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Low-Cost



GREENHOUSE

RAYMOND L. SELF and HENRY P. ORR¹

A NEW TYPE plastic greenhouse suited to almost any space or ground contour can now be built by nurserymen and hobbyists.

Advantages of this house are economy of construction, simplicity of design, availability of construction materials, and serviceability as compared with more expensive houses.

Cost of all materials (retail prices) for this new type construction is 25½ cents per square foot for a 12x54-foot greenhouse. For one 18x36 feet, the square foot cost is 35 cents. Expense for blade-equipped tractor and operator for leveling site and labor for erecting the greenhouse would be in addition to the cost of needed materials. (See material list, page 4.)

Curved-type greenhouses have been available several years. However, the type of structure described here differs in that reinforcing wire mesh is the only support needed for 12-foot width houses. Only one lengthwise center support is needed for houses 13 to 20 feet wide.

The house is built in sections of reinforcing wire cut to measured lengths. Ends of the wire sections are anchored to a rigid foundation extending along each side of the house.

The frame ends of the house, including doors, are wood, and shaped to wire curvature. After fastening the wire sections together and covering house with plastic shade cloth and polyethylene film, the frame ends are built in place.

Adequate ventilation on warm days can be obtained by opening doors at both ends. The test greenhouses with one coat of the film provided about a 10° warmer temperature than outside. Readings on December 2, 1960 were as follows:

	<i>High</i>	<i>Low</i>
Weather station, outside temperature.....	67°	23°
Plastic greenhouse, inside temperature.....	78°	32°

Inner liners reduce the need for supplemental heat (electric or gas). With 2 mil. inner liner, one of the greenhouses

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was 17° warmer inside (low) than outside temperature. January 4, 1961, readings were as follows:

	<i>High</i>	<i>Low</i>
Weather station, outside temperature.....	58.5°	26°
Plastic greenhouse, (2 coats) inside temperature	63.0°	43°

In case of extremely high inside temperature, it will be necessary to provide exhaust-fan ventilation.

Building details reported herein were developed at this Field Station. Trials were conducted during 1960 to develop simple methods for erecting low-cost greenhouses.

STEPS IN CONSTRUCTION

Determining Size

Decide on the size of greenhouse to meet your needs. Keep in mind that the widths of the wire-plastic type houses range from 12 to 20 feet. The house length must be in multiples of 6 feet (width in which the reinforcing wire comes).

If you choose to build a 12-foot width greenhouse, divide the ground area into two 4½-foot beds separated by a 3-foot center passageway. In the case of an 18-foot width, divide into two outer beds and a center bed of 4 feet each, separated by two 3-foot walks. If you prefer use raised benches in place of ground beds.

Site Selection

Carefully select the site for your greenhouse. Commercial greenhouses should be in open areas with full exposure to the sun. No obstructions should be close enough to cast shadows. Locate your greenhouse so that it is accessible to electricity, water, trucks, and tractors. A natural gas supply near the house is desirable.

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Select an area that is well drained or one that can be graded and drained at minimum expense. The same conditions should govern the location of hobby greenhouses as far as possible.

Site Preparation

Site preparation consists of **leveling** the area, filling where necessary, and providing drainage ditches for runoff water to prevent flooding greenhouse. (See Diagram A, inside spread.)

Sterilize the soil to eliminate weeds, nematodes, insects, and disease-producing organisms. For this use such soil fumigants as methyl bromide, mylone, or vapam, following directions of the manufacturers. Also incorporate an insecticide into the soil to give long lasting protection against grubs, ants, milipedes, centipedes, and similar soil insects.

Suggested materials and rates of 10 per cent granular insecticides per 100 square feet of area, worked thoroughly into the top 3 to 4 inches of soil, are: dieldrin, 1 ounce; heptachlor, 1 ounce; or chlordane, 3 ounces. Broadcast by hand or with a seeder. Or spray comparable rates of liquid or wettable powder, applying with a sprayer or a hose-on applicator.

If you choose to use ground beds, apply lime, phosphate, and other fertilizer materials according to soil analysis. Thoroughly work these fertilizer materials plus peat moss into the bed soils before you begin house construction.

Foundation

After site preparation you are ready to locate the four corners of the greenhouse foundation.

Caution: Take particular care in locating the corners, which must be at right angles. Corners incorrectly located will lead to later construction troubles.

Laying Out 18x36-Foot House. Cut six stakes 18 inches long from 2x2-inch stock, sharpening one end of each stake. Use four as corner stakes and two as alignment stakes midway along sides of foundation. Measurements between four corner stakes should be made at the inside corners.

A simple but accurate way to establish 90° corners is the diagonal measurement method. In the case of the 18x36-foot house, the two diagonals must be 40 feet, 3 inches.

Begin by driving two corner stakes exactly 18 feet apart at one end of your prepared site. Next measure 36 feet at a right angle from inside corner of second stake. The point at which the 40-foot 3-inch diagonal and 36-foot measurements meet is the exact position of inside corner of third stake. Working from your first stake, follow the same procedure for correct location of fourth stake. When between stake measurements are exactly 18 feet (width), 36 feet (length), and 40 feet 3 inches (diagonals), your foundation is square.

Drive stakes about 1 foot into ground. Use heavy twine or builder's chalk line for foundation lines. Wrap twine so that the stakes are on outside of chalk lines. Set alignment stakes outside but flush with twine and mid-point at sides of 36-foot foundation lines.

