filler strip.

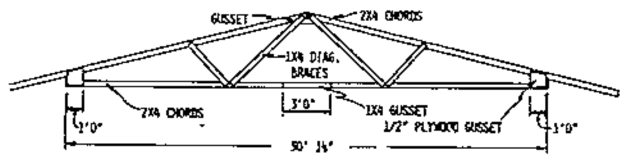


FIGURE 21.—Dropped-chord roof truss.

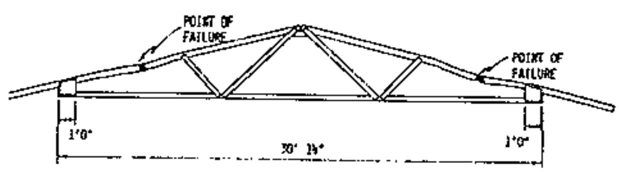


FIGURE 22.—Roof truss showing points of failure under a uniformly distributed load of 40 pounds per square foot.

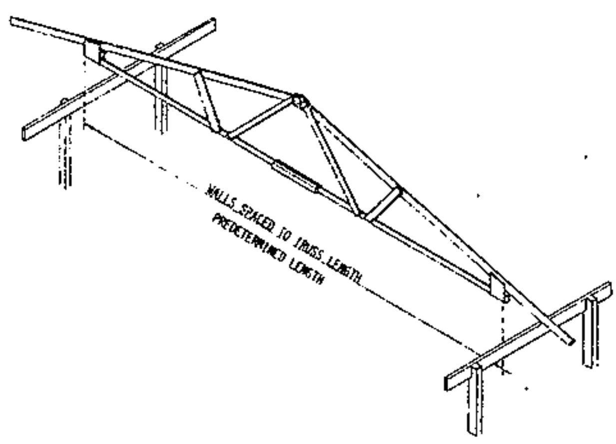


FIGURE 23.—Roof-truss and pole-frame assembly.

When joints are expanded or telescoped, a spacer block must be added to cover the space between panels. One must be sure that the spacer blocks are made from pressure-treated wood of the same quality used in the basic foundation panels.

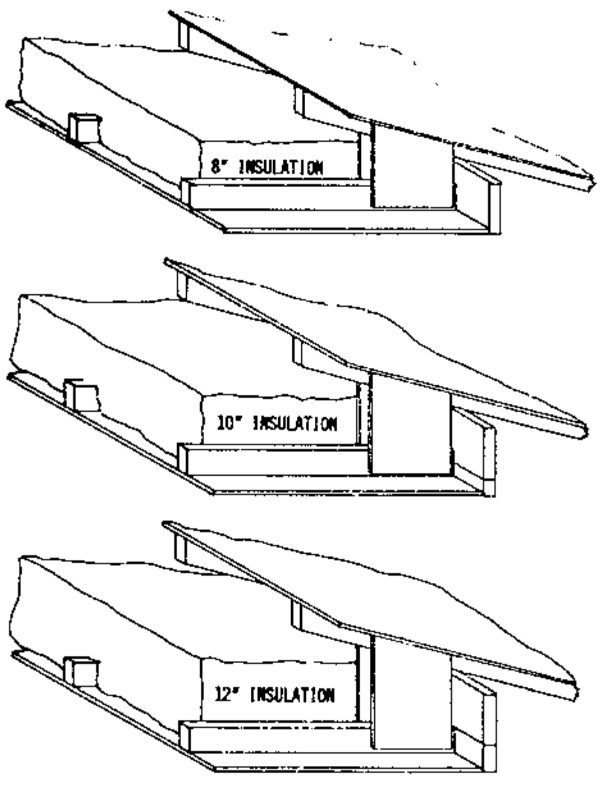


FIGURE 24.—Insulation pockets created by dropped chord.

