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The Curved Roof Machinery Building

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A large number of the combined bent-rafter-and-frame machinery storage buildings have been built throughout the Middle West. In many of these the arch members were made in the form of a semi-circle. One advantage of this arch type structure is economy of construction. The enclosure is secured with a minimum of material. Another advantage comes from the fact that it is well adapted to partial prefabrication and this, combined with the fact that less material is used, results in a saving in labor of construction.

While this type of structure makes for simplicity in design, the former plan, as it was being used, offered some very definite disadvantages. The first objection is to the appearance of the structure, since the round roof is not a pleasing shape and does not blend well with other buildings. The second objection is from the structural point of view. The material in the center section of the rafter-frame combination is not well placed to withstand the stresses

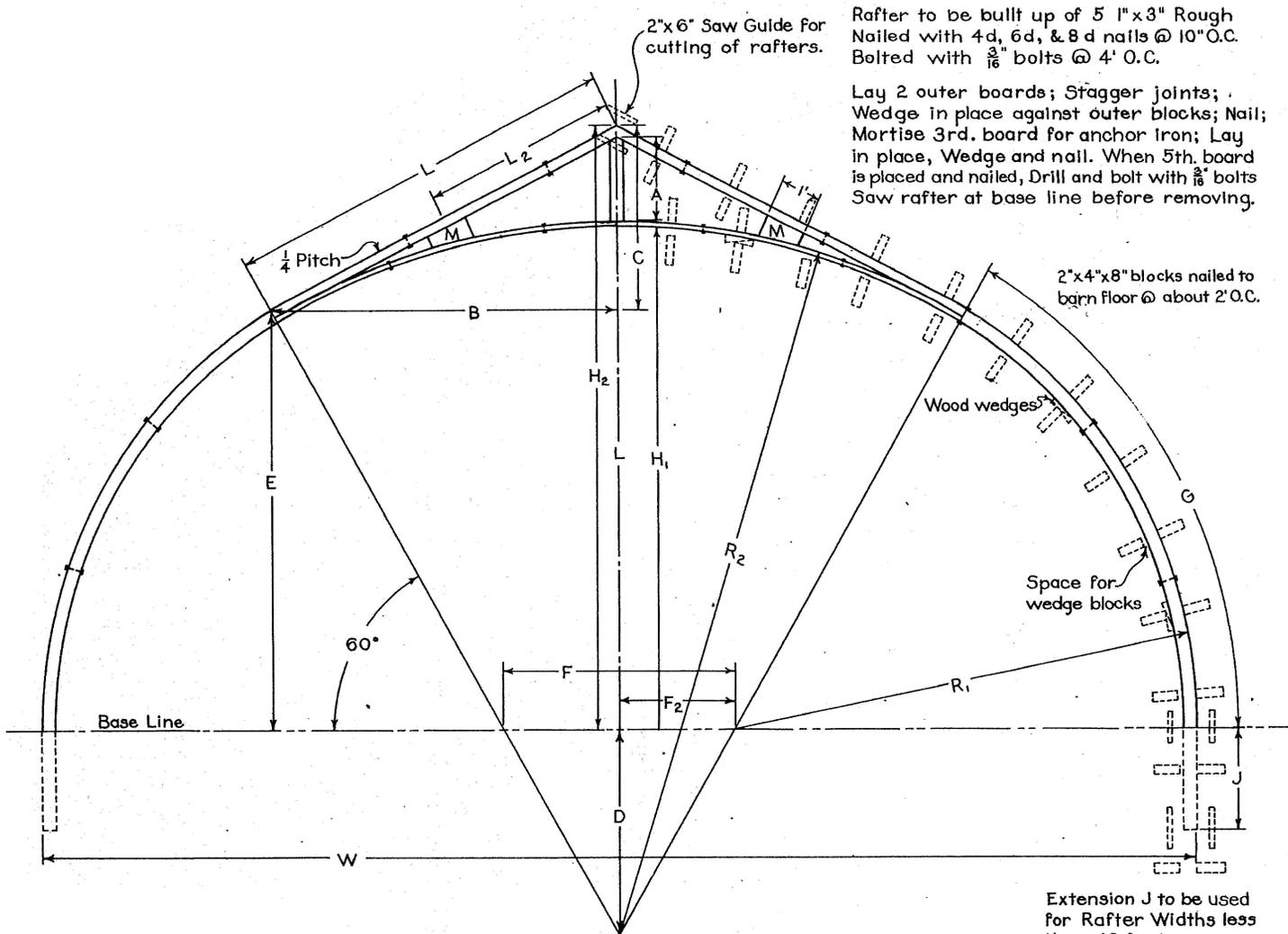


Fig. 1.—The design of a curved arch for various widths.