In the case of a house 12 feet wide and 54 feet long, the diagonal measurement is 55 feet, 4 inches.

Types of Foundation. The simplest is a double board foundation, set on edge at ground level, extending full length of the house. In the case of a house 36 feet long, you will need six 1x6-inch pressure-treated, 12-foot boards for each side.

Beginning 3 inches in from each corner stake, put the three, squared-end, inner boards flush against the twine foundation line, each butting to the next. (Overall length, 35½ feet allows 3-inch space at each end for adjoining curved frames.) Anchor these inner boards to the ground with 1x4-inch stakes 2 to 2½ feet long placed 6 feet apart beginning at each end of foundation. Drive stakes part way into ground and then level

the three boards with a carpenter's level, making any necessary adjustments. It is extremely important that they are level end to end. Then finish driving in the stakes flush with top of boards and nail.

Repeat this same procedure for the other side. Then level (crosswise) the staked, inner boards at several points along sides. This may be done by resting carpenter's level on edge of two 1x4-inch straight boards (each 12 feet long, carefully lapped 4 feet and nailed) and raising or lowering the staked foundation boards as necessary.

Do not install the outside foundation boards until the reinforcing wire has been put in place and stapled to the outside surface of the inner boards.

Raised foundations require more materials, but offer you the advantage of more headroom and air space. Concrete block foundations are substantial, but are not recommended unless you intend to equip your greenhouse with raised benches.

Center Support

You will **not** need a center support for a 12-foot width house. Wider houses, however, must have support at center lengthwise of structure. An economical method is to make your center support an overhead watering system.

Example, 18x36-Foot House. Begin by setting a 4x4-inch, 10-foot treated post on exact center at each end of house, inside, flush and square with chalk line. Set post 3 feet in ground (7 feet above ground) and embed in concrete. Use carpenter's level for plumbing post; brace in position until concrete sets.

Buy four 9-foot pieces and two 4½-foot lengths of 1½-inch galvanized pipe with all ends threaded. Make up two sections of 18 feet each, connecting with 1½x1½x¾-inch T's (outlets for sprinklers). Cap one end of one section and screw a 1½x¾-inch bell reducer on one end of other section. Connect threaded open ends of the two sections with a 1½x1½x1½ T. Lift the completed overhead waterline (36+ feet long) in place on top of the two end posts, center, and temporarily nail in place. The bell reducer should extend just beyond post.

Use the two 4½-foot lengths of 1½-inch pipe to support your overhead line at mid-point between the end posts. Cut a 7-foot piece of scrap lumber to support the waterline until the center post is completed.

Connect the two 4½-foot pieces with a 1½x1½x¾-inch T (outlet for hose spigot), and cap the ground end.

Dig a hole 2½-feet deep immediately under the center T-joint of your water supply line. Place the completed pipe support in hole and then screw into the center T. Partially fill hole with concrete; after setting, complete filling hole with dirt. Then screw 4-inch nipple into 1½x1½x¾-inch T and attach ¾-inch hose spigot.

To complete inside portion of watering system, screw the two ¾x8-inch nipples into the 1½x1½x¾-inch T's and attach sprinklers.

The outside plumbing extending down from bell reducer at end of house includes: galvanized pipe, union, globe valve with soft washer, two 6-inch nipples, and hose spigot, all of ¾-inch size.

Cut and thread two 2-foot lengths of pipe and one piece 3 feet long. Screw one 2-foot length into the ¾-inch opening of bell reducer.

Next assemble the other 2-foot long pipe, globe valve, 6-inch nipple, ¾ T, and 3-foot pipe in that order. Screw on a ¾-inch elbow at open end of the 3-foot pipe. This is for connection with your water supply line below ground. When completed attach your assembly to the 2-foot pipe extending down from reducer, using a union to close the joint. The completed outside plumbing should be plumb with the wood center post, and extend into ground about 10 inches. (See Diagram B, inside spread.)

Cutting Wire and Attachment

The most satisfactory wire at this Field Station is 6 feet wide, with 170 feet in a roll weighing 540 pounds. The mesh is 4x8-inch with vertical wires (4 gauge) 4 inches apart and horizontal wires (9 gauge) 8 inches.²

For a 12-foot width house, cut an 18-foot length. This length gives a good arc with a center height of 6 feet and a 5-foot height at 20 inches from foundation.

Cut 27-foot lengths for a house 18 feet wide and 7-foot height at center. This length gives a height of 5 feet at about 3 feet in from foundation.

Example, 18x36-Foot House. Use two men to cut wire sections. One stands on the loose end while the other cuts with a set of bolt cutters.

Unroll wire and cut six lengths of 27 feet each. The roll comes with 2-inch open ends of horizontal wires at one end and ½-inch overhang at other end. These are for interlocking the sections.

Beginning at one end of greenhouse, pass wire section over center support and spread ends to outside of foundation boards. Extend wire 3 inches beyond each end of inner foundation. Force wire into ground against outside face of foundation boards. Staple to board at weld joints at 3-foot intervals after wire is evenly in place at all points. For added stiffness, attach reinforcing wire at intervals to the center support (water-line) with galvanized wire.

Put the next section in place, making certain that the outside vertical wire of the two sections adjoin alternately throughout section lengths. After stapling to outside of foundation board, loop the 2-inch ends around the two adjoining vertical wires. A ¼-inch pipe 4 inches long is a handy tool for bending and joining. Repeat procedure with other four sections.