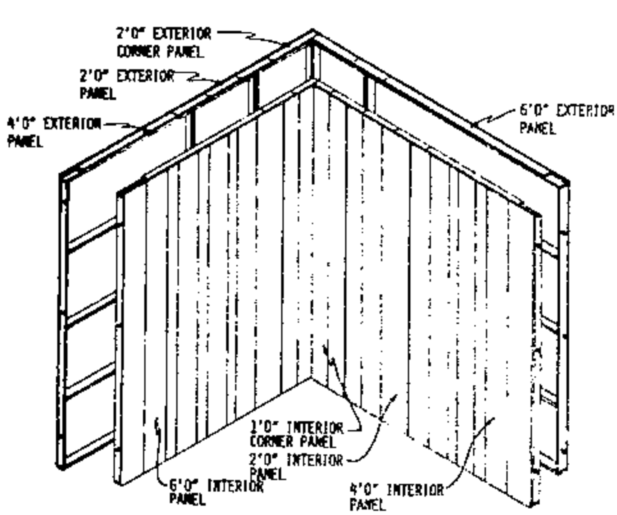


FIGURE 25.—Interior and exterior split-frame wall panels.

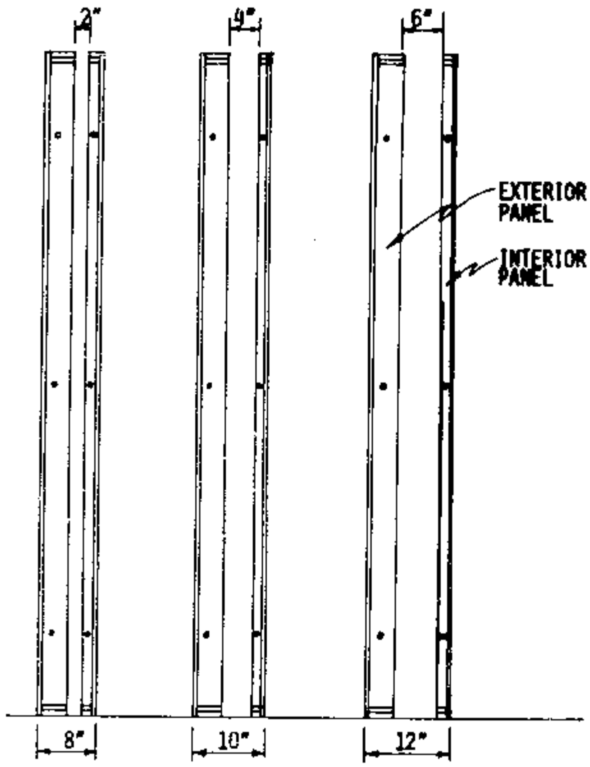


FIGURE 26.—Cross section of exterior wall showing variations in panel spacing for adding insulation or for hiding obstructions.

Pole frame

The problem of water flowing into the crack at the base of the wall panels was solved by placing a 1-inch filler strip between the poles and the foundation panels (fig. 20).

The poles of the pole frame were lengthened approximately 8 inches to raise the perimeter beam above the ceiling line and provide full clearance for inserting modular units into the space between the floor and the ceiling. This change created the need to redesign the roof truss in order to maintain the ceiling at its original height.

Dropped-chord roof truss

The extension of the post and the intrusion of the beam resulted in a new truss design that is superior in many aspects to the old truss. The new truss, or "dropped-chord truss", was so named because the lower tension chord was lowered 8 inches to a position between the perimeter beams, thus dropping the ceiling below the perimeter beams (fig. 21). The interior braces were lengthened, and larger gusset plates were required to assemble the truss. Since the dropped chord destroyed the regular triangular sections of the truss, it was necessary to conduct loading tests on the new truss, using the same nailing schedule as designed for a regular 30-foot truss at a 25-pound load.

All trusses that failed did so as a result of local bending of the top chord between the end gusset and first brace (fig. 22). In no case did the interior braces fail, nor were there any indications of failures at the nailed joints.

The dropped-chord truss provides several structural and construction advantages. (1) The bottom chord of the truss fits between the perimeter beams instead of on top of them (fig. 23), thus providing a positive, uniform spacing of the side walls of the house along its entire length. (2) The

