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LARGE-CAGE DESIGN FOR INSECT AND PLANT RESEARCH

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SARAN SCREEN CAGE

A 1-acre Saran[2/] cage was designed for colony-behavior and pollination studies by the Bee Culture Laboratory at Madison, Wis., in 1959. The design of this cage will be of interest to research workers concerned with population dynamics of insect species, host-parasite relationships, and similar studies. Plant breeders may also find the design of interest in initial breeding and seed-stock expansion programs under controlled pollination. Figure 1 shows a colony of bees within the cage for food-consumption studies, figure 2 the guy-wire installation at the corner of the cage, and figure 3 a red clover crop within the cage just prior to blossoming.

Research Requirements

The cage at Madison was designed for studies pertaining to (1) the quantity of pollen and honey consumed by a normal colony over a period of 1 year in relation to seasonal changes in population and brood production; (2) the quantity and quality of pollen produced by 1 acre of different species or varieties of legumes and other agricultural crops; (3) the distribution and foraging behavior of honey bees (Apis mellifera L.) at different distances from the colony within a 1-acre enclosure when the cage is erected with dimensions approximately 60 by 720, 40 by 1,100, and 20 by 2,200 feet; (4) the determination of effective pollination of different plant species by a full-strength colony; and (5) the determination of the number of bees required to obtain maximum pollination and seed set of the different plant species. Such studies are of major interest to cooperating plant breeders, who have the problem of expanding foundation seed stock under complete pollination control.

1/ In cooperation with the Wisconsin Agricultural Experiment Station.

2/ Mention of trade names in this report does not necessarily imply endorsement of these products by the U.S. Department of Agriculture.

Figure 1. — Colony of bees used for food-consumption studies in large cage.

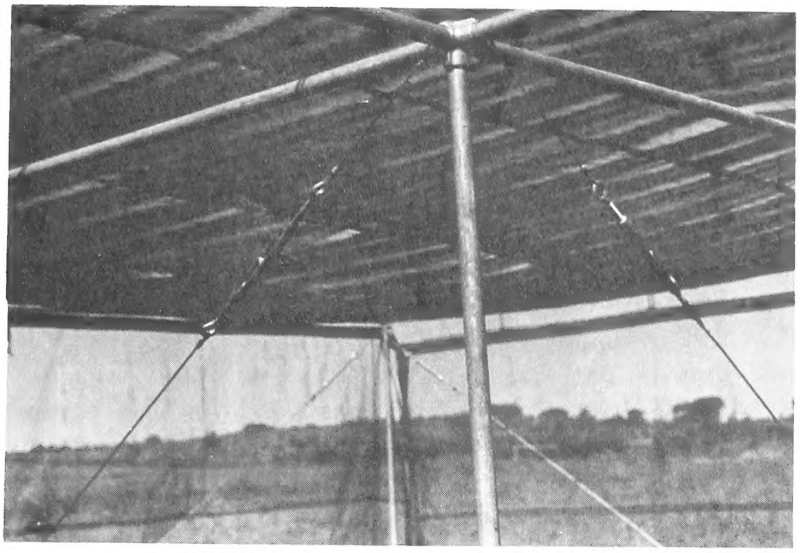


Figure 2. — Guy-wire installation at corner of cage.