When completed, add the outside foundation boards. Extend boards 3 inches beyond inner boards at ends of house. After cutting and fitting, nail the outer boards against the stapled reinforcing wire into the inner foundation boards. (See Diagram C, inside spread.)

Shade Material

Plastic greenhouses become hot on sunny days even in winter if not shaded. The most satisfactory shade is luminite saran shade cloth, a long-lasting plastic mesh. Use a mesh giving 50 to 64 per cent shade. This material costs about 30 to 35 cents per square yard (9 square feet). You can order this material to exact size to fit your greenhouse.

Before putting on the covering, be sure that all wire ends are turned in to avoid damage to the plastic material. Beginning at ground line of one foundation, unroll the shade cloth over the curved reinforcing wire and down to ground line of opposite foundation. Allow a 3-inch overhang beyond wire at ends of house. Smooth the shade cloth by gently pulling both crosswise and lengthwise. Do not stretch.

Plastic Cover

Polyethylene film, 4 mil. thickness, has proved satisfactory. You can buy this material in sheets wide enough to cover the house. It is also available in narrow widths. If used, be sure to lap the joints 6 to 12 inches. The 4 mil. plastic costs about 1½ to 2 cents per square foot. It normally lasts about 6 months; better, more expensive grades last considerably longer.

² This grade of wire was developed by the Truscon Division, Republic Steel Corp., and is marketed under the trade name, "Truscon Winter Garden Fabric."

Use the same method for putting on the plastic cover as that used in applying the shade cloth. Allow the same 3-inch overhang at house ends. Pull the plastic gently both ways to avoid wrinkles, but do not stretch (shrinks in cold weather).

Fasten both shade cloth and plastic covering on top of the outside foundation boards using strips of lath and small nails.

By putting on the shade cloth first, you can remove the polyethylene cover after danger from cold damage is passed.

End Construction

The best method for constructing the end frames for 18x36-foot house is to build them in place. Your first step is to build for each end four laminated sections, bowed to fit approximately the curvature of house. These formed pieces may have to be built in a woodworking shop if you do not have the necessary wood floor space and tools.

Bowed Laminates. Use three pieces of knot-free stock, 1x3 inches 14 feet long (dressed size 5/8x2 5/8 inches) for each of the eight laminated, bowed frames.

Lay out full size pattern on wood floor. (See Diagram D, inside spread.) Draw a 9-foot base line (AC) and a 7-foot vertical line (BC). Make a string compass of heavy twine, tying one end to chalk and other end to a nail. The chalk and nail must be 9 feet apart.

From point "A" scribe an arc down from point "C," using the 9-foot radius; from point "B" scribe another 9-foot radius arc. At the point where the two arcs cross, "D," scribe the arc from "A" to "B," again using the 9-foot radius.

Anchor with heavy nails 2x4-inch blocks on outside of curve AB, using as many blocks as needed to pull the three-ply laminate into place. There must be blocks at points "A" and "B."

Next place three strips on edge, centered between "A" and "B." Using furniture clamps and working from the middle three blocks, begin to tighten. Make necessary adjustment of clamps' jaw openings as you bring laminate fully into place. If needed, use "C" clamps for the other blocks.

Next nail the bowed strips at several places between blocks from outside to inner strip. Use a sledge to "buck" when nailing and bradding.