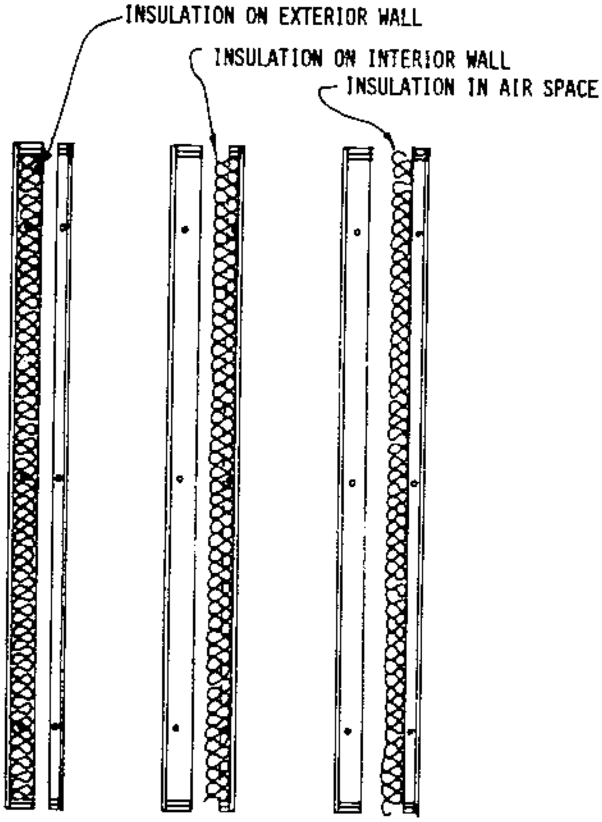


FIGURE 27.—Cross section of exterior wall showing variations in insulation placement.

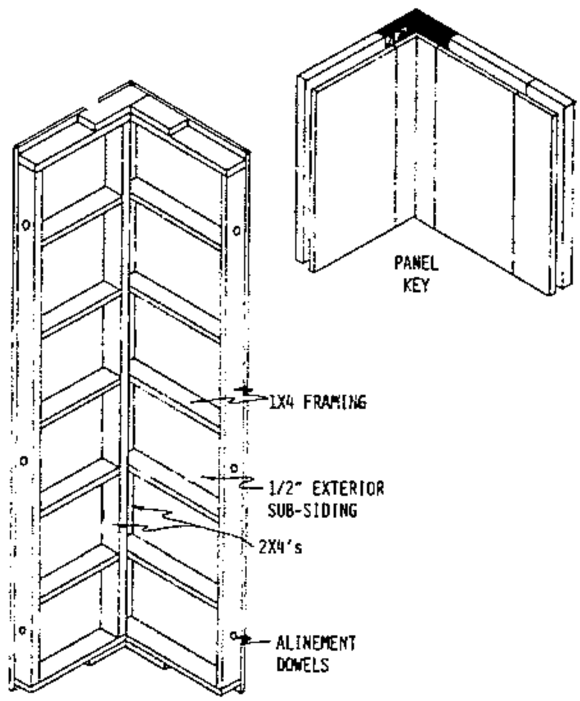


FIGURE 29.—Exterior corner split-frame panel

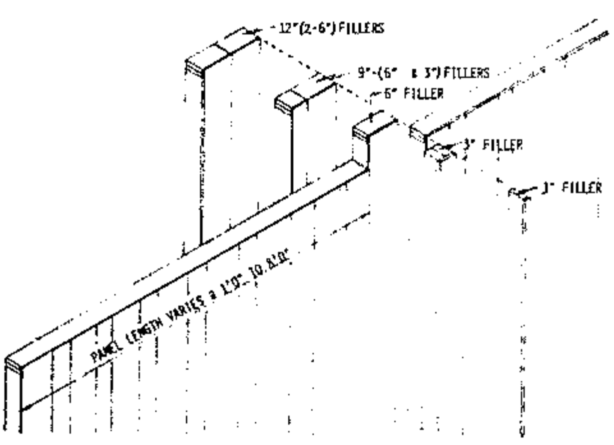


FIGURE 28.—Exterior panels and filler strips.