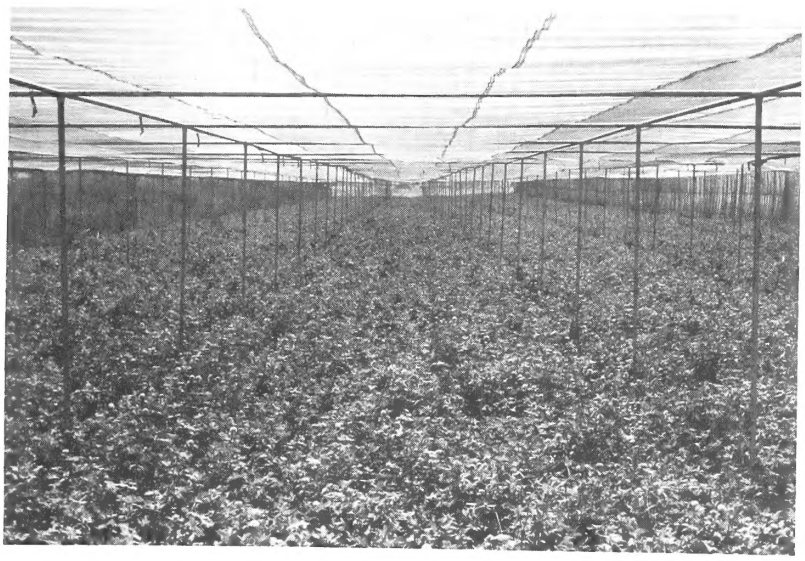


Figure 3. — Red clover crop just prior to blossoming within cage.

Structural Design

The structural design of the Saran screen cage is well adapted to any cage dimension required. The cage has withstood wind velocities as high as 60 miles per hour during its use for three seasons.

The framework supporting the cage is constructed of $\frac{3}{4}$-inch steel pipe attached with slip-on fittings (fig. 4). These fittings connect the pipe to form a 10-foot gridwork 7 feet high. The framework is stabilized with internal guy wires (fig. 5) anchored with $\frac{3}{4}$-inch steel pipes 28 to 30 inches long that have 3/8-inch steel hooks welded on the side of one end to hold the ground rail firm. The stakes are driven at a slight angle to anchor the ground rail adjacent to each supporting post, and two are used at each corner. A completely stabilized frame eliminates the need for guys being attached to the screen, a common practice that adds objectionable stress on the fabric.