Extension J to be used for Rafter Widths less than 16 feet.

TABLE OF PROPORTIONAL DIMENSIONS FOR VARIOUS WIDTHS

| WidthW | R ₁ | R ₂ | A | B | C | D | E | F | F ₂ | G | H ₁ | H ₂ | L | L ₂ | J |
|--------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|------------------------------------|------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|-------------------------------------|------------------------------------|-------|
| 10' | 4'-0" | 5'-9 ³ / ₄ " | 0'-8 ¹ / ₂ " | 3'-0" | 1'-6" | 1'-8 ³ / ₄ " | 3'-5 ³ / ₄ " | 2'-0" | 1'-0" | 4'-2 ¹ / ₂ " | 3'-11 ¹ / ₄ " | 4'-11 ³ / ₄ " | 3'-4" | 1'-8" | 2'-0" |
| 12' | 4'-9 ¹ / ₂ " | 7'-0 ¹ / ₄ " | 0'-9 ¹ / ₂ " | 3'-7 ¹ / ₄ " | 1'-9 ¹ / ₂ " | 2'-1" | 4'-1 ³ / ₄ " | 2'-4 ³ / ₈ " | 1'-2 ³ / ₈ " | 5'-0 ³ / ₈ " | 4'-9 ³ / ₄ " | 5'-11 ¹ / ₄ " | 4'-1" | 2'-0 ¹ / ₂ " | 1'-0" |
| 14' | 5'-7 ¹ / ₄ " | 8'-2 ¹ / ₂ " | 0'-10 ³ / ₈ " | 4'-2 ¹ / ₂ " | 2'-1 ¹ / ₄ " | 2'-5 ⁵ / ₈ " | 4'-10 ¹ / ₄ " | 2'-9 ³ / ₄ " | 1'-4 ⁷ / ₈ " | 5'-10 ¹ / ₂ " | 5'-9 ⁵ / ₈ " | 6'-11 ¹ / ₂ " | 4'-8 ¹ / ₂ " | 2'-4 ¹ / ₄ " | 0'-6" |
| 16' | 6'-4 ³ / ₄ " | 9'-5" | 1'-1" | 4'-9 ¹ / ₂ " | 2'-4 ³ / ₄ " | 2'-9 ¹ / ₄ " | 5'-6 ¹ / ₂ " | 3'-2 ¹ / ₂ " | 1'-7 ¹ / ₄ " | 6'-8 ¹ / ₂ " | 6'-6 ¹ / ₄ " | 7'-11 ¹ / ₄ " | 5'-4 ³ / ₈ " | 2'-8 ¹ / ₄ " | 0'-0" |
| 18' | 7'-2 ¹ / ₂ " | 10'-7 ¹ / ₄ " | 1'-3" | 5'-4 ³ / ₄ " | 2'-8 ¹ / ₂ " | 3'-1 ¹ / ₂ " | 6'-3" | 3'-7 ¹ / ₄ " | 1'-9 ⁵ / ₈ " | 7'-6 ¹ / ₂ " | 7'-4 ¹ / ₂ " | 8'-11 ¹ / ₂ " | 6'-3" | 3'-1 ¹ / ₂ " | 0'-0" |
| 20' | 8'-0" | 11'-9 ³ / ₄ " | 1'-4 ¹ / ₂ " | 6'-0" | 3'-0" | 3'-5 ¹ / ₂ " | 6'-11 ¹ / ₄ " | 4'-0" | 2'-0" | 8'-4 ¹ / ₂ " | 8'-2 ³ / ₄ " | 9'-11 ¹ / ₄ " | 6'-8 ¹ / ₂ " | 3'-4 ¹ / ₄ " | 0'-0" |