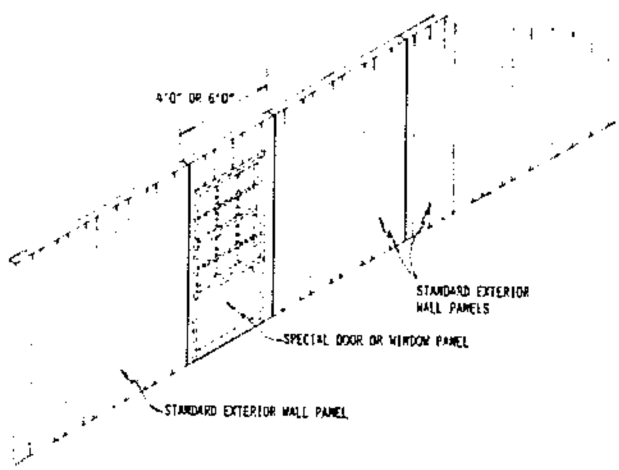


FIGURE 30.—Special door or window panel for exterior walls

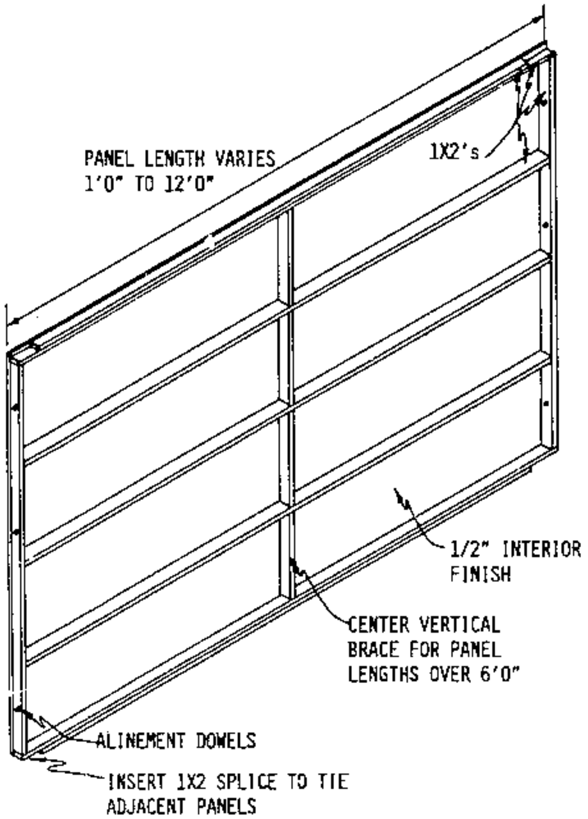


FIGURE 31.—Interior panel of exterior wall.

truss no longer needs to be fastened in place by toenails and straps, since nails are driven through the perimeter beam and into the end of the bottom chord of the truss, providing a rigid, shear-type joint. (3) The dropped chord provides space for placement of insulation (fig. 24) and eliminates one of the common attic-ventilation problems caused by insulation spilling into or being stuffed into the overhanging section of roof, thus inhibiting airflow and creating a sweating and decaying problem.

Split-Frame Wall Panels

The exterior walls for the second-generation house are split-frame panels (fig. 25). With the split-frame concept, a wall panel is finished on only one side. To form a complete wall, interior and exterior panels are required, and two rows of panels are placed back to back. Since the two rows are independent, the interior panels can be altered, changed, removed, or replaced without disturbing the exterior panels. The thickness of the wall can be varied by shifting the interior row of panels (fig. 26).

A need for added insulation may require a increase in wall thickness. Insulation can be in stalled on exterior or interior panels or in th space between the panels (fig. 27).

The exterior panels have a ½-inch, C–D exteri or plywood sub-siding mounted on a frame of by 4's; a better grade of finish can be added afte installation. The panel is built in 1-foot incre ments up to 8 feet, and special filler strips are de signed in 1- to 11-inch lengths to complete th length of irregular or nonmodular spans (fig. 28)

(Continued on page 18.)