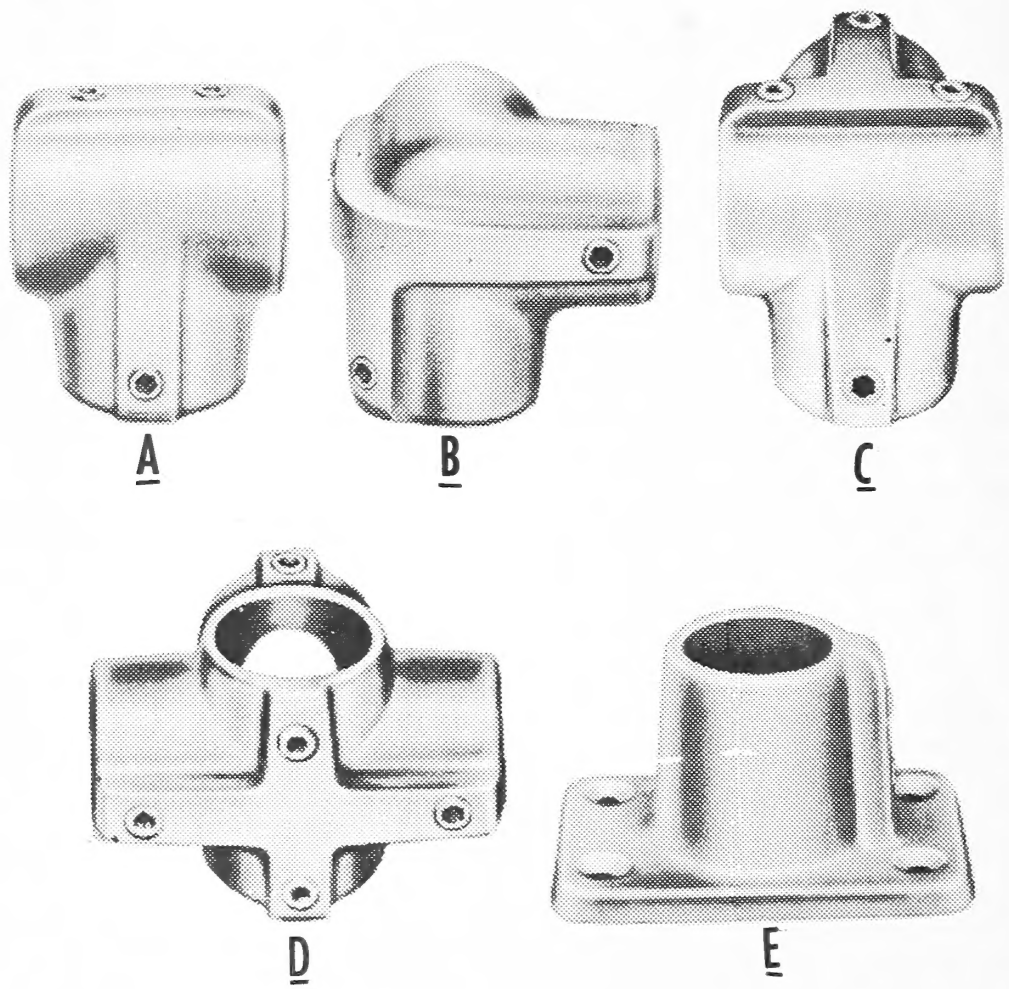


Figure 4. — Slip-on fittings for 3/4-inch steel pipe for erection of large-cage frame: (A) No. 5 tees for posts to outside ground rail; (B) No. 9 side outlet elbows for top and bottom corners; (C) No. 11 side outlet tees for top of outside posts; (D) No. 13 side outlet crosses for top of inside posts; (E) No. 47 rectangular base flanges for bottom of all inside posts.

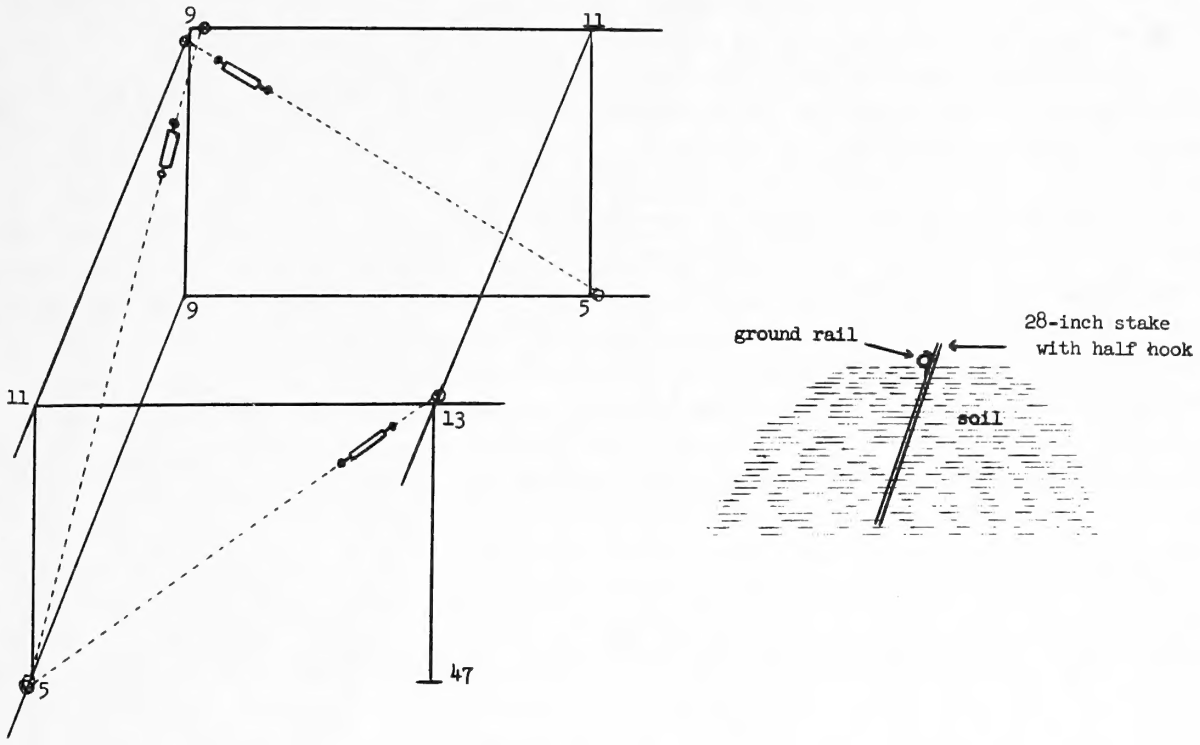


Figure 5. — Diagram of framework, guy wires, and anchor stakes with fitting numbers indicated.