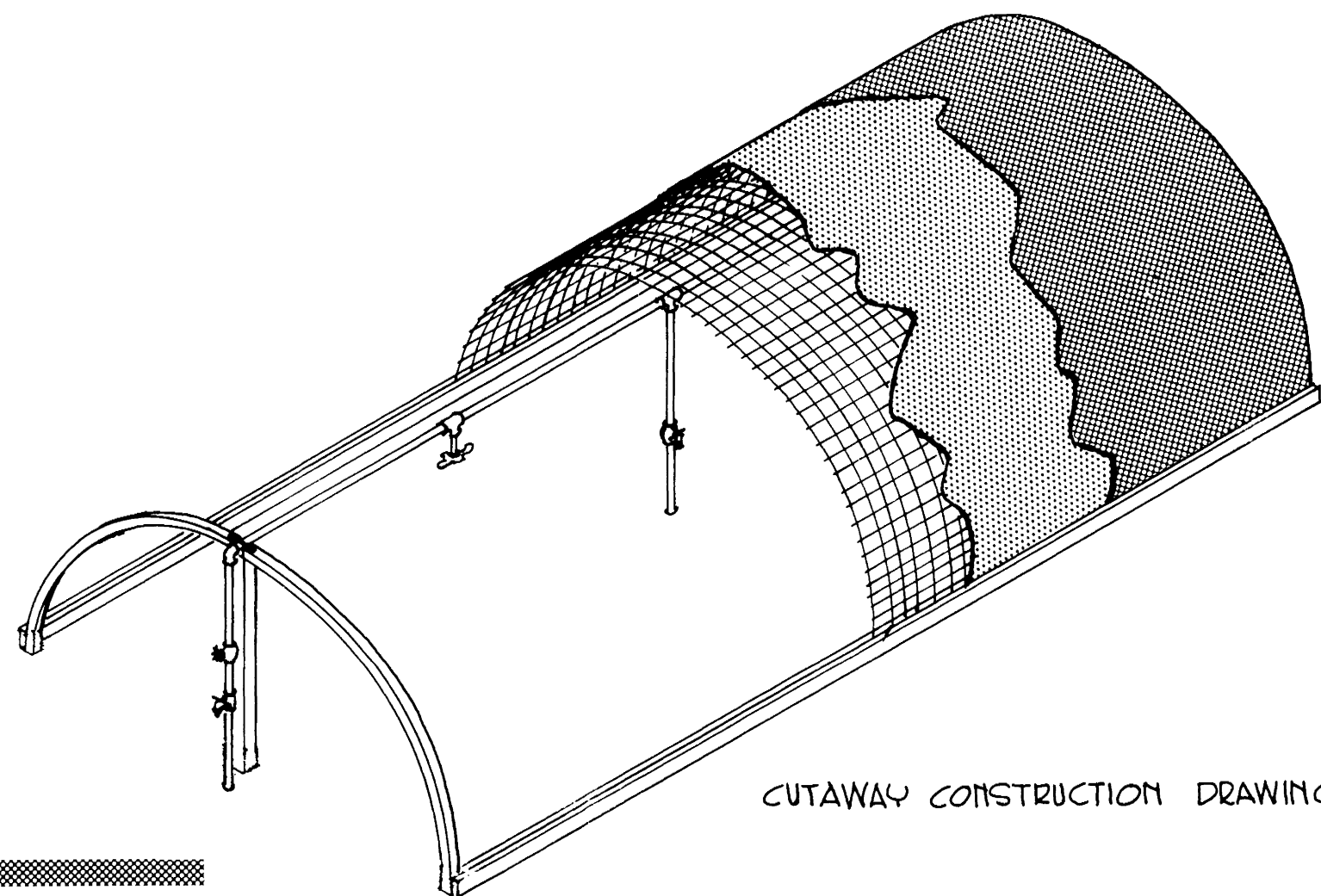
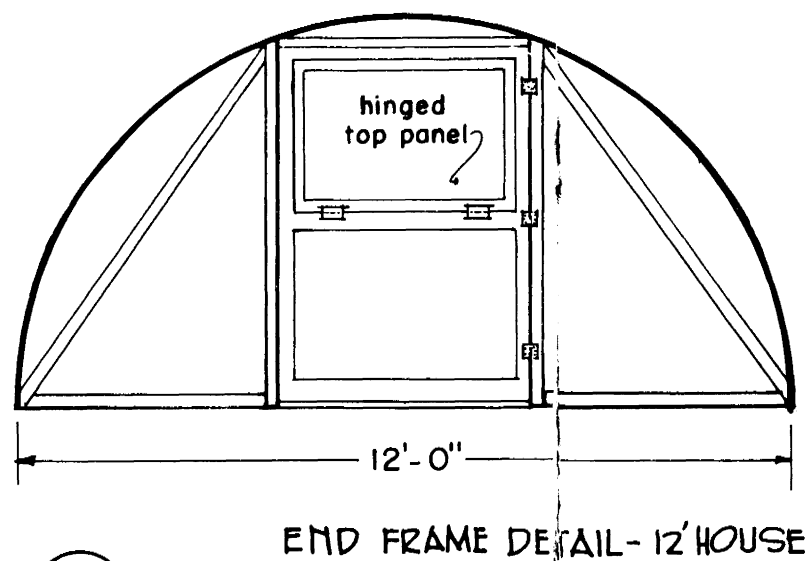
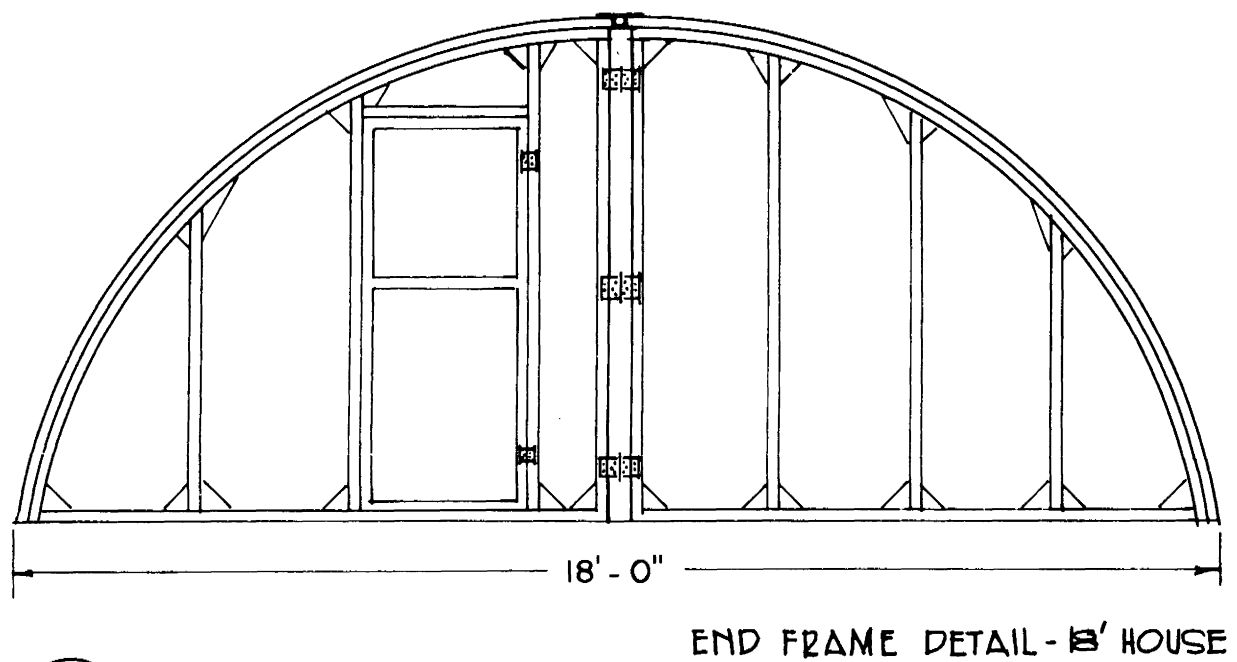
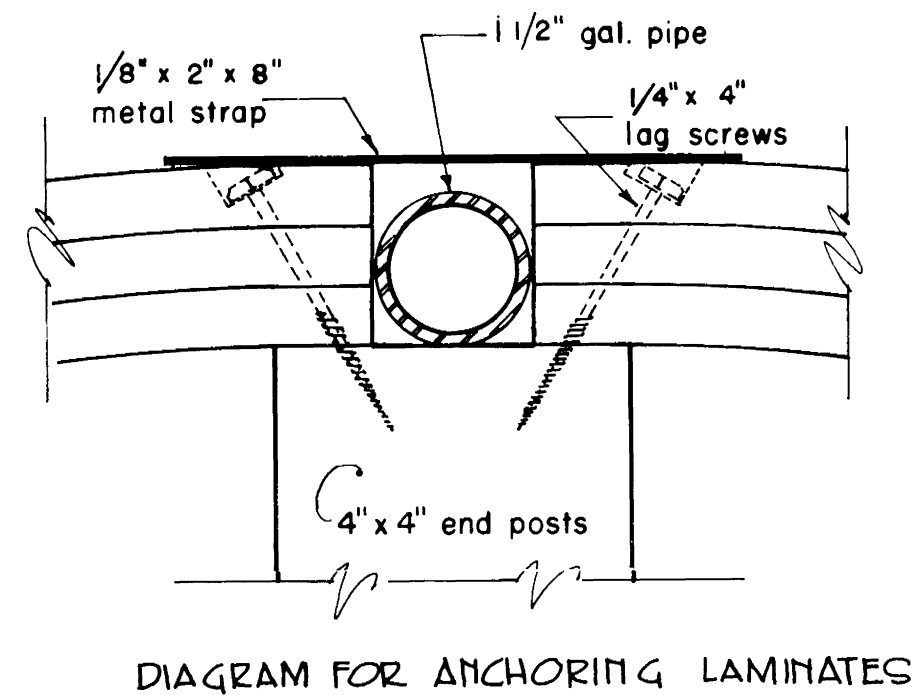
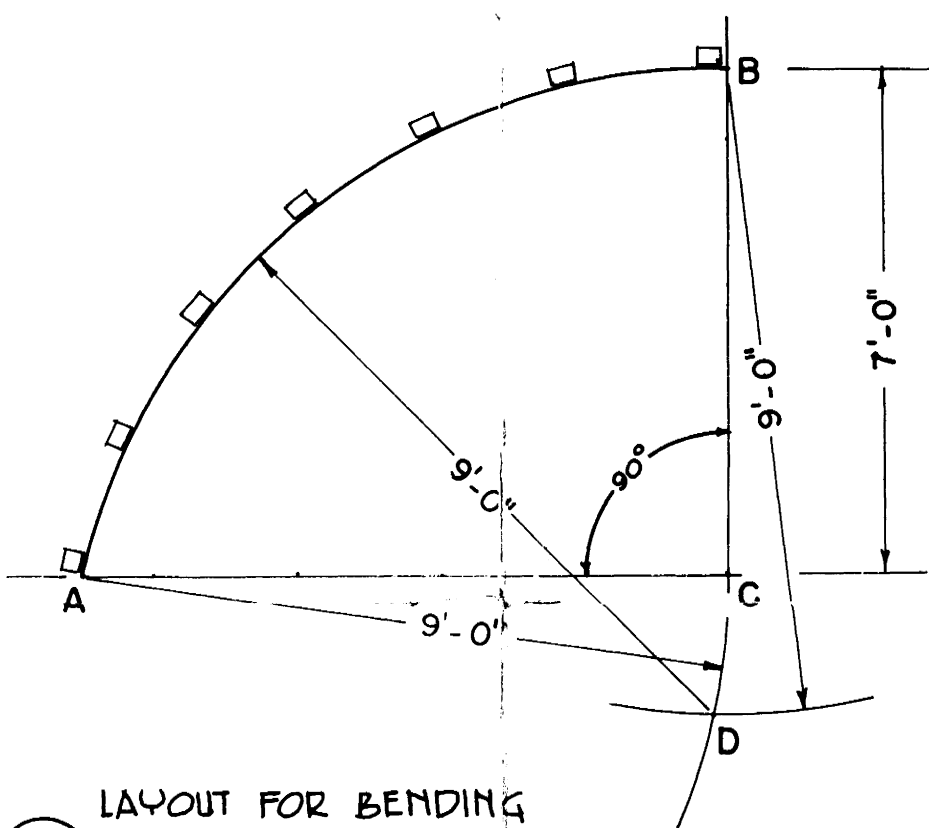