| 22' | 8'-9 ¹ / ₂ " | 13'-0" | 1'-6 ³ / ₄ " | 6'-7 ¹ / ₄ " | 3'-3 ¹ / ₂ " | 3'-10 ¹ / ₄ " | 7'-7 ¹ / ₂ " | 4'-4 ³ / ₄ " | 2'-2 ³ / ₈ " | 9'-2 ¹ / ₂ " | 9'-0 ¹ / ₄ " | 10'-11" | 7'-1" | 3'-6 ¹ / ₂ " | 0'-0" |
| 24' | 9'-7 ¹ / ₄ " | 14'-2 ¹ / ₂ " | 1'-8 ³ / ₄ " | 7'-2 ¹ / ₄ " | 3'-7 ¹ / ₄ " | 4'-2 ¹ / ₄ " | 8'-4" | 4'-9 ³ / ₄ " | 2'-4 ⁷ / ₈ " | 10'-0 ¹ / ₂ " | 9'-10 ¹ / ₂ " | 11'-11 ¹ / ₄ " | 8'-0 ¹ / ₂ " | 4'-0 ¹ / ₄ " | 0'-0" |
| 26' | 10'-4 ³ / ₄ " | 15'-5" | 1'-9 ¹ / ₄ " | 7'-9 ¹ / ₂ " | 3'-10 ³ / ₄ " | 4'-6" | 9'-0" | 5'-2 ³ / ₈ " | 2'-7 ¹ / ₄ " | 10'-10 ³ / ₄ " | 10'-9 ¹ / ₂ " | 12'-10 ³ / ₄ " | 8'-8 ¹ / ₂ " | 4'-4 ¹ / ₄ " | 0'-0" |
| 28' | 11'-2 ¹ / ₂ " | 16'-7 ¹ / ₄ " | 1'-1 ¹ / ₂ " | 8'-4 ³ / ₄ " | 4'-2 ¹ / ₂ " | 4'-10 ¹ / ₄ " | 9'-8 ¹ / ₂ " | 5'-7 ¹ / ₄ " | 2'-9 ⁵ / ₈ " | 11'-9 ¹ / ₄ " | 11'-7 ¹ / ₂ " | 13'-11" | 9'-4 ³ / ₄ " | 4'-8 ³ / ₈ " | 0'-0" |
| 30' | 12'-0" | 17'-9 ³ / ₄ " | 2'-0 ³ / ₄ " | 9'-0" | 4'-6" | 5'-2 ¹ / ₄ " | 10'-4 ³ / ₄ " | 6'-0" | 3'-0" | 12'-7 ¹ / ₄ " | 12'-6" | 14'-10 ³ / ₄ " | 10'-0 ³ / ₄ " | 5'-0 ³ / ₈ " | 0'-0" |
| 32' | 12'-9 ¹ / ₂ " | 19'-0 ¹ / ₄ " | 2'-2 ¹ / ₂ " | 9'-7 ¹ / ₄ " | 4'-9 ¹ / ₂ " | 5'-6 ¹ / ₂ " | 11'-1 ¹ / ₄ " | 6'-4 ³ / ₄ " | 3'-2 ³ / ₈ " | 13'-4 ⁷ / ₈ " | 13'-4 ¹ / ₄ " | 15'-10 ³ / ₄ " | 10'-8 ¹ / ₂ " | 5'-4 ¹ / ₄ " | 0'-0" |
| 34' | 13'-7 ¹ / ₄ " | 20'-2 ¹ / ₄ " | 2'-4 ³ / ₄ " | 10'-2 ¹ / ₂ " | 5'-1 ¹ / ₄ " | 5'-10 ³ / ₄ " | 11'-9 ¹ / ₂ " | 6'-9 ³ / ₄ " | 3'-4 ⁷ / ₈ " | 14'-3" | 14'-2" | 16'-10 ³ / ₄ " | 11'-4 ³ / ₄ " | 5'-8 ³ / ₈ " | 0'-0" |
| 36' | 14'-4 ³ / ₄ " | 21'-5" | 2'-6 ¹ / ₄ " | 10'-9 ¹ / ₂ " | 5'-4 ³ / ₄ " | 6'-3" | 12'-6" | 7'-2 ¹ / ₂ " | 3'-7 ¹ / ₄ " | 15'-1" | 15'-0 ¹ / ₂ " | 17'-10 ³ / ₄ " | 12'-1 ¹ / ₄ " | 6'-0 ⁵ / ₈ " | 0'-0" |

to which it is subjected. Many of these buildings have sagged in the center giving a very undesirable appearance to the building.