The initial cage covering was fabricated with Government surplus 20-mesh Saran screen sewn into large panels, which were attached with zippers $82\frac{1}{4}$ inches long — nine zippers on the sides and three on the ends. All zippers were the same length and oriented so that the panels were interchangeable. The number and length of the zippers were determined on the basis of economical cutting of uniform pieces from standard 21-foot pipe lengths.

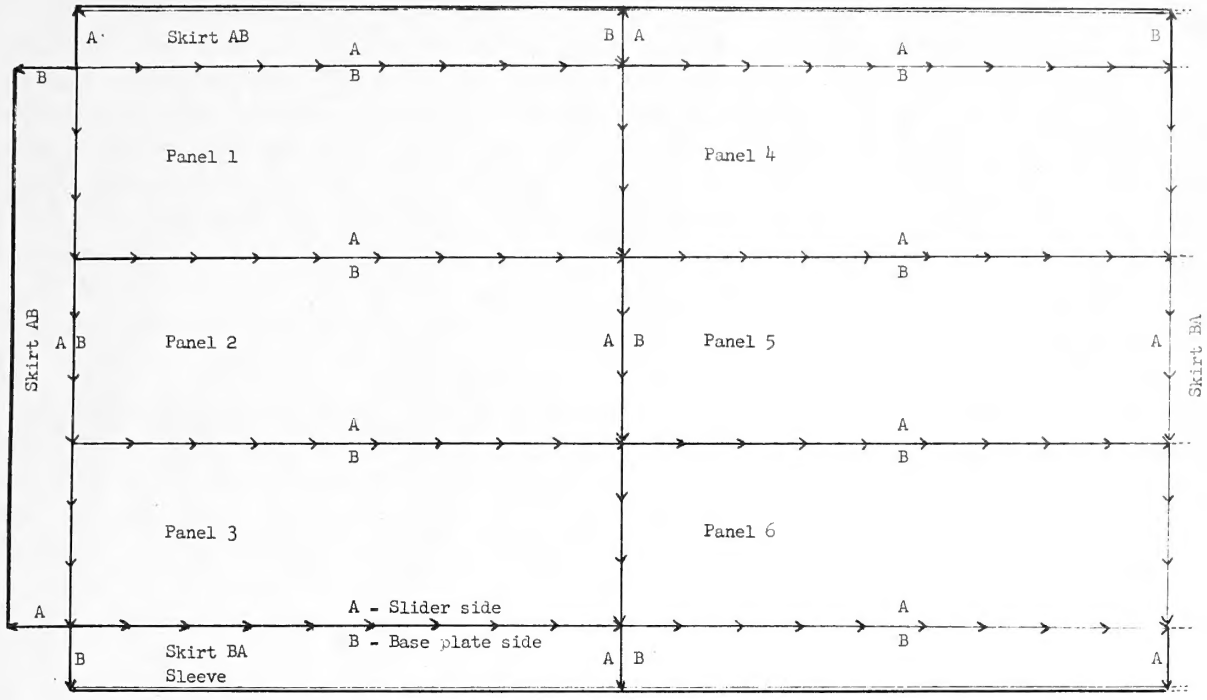
Medium-duty zippers on high-quality, mildew-resistant webbing were recommended by several manufacturers. Heavy-duty 101-inch zippers have since been obtained from Government surplus, and these would be our choice provided the webbing lasts as long as the heavier zippers. It is essential that all zippers be of equal length. Factory-run zippers of 6- to 9-foot lengths vary in length as much as 4 inches. The zippers used were obtained in uniform length at an additional cost of 20 percent. It is not difficult to adjust them to standard length (minimum of factory run) by changing the stopping link or pin, depending on the type, but such changes add to the cost either in fabrication or installation.