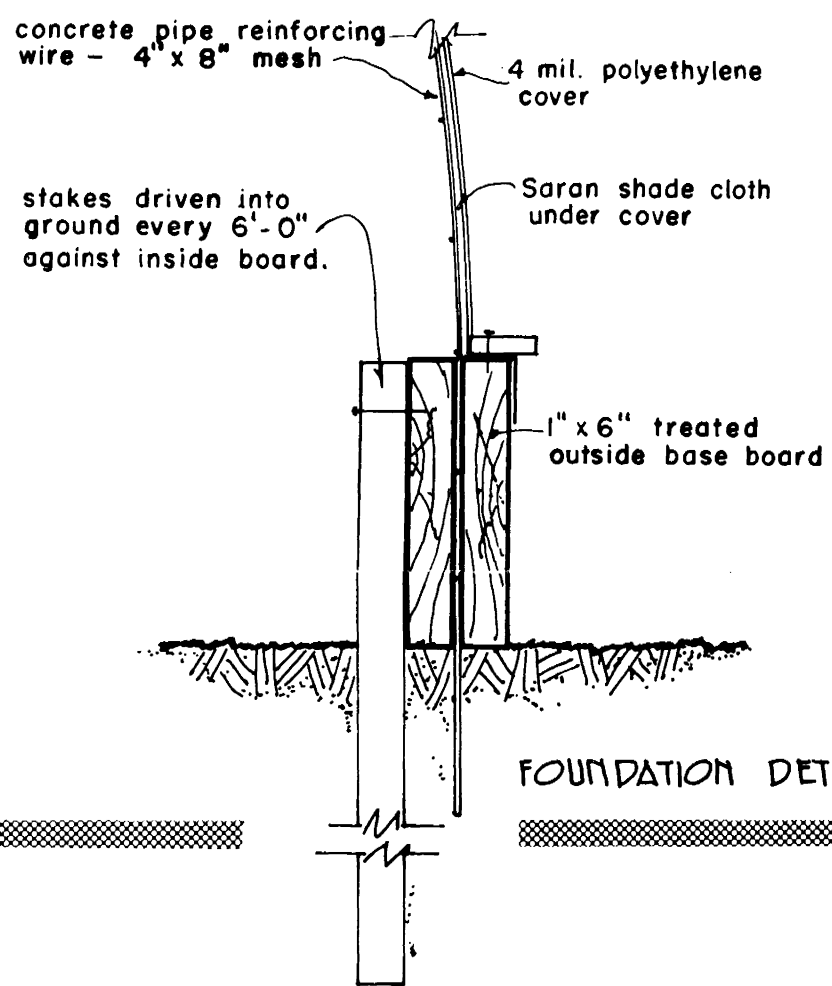
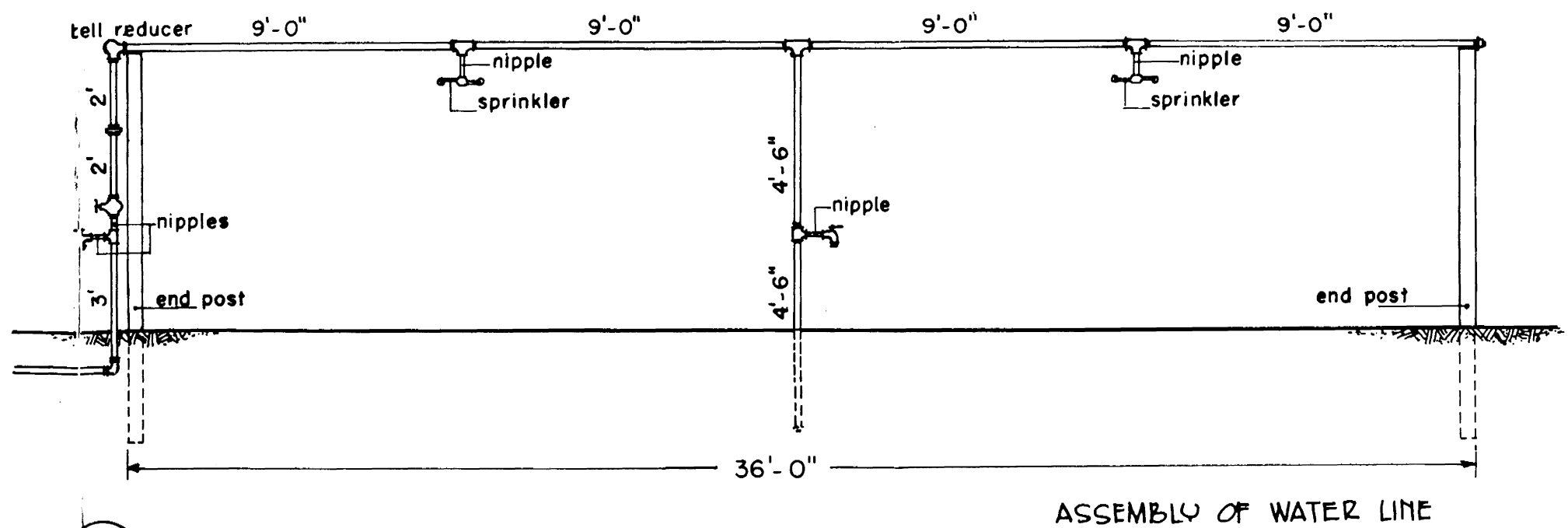
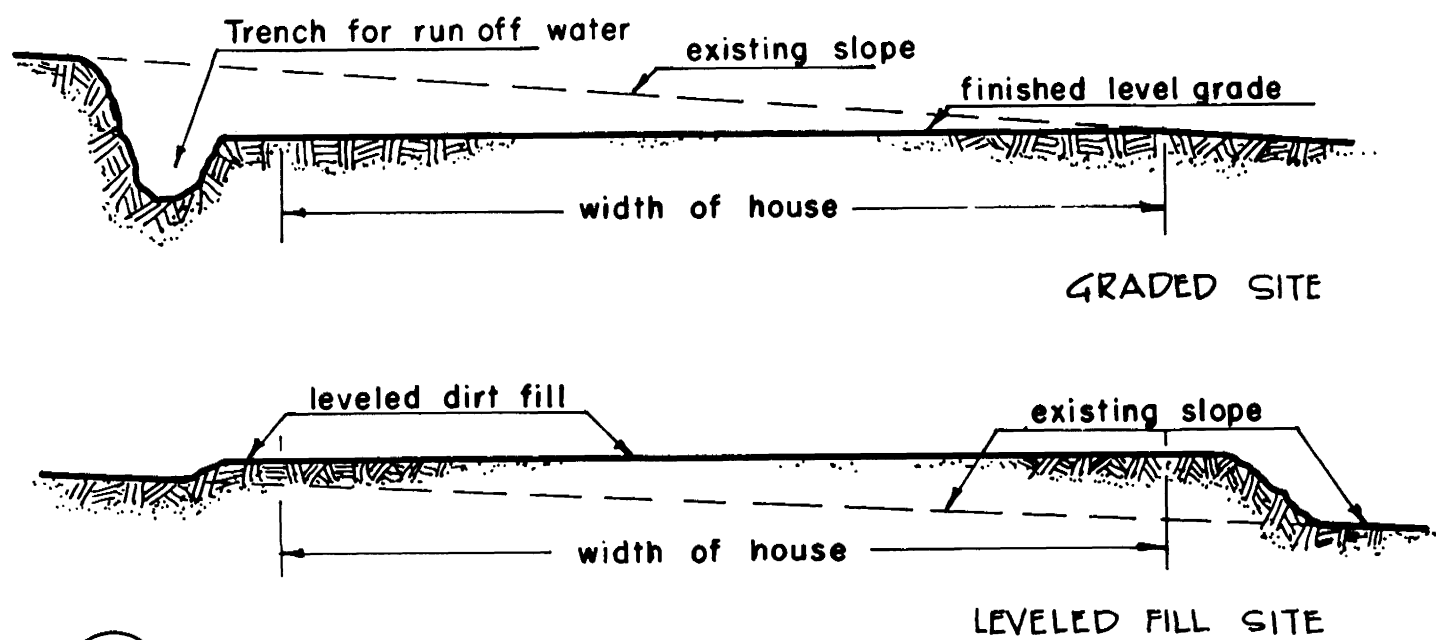
Use a 1x4-inch piece of scrap lumber 14 feet long nailed to ends of laminate to hold temporarily. Before removing from form, **mark and label** the laminate at points "A" and "B." Follow the same procedure for next three laminated bows.