A number of different types and shapes of arches were built and tested in experimental work. The object of this research was, first, to improve the appearance and second, to secure a design that offers greater stiffness in the arch construction.

The design shown in Fig. 1 was selected because of its many advantages over all other types. The deflection under load was very slight; the waste space in the structure due to high ceilings and sloping walls was reduced to minimum and the appearance was very satisfactory.

A machine shed 30' wide and 40' long was constructed using this design. This size was selected because it seemed to be well suited to the needs of the average Missouri Farm. Doors in each end provide for a central driveway through the long way. A 36' width would have been better from the standpoint of parking machines, but the shed has proved to be very practical for storage of most machinery.

The Combination Roof and Frame Members

After the sill had been placed these roof-frame trusses were built using the sill as part of the supporting platform as is shown in Figure 2.

These trusses were made up by using five thicknesses of 1" x 3" oak. Lengths varying from 4' to 16' were used, care being taken to distribute splices throughout the length of the truss.

Blocks were fastened in place to form the exact outside curve for the truss. Three thicknesses were assembled and wedged into the correct position. These three pieces were nailed together using 6^d nails in pairs spaced about 1' a part, alternating from the outside to the inside piece.

These three pieces were cut to fit together at the ridge the same as a $\frac{1}{4}$ pitch roof.

The fourth piece was pressed out against these three up to the point where the open section of the truss started and then they were bent to the new curve. See Figure 1.

The fourth piece was nailed to the upper three up to the point of separation with 10^d nails and the fifth with 16^d spikes. $\frac{3}{8}$ " bolts were used near the point of separation, about 12" above the sill and about half way between these points. A piece of strap iron $\frac{1}{8}$ " x $1\frac{1}{8}$ " was drilled for $\frac{3}{16}$ " bolts and placed over the junction of the rafters at the ridge to hold these two members in place.

Three vertical members were inserted as shown in Figures 2 and 3 to give stiffness to this open section. The cut, to fit on the sill, was made while the truss was still in the form. Two men removed the trusses carried and piled them to prevent warping until the building was erected. Two men were able to build 7 trusses in an eight hour day.

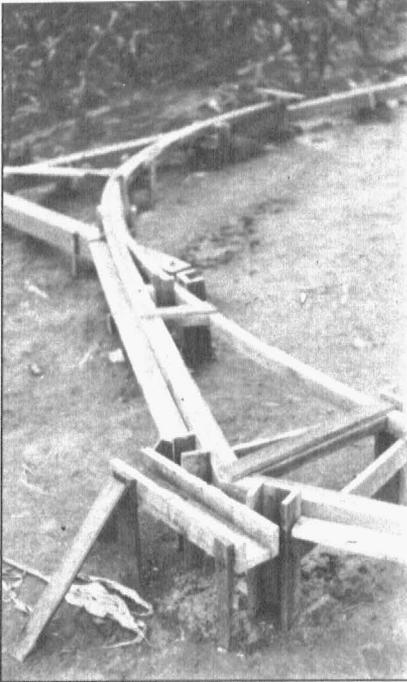


Fig. 2.—Construction of roof-frame trusses.



Fig. 3.—Setting up the trusses.

To prevent these trusses from slipping on the sill, dowel pins consisting of one-half inch rods 8" long were used. (Holes were bored into the sill and into the lower end of the truss.) To prevent the truss from lifting off the sill, pieces of $\frac{1}{8}$ " x $1\frac{1}{8}$ " iron about 14" long were drilled for 16^d spikes and these were nailed to the sill and on the outside of the truss.

Bracing.—Four or five sheathing boards were nailed in place near the ridge to space and hold rafters in place. A cable made from four No. 9 wires was fastened at the junction of the two end rafters at the ridge and fastened to the sill at opposite end of the building. This cable was wired back to alternate rafters through the length of the building and then twisted to secure the tension needed. Three other cables installed in similar fashion gives the building ample bracing. There is considerable vertical strain at the ridge where these cables are anchored. To overcome this it is suggested that a box plate be built over the door openings and a vertical member be placed to prevent sagging at the end of the ridge.