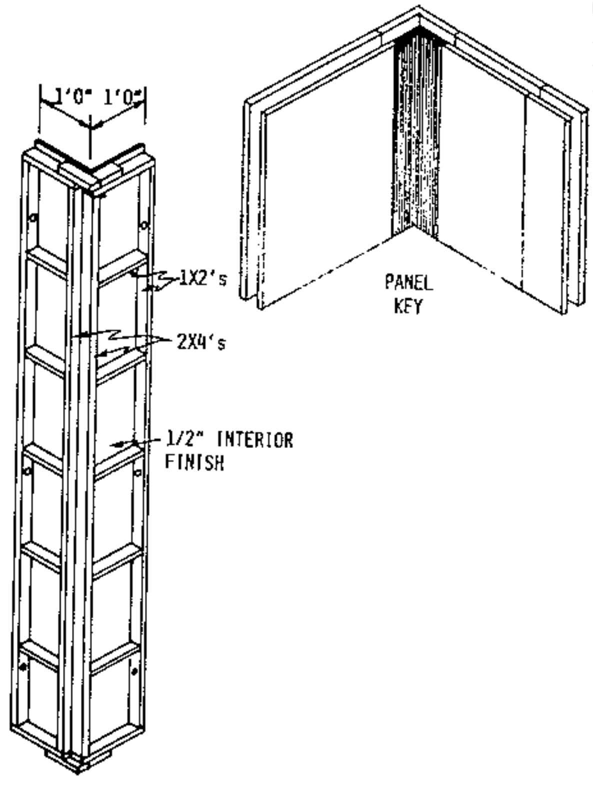


FIGURE 32.—Interior corner split-frame panel.

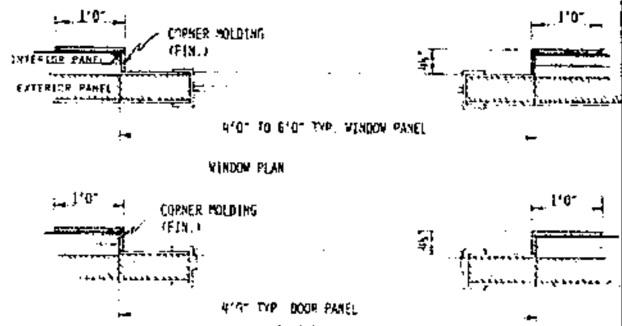
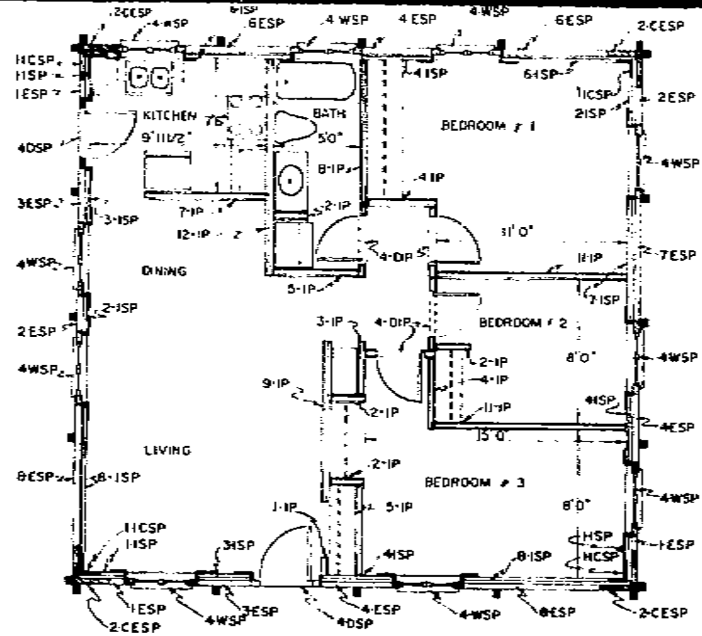


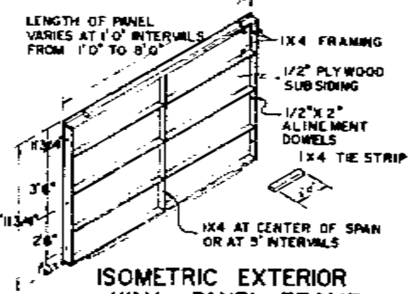
FIGURE 33.—Door and window-panel molding.