Draw a line full length along inside curve of the fourth laminate before taking out of form. This is your new working line (8-foot, 10-inch radius) to which you bend the four laminates for the large doors.

Move blocks to the new inner curve line and anchor them to floor. Then bend the laminating stock (three pieces) into position and nail together just as you did in forming the first four bowed pieces. **Mark and label** points "AA" and "BB," and nail scrap stock to hold bows temporarily in position. Repeat procedure for bending other three laminates for doors.

Supporting End Frames. Use the first four "AB" laminates for supporting reinforcing wire at ends of house. Remove the 1x4 holding strip. Saw off extra length at point "A" and position against extended end of outside foundation board to "try for size." The point "B" end of laminate is to butt to the 1½-inch pipe centered on the 4x4 post. With removal of holding strip, the laminate will lose some of its bow. Therefore, spring it to conform to curvature of reinforcing wire and mark the point at which laminate will butt the center pipe. Remove laminate and saw off the extra length.

Butting end "B" to center pipe, lag screw at an angle to top of post. For details of anchoring end "B" (see Diagram E, inside spread). Next spring end "A" into position at extended end of outer foundation board. Repeat this same procedure for other AB bowed frames for supporting wire.



When completed, tie each pair of bowed frames together with 2x8-inch metal straps, ½-inch thick, centered across 1½-inch pipe; nail or screw to butting ends of the frames as shown in Diagram E. Next fold shade cloth and plastic cover around and under bowed frames and fasten with stapling gun.

Door Frames. Fit laminate AA-BB for top of door under supporting bow, cutting to correct length (from side of post to point "A"). Use shims, or thin tapered wedges, between the two bowed laminates while building the large door. Use 2x2-inch rough-sawed stock for framing. With the laminate fitted, in place, and shimmed, cut the bottom piece for door to fit between "AA" and side of center post. Saw the upright at post-side of door to fit between laminate and bottom 2x2. Space the second and third uprights to accommodate an inner door (2 feet, 8 inches wide and 6 feet high) 1 foot in from center post. Cut a 32-inch piece for top of inner door opening, and nail between the two uprights. Center the fourth upright in remaining space at bottom 2x2 and cut to fit between bottom piece and laminate. Toenail uprights at bottom 2x2 and center nail all other joints. Next build inner door frame to fit opening. This door will permit entrance to house without excessive loss of heat during cold weather.