The ends of the building were closed using car siding placed vertically. A door 9' wide and 10' high was provided in each end. The trusses were sheathed and then covered with wood shingles, 5" to the weather on the sides and 4" on the quarter pitch section.

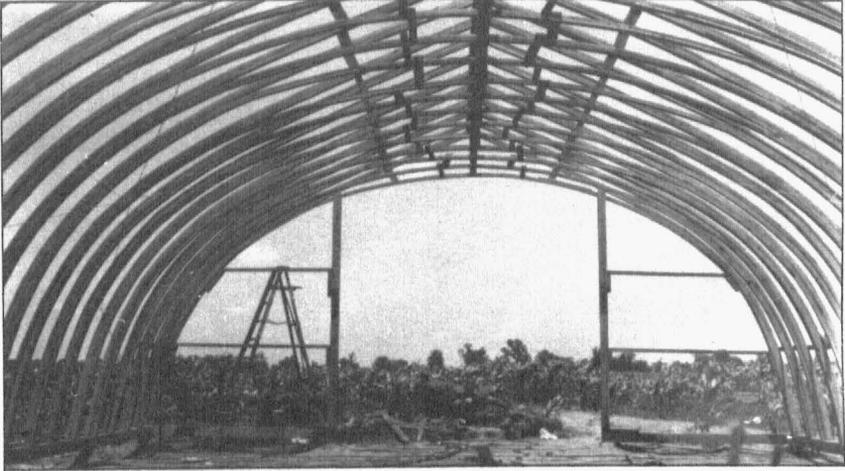


Fig. 4.—Trusses in place showing diagonal cable bracing. Cables extend from the sill at one end to the ridge at the other, and are wired back as shown to prevent center rafters from sagging. Notice the unobstructed interior.

Strip sheathing 16", on centers, covered with metal sheets placed vertically would decrease the cost over a wood shingle roof.

The Foundation and Sill.—There was a possibility that the building might be moved and for this reason 6" x 6" sills were used. These were set on 6" x 6" piers spaced four feet apart. A solid wall foundation with a 2" x 6" sill would have been preferable for a



Fig. 5.—Ends are closed and roof sheathing is in place.

stationary building and the bill of material is made up for such construction.

Saving in material.—A bill of material for a conventional type machine shed 30' x 40' calls for 5648 board feet of lumber. This type of construction uses 4220 board feet resulting in a saving of 1428 board feet or 25% on materials. The decrease in material to be fabricated and the standardization of much of the work results in an even greater saving in labor.

The material cost for the building was \$349.75. This cost is based on prices in 1942 when the materials for the building were purchased.

MATERIAL LIST

Foundation (1-1½-4 mix) and footing (1-3-5 mix)

- 49 sacks cement
- 4½ cubic yards of sand
- 7½ cubic yards of rock

Lumber

- 4——4" X 4"——12' long Oak
- 12——2" X 6"——10' " "
- 4——2" X 4"——12' " "
- 5——2" X 4"——10' " "
- 8——2" X 4"——8' " "
- 4——1" X 6"——10' " "
- 10——1" X 2"——10' " "
- 24——1" X 1"——12' " "
- 1350 bd. ft. 1" X 3"——8' to 16' "
- 1320 " " 1" X 4"——8' to 16' "
- 300 " " 1" X 6"——10' Car Siding Yellow Pine
- 7——1" X 6"——12' Yellow Pine
- 72 bundles of 5 to 2 No. 1 grade wood shingles

Hardware

- 21 lb. 16^d spikes
- 35 " 10^d common nails
- 70 " 8^d " "
- 4 " 6^d " "
- 40 " Shingle Nails
- 1 " No. 8 Flat head wood screws 1¼" long
- 160——¾" X 5½" Carriage bolts with washers
- 4——¾" X 3" " "
- 4——¼" X 1½" Stove " "

48 pieces $\frac{1}{2}$ " X 8" Rod. (Dowels)
69' Pipe Strap $\frac{1}{8}$ " X $1\frac{1}{2}$ "
4—6' Sections door track
4 Pairs door hangers
6 " 6" Strap hinges
2 6" Hasps
42' Galvanized Ridge Roll

Paint

$1\frac{1}{2}$ gal. Primer Paint
1 " Outside White