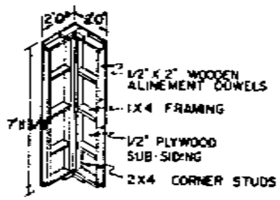
FLOOR PLAN

PANEL SCHEDULE

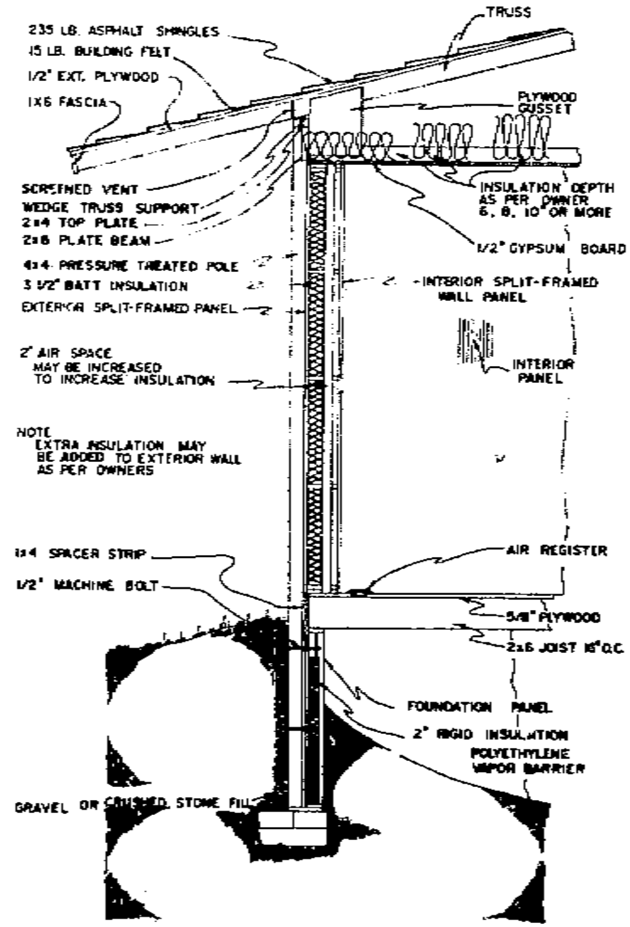
PANEL I.D.	DESCRIPTION OF PANEL	LENGTH
ESP	EXTERIOR SPLIT FRAME WALL PANEL	1'0" - 8'0"
CESP	EXTERIOR CORNER SPLIT-FRAMED WALL PANEL	2'0"
WSP	EXTERIOR WINDOW PANEL	4'0"
DSP	EXTERIOR DOOR PANEL	4'0"
ISP	INTERIOR SPLIT-FRAMED WALL PANEL	1'0" - 8'0"
ICSP	INTERIOR CORNER SPLIT-FRAME WALL PANEL	1'0"
FILL STRIP	INTERIOR WALL FILLER STRIP	1" - 1'0"
IP	INTERIOR PARTITION PANEL	1'0" - 12'0"



ISOMETRIC EXTERIOR WALL PANEL FRAME



ISOMETRIC EXTERIOR CORNER WALL PANEL



SECTION EXTERIOR WALL SYSTEM

FIGURE 34.—Floor plan, exterior wall section, and exterior wall panels for second-generation house.