The 1-acre cage now in use has top panels that are 20 feet $6\frac{3}{4}$ inches wide and 61 feet $7\frac{1}{4}$ inches long. The side panels are the same length except for 12 that were made 20 feet $6\frac{3}{4}$ inches long to permit flexibility in the width of the assembled cage. Medium-length zippers were chosen to facilitate repairs when a section becomes damaged and requires replacement, even though the full-length ones are available at higher cost. The panels were made large in order to reduce the number of zippers required. The panel size was limited by the weight of the material and the length of panel rolls that could be handled. However, when using material as heavy as 20-mesh Saran screen, panel lengths of approximately 30 feet would be recommended.

All seams and zipper attachments were sewn with a double-needle industrial machine. Dacron thread, Nos. 12 and 24, was used. Orlon thread should be equally satisfactory, but nylon is not recommended because of its greater elasticity. The zipper bases should be sewn to panel corners in contact with adjacent closed sliders. Small openings (3/8 to 3/4 inch) occur at four-way junctions of zippers, but there has been no evidence that bees escape from or enter these openings. These openings can be covered with temporary patches if necessary.

The orientation of the zippers must be the same on all panels, as shown in figure 6. Note that attachment of the slider side (A) and base plate side (B) of the vertical zippers is reversed on the ends of the opposite side and end skirts to provide for AB and BA closures. For example, when vertical A is attached to the starting end of the skirt panels having the A zipper sections for attachment to the B sections of the top panels, vertical B must be used at the starting end of the skirts having the B sections for attachment of the A sections of the top panels. The end panels can be the same length as the three top panels, or the end panels can be made equal to the width of the top panels in order to obtain greater flexibility in the dimensions of the cage.

Regardless of the panel dimensions, the panels should overlap the side of the framework by about 2 inches. The side skirts should have a 4-inch sleeve through which the ground rail passes to anchor these skirts firmly to the ground. The sleeves are sewn the full length of the side skirts and slit about 4 or 5 inches at the point of the supporting post for insertion of the ground rails.



> represents direction of closure and number of zippers. In sewing zippers, closed sliders must butt against adjacent base plates. (Note vertical zippers on skirts reverse on opposite sides and ends (AB and BA), because end-skirt zippers must close in same direction when large panels are used.)

Figure 6. — Orientation of zippers on panel layout.

Erection of Cage

The framework of the cage should be erected with side skirts in position as early in the season as practical, well in advance of the development of the crop. The turnbuckles should be at the top of the inner line of posts (fig. 5). (Note that position of the corner guy wires puts the maximum downward pressure at the corner.) Reversing the internal guy wires would cause more downward pressure to be applied on the outside line, but the recommended position has proved adequate and the wires produce minimum obstruction. Also, the second line of posts would have to be anchored if the guy wires were reversed. The looped ends of the wires must be on the opposite side of the slip-on fittings attaching the outside and inside posts.

After the framework has been oriented to the area and alined, all Allen screws, which should have knurled tips, MUST be checked for firm attachment to all pipe lengths. One loose joint could place undue stress on the entire cage under high wind velocity.

It is recommended that the longitudinal pipes butt against each other at their ends, which meet at the center of the sleeve fittings, and that the transverse pipes butt against the sides of the longitudinal pipes. Once the framework is alined with the side skirts in place, stakes should be driven to anchor the ground rail firmly to the ground, one at each post and two at the corners. Note that the direction of tension on the corner guy wires tends to pull down on the corner posts (fig. 5).

Poles used to roll the screen panels can be cut from 2-inch knot-free lumber, which should be at least 2 feet longer than the width of the panels. The panels must be rolled starting at the slider closure end with the sliders down for inside closure, so that the pinned end of the zippers will be to the outside of the roll for attachment to the side skirts when erecting the cage.

Proper procedure for erecting the cage (panels diagramed in fig. 6) is as follows: Place the first panel roll over the first three lines of posts and unroll about $1\frac{1}{2}$ zipper lengths. Attach the pin ends and close the zippers to attach the panel to both the end and side skirts. Place panel 2 on lines 3, 4, and 5, but unroll slightly less than panel 1 and attach zippers. Follow with panel 3 placed on lines 5, 6, and 7, unrolling slightly less than panel 2. All zippers must be attached to the appropriate skirts and top panels in sequence as the top panels are unrolled. Follow the same sequence as additional panels are added.