To strengthen joints, use gussets (triangular braces) cut from scrap ¾-inch weatherproof plywood; nail them to inside face of door frames.

Build the other three large doors in place, following the same procedure, except omitting the small passage door. Instead, equally space the uprights along the bottom 2x2's.

To swing the large doors out to center line of house, screw or nail hinges to center post and adjoining uprights. Provide all doors with hasps or latches. Also install hinges for inner door. (See Diagram F, inside spread.)

Cover all doors with shade cloth and plastic film, fastening to framing with stapling gun. Allow about 3 inches overhang of covering materials for folding around curve of door. Using a sharp knife, cut along top and edge of inner door, leaving overlap at bottom.

To reduce draft through the house during cold weather, nail door stops about 4 inches wide along inside of laminates supporting the reinforcing wire. Cut the "stops" to curvature, using ¼-inch plywood scrap, repeat for inner door if needed.

End Frame, 12-Foot House. Since a 12-foot width house requires no center support, end frame construction is simpler than that for wider houses. Build two ends according to framing details, using scrap lumber. (See Diagram G.)

The framing for each end consists of a 12-foot baseboard (pressure treated) nailed to ends of foundation boards at side; two vertical pieces for door opening to which reinforcing wire is stapled at top; a crosspiece at door height; and two diagonal braces from ends of baseboard to top of vertical supports. Saw pieces to measured lengths and nail in place. Next build door to fit opening, including a panel hinged at bottom (open outward) for ventilating house. Cut a piece of shade cloth to cover opening for hinged panel, and staple to inside of door frame to keep out insects while panel is open. Also, cover outside of panel with plastic film. Next cover remainder of end with shade cloth and plastic, stapling to the framing. Allow an overlap at top for joining covering materials of ends with that of the top, using a hand stapler. Cut out the door opening, and cover lower door panel with shade cloth and plastic film.

Inner Liner

To reduce need for heat, an inner liner of 2 mil. polyethylene film may be applied to inside of greenhouse. This liner provides air space between outer and inner plastic covering that acts as insulation. The inner plastic supported by wires extends from end to end of house.

Materials required for installation of inner liner in an 18-foot width house are: one 300-foot roll of 16 or 20-gauge wire, and 75 feet of 2 mil. plastic 16 feet wide.

Stretch one length of the plastic lengthwise and anchor from center of house at ends, using a P-9 staple gun. Then attach one end of wire to end of house adjacent to water pipe, stretch wire, and anchor at other end of house. Repeat this with three more wires evenly spaced between first wire and foundation board. Four wires per side provide about 6 inches of air space at midpoint between each pair of wires.

Next clamp supporting wires and plastic liner to horizontal wires of reinforcing mesh. Use "hognose" type clamps, applying them with a P-7 Bostick gun. Space clamps 2 feet apart along each wire. Staple loose end of liner to inside of foundation boards. Repeat procedure at other side.

MATERIAL LIST and RETAIL COSTS

Materials Required	Costs	
	12'x54' house	18'x36' house
Galvanized concrete pipe reinforcing wire, 4"x8" mesh.....	\$82.50	\$82.50
Plastic, polyethylene film, 4 mil.....	15.00	15.00
Saran plastic shade cloth, mesh to give 50 to 64% shade.....	42.00	42.00
Wood foundation, 12'x54' house.....	19.22	
18 pc. 1"x6"x12', rough, pressure treated		
4 pc. 1"x4"x12', rough, pressure treated		
Wood foundation, 18'x36' house.....		13.02
12 pc. 1"x6"x12', rough, pressure treated		
3 pc. 1"x6"x12', rough, pressure treated		
Wood framing for ends, including hinges....	6.00	25.00
	<hr/>	<hr/>
	164.72	\$177.52
Center support, fittings for 18'x36' house		
2 4"x4"x10' posts, pressure treated at \$1.95....		\$ 3.90
4 ¼"x4" lag screws at 2½c.....		.10
1 pc. ¾" gal. pipe, 7' at 18c per foot.....		1.26
4 9' pc. and 2, 4½' pc. 1½" gal. pipe all ends threaded.....		22.05
1 1½"x1½" T.....		1.10
3 1½"x1½"x¾" T's at \$1.45.....		4.35
1 ¾"x¾"x¾" T.....		.33
1 ¾"x4" nipple at 27c.....		.27
2 ¾"x6" nipples at 27c.....		.54
2 ¾"x8" nipples at 27.....		.54
1 ¾" union.....		.59
2 1½" caps at 55c.....		1.10
1 ¾" elbow.....		.28
1 1½"x¾" bell reducer.....		.79
1 ¾" globe valve with soft disc.....		1.98
2 ¾" hose spigots at 99c.....		1.98
2 No. 20-U, upside down, sprinklers at \$4.....		8.00
		<hr/>
		\$ 49.16
TOTAL, sales tax not included.....	\$164.72	\$226.68
Cost per square foot.....	25.4c	35.0c

The foregoing list for the 18x36-foot house does not include cost of materials for inner liner. Add \$8.50 for these items.

Note: The information given in this report regarding materials is supplied with the understanding that no discrimination is intended and no endorsement by this Agricultural Experiment Station is implied.

ACKNOWLEDGMENT

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