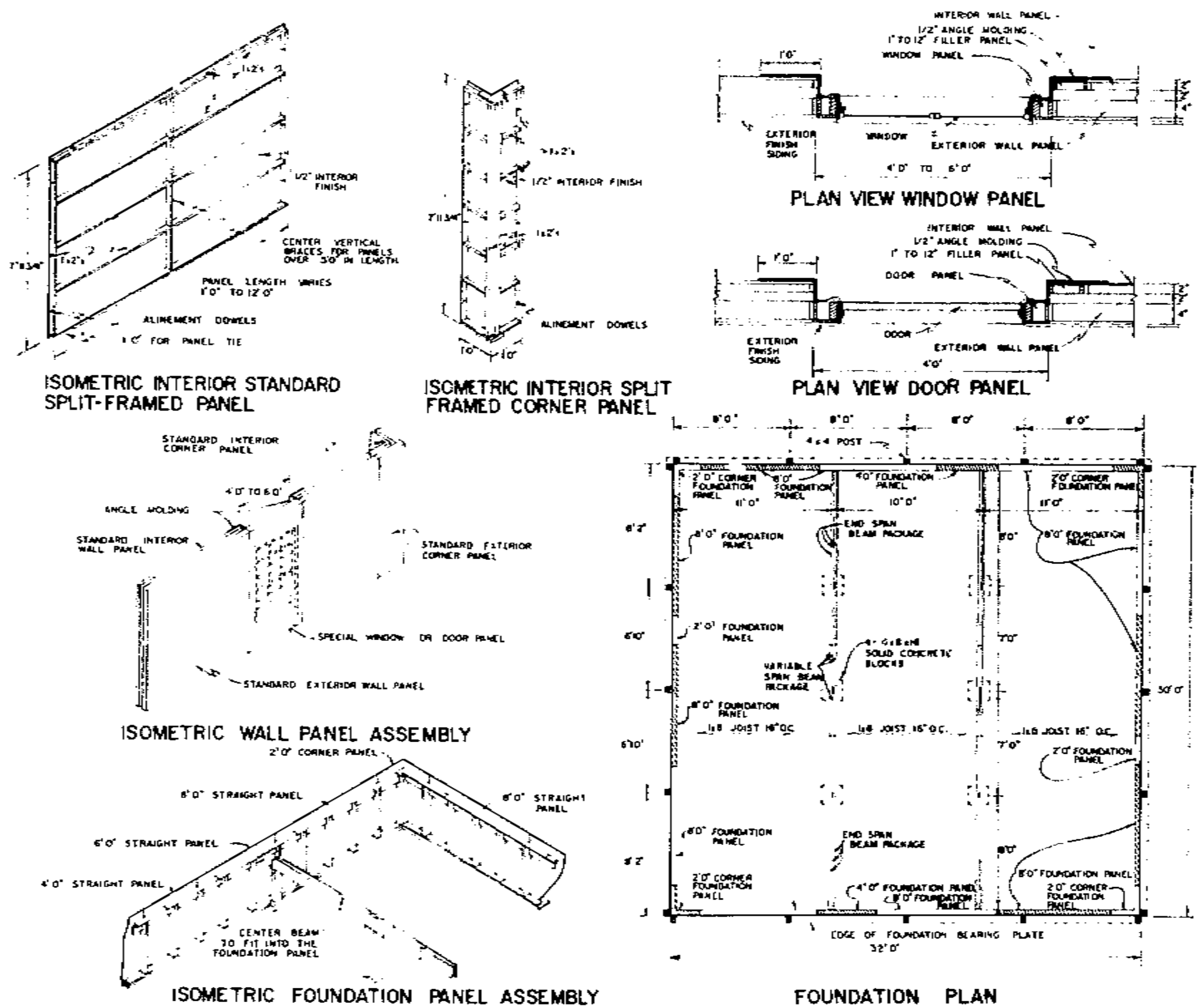


FIGURE 35. — Foundation plan and various panels for second-generation house.

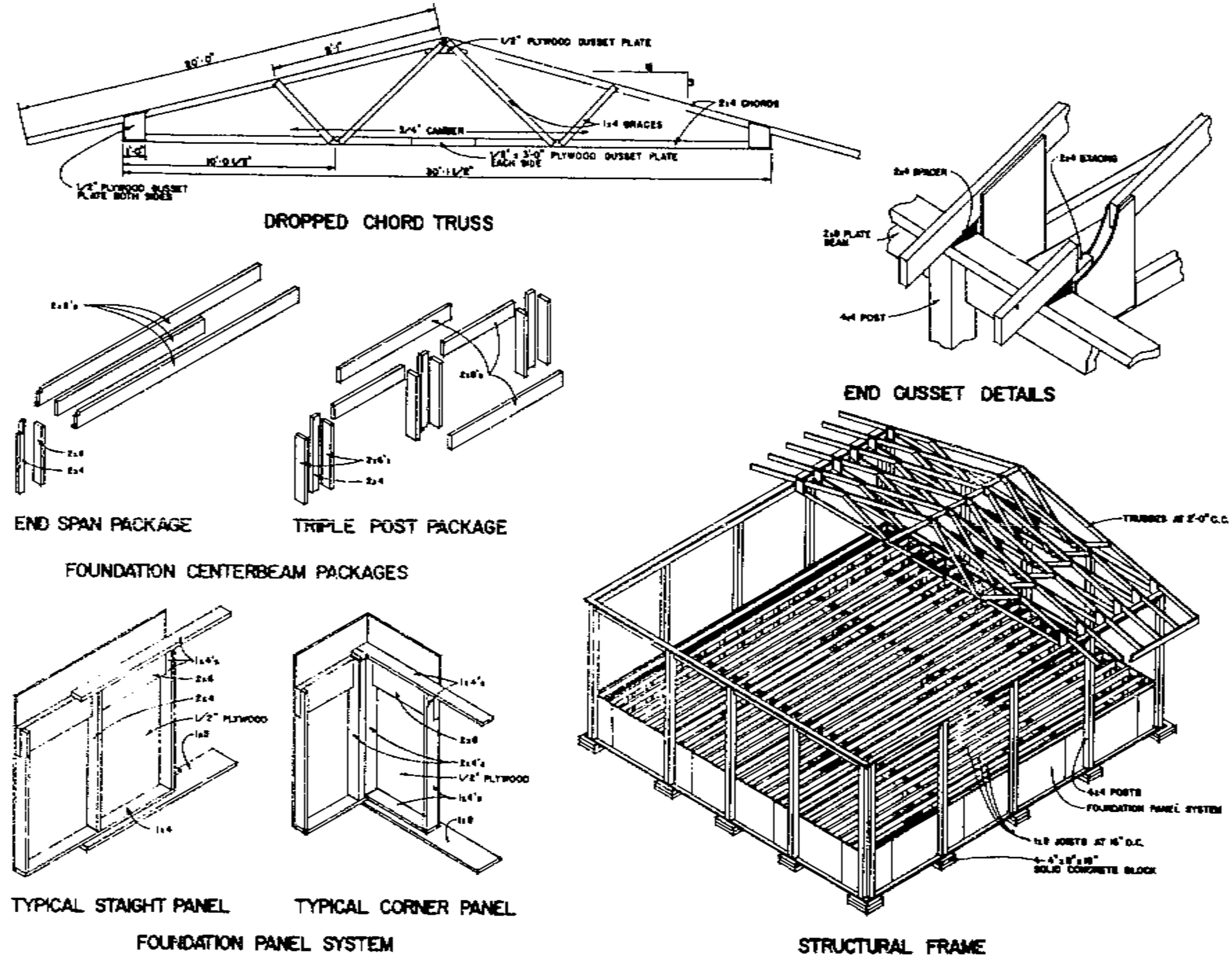


FIGURE 36.—Structural frame, dropped-chord truss, end gusset, and foundation panels and packages for second-generation house.

Corners are formed by special corner panels that eliminate cutting and fitting and provide a strong, tightly sealed structural and functional unit for either standard or obtuse corners (fig. 29).

The windows and doors are contained in special panels. Door or window panels are inserted in the place of standard 4- or 6-foot panels (fig. 30). The door and window panels are not split framed, but they have a sub-siding exterior finish and an interior finish.

The interior finish of the interior panel is attached to a frame of 1 by 2's. The panels are available in 1- to 12-foot lengths (fig. 31). The basic frame is similar to that of the exterior panels, and the prefabricated corner panels reduce onsite fitting to a minimum (fig. 32).

The interior panels form the finished wall spans between the door and window panels. Each span of wall is independent of other spans; thus, a starting and finishing molding or paneling is used at each door and window panel (fig. 33). This molding or paneling includes a cover plate that extends 12 inches along the wall on each side of the window or door and serves as the interior finish from the interior panel to the finished window. Thus, when 1-foot modular panels will not fit or complete a span of wall, 1- to 12-inc' nondecorative filler panels are added to complete the span behind the 12-inch decorative cover. The complete plans for the second-generation house are shown in figures 34, 35, and 36.

DISCUSSION

The variable-length foundation panels are adaptable to houses of almost any design, shape, or size. Use of this design would reduce onsite labor, cut weather delays, and provide a solid, well-insulated, long-lived foundation.

The dropped-chord truss is adaptable to standard housing, and it increases the structural integrity of the house. The redesigned pole frame and the split-frame panel greatly increase the degree of flexibility and versatility in house design and construction.

Cost and insulation are apparently the major considerations for exterior panels. The polyurethane panels were relatively low in cost (75 cents per square foot) but still projected above the cost of the lightweight-frame panels, which were as low as 40 cents per square foot, including insulation.

Though the wiring in this house was confined to the baseboard and other wire molding, special techniques will be required if wiring is to be included in the foamed panels.

The dry-wall ceiling was taped and spackled and the carpet was laid before the partitions were installed. However, the textured ceiling finish was not applied until all partitions were in place. Once the technique for erecting this house is firmly established, the ceiling should be painted before the floor covering is in place to save time and reduce cleanup cost.

New ideas are being considered for incorporation into future prototype houses, and additional ideas will develop from the construction of the second-generation house. Panelized floor and roof systems are already under consideration.

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