If a mistake is made in rolling the panels onto the poles, it is best to lay the panels out on flat ground and reroll rather than attempt to pull the panels across the framework after they have been unrolled. It is important that all zippers be attached in sequence during the unrolling of the screen panels.

The cage is dismantled in reverse of its assembly, and the panels are rolled with the closure ends of the zippers on the inside of the rolls.

The rolled panels are stored on a demountable rack 2 feet wide, 24 feet long, and 12 feet high, fabricated with short lengths of $\frac{3}{4}$-inch pipe and the slip-on fittings. Flange plates are bolted at 20-inch intervals to four lengths of 3-inch channel iron spaced $6\frac{1}{2}$ feet apart and anchored to the building wall. Tees and flange plates provide rigid attachment of the short lengths of pipe for supporting the panel rolls and for obtaining the required height of the rack. The rolled panels MUST be stored in a mouse-proof building. The pipe is stored out of doors.

It is important that all panels be of a dimension that will fit the framework of the cage, so that miscellaneous lengths of pipe will not be needed. If mistakes have been made in the basic layout of the cage, it may be necessary to have some odd lengths of pipe at one end of the cage.

The cage described requires only two lengths of pipe— 6-foot 10-inch posts and 10-foot frame rails. These lengths can be cut with a minimum of waste from standard 21-foot pipe lengths. It is best to remove the threaded end of the pipe, even though this operation necessitates one additional cut for each 21-inch length of pipe.

Inexperienced help can make any number of time-consuming mistakes. One supervisor thoroughly familiar with the details should not attempt to direct more than two inexperienced helpers. Erection and dismantling of the cage can be accomplished by a crew of three in approximately 2 days—1 day for the framework and 1 day for the covering— or a total of 6 man-days to erect and 6 to dismantle the cage. A sloping terrain and other situations may double the labor required.

The No. 5 tees could be improved if the Allen setscrews were on the side rather than on the base. The setscrews in the standard fittings require that the ground rails be lifted and the screws tightened blindly by feel. It is important that the ground rails be centered in the tees and firmly attached by setting the Allen screws during the initial layout of the framework and before the anchor stakes are driven.

Tightening the Allen screws on a 7-foot-high cage is a little awkward. Light platforms constructed of brazed $\frac{1}{2}$-inch conduit frames with a wooden top were made to elevate the men working on the frame.

The 20-mesh Saran screen enclosing such a large area had no effect on the temperature or humidity within the cage. It did depress the light 50 percent and caused the plants to grow rank. The cage was constructed 7 feet high to give maximum freedom for bee flight and to cover a crop such as sweetclover, which was used in 1962.

FIBERGLASS SCREEN CAGES

Two smaller cages, 24 feet 8 inches by 133 feet, with 8- and 12-mesh fiberglass screening, were constructed in 1962 to determine the effect of light on the activity of the bees and the physiology of the plants in regard to pollination and seed set. Fiberglass screening appears to have the structural strength and durability equal to the Saran screening and is much lighter in weight, even considering the differences in mesh. Costs are competitive between the two types of materials. The 8-mesh costs considerably less than the 12-mesh fiberglass or the 20-mesh Saran.

Panels for these cages were sewn 8 feet 4 inches wide and 33 feet 4 inches long to permit use of 100-inch Government surplus zippers and to fit the cages to the planted field of sweetclover. For these dimensions two odd lengths of pipe were required— 4-foot 4-inch cross pipes and 3-foot end pipes. Otherwise the framework was identical to that of the larger Saran screen cage.

EXPENDITURES AND ESTIMATED COSTS OF THREE LARGE CAGES[3/]

One 1-acre Saran screen cage 61-1/2 by 738 feet (45,387 sq. ft.)

63,500 sq. ft. 20-mesh Saran screen (Government surplus, $3,200 estimate) freight only	$173.94
875 zippers, 82-1/4 inch medium-heavy, class A, style 7, 1-inch tape, uniform length, (Conmar Products Corp., Newark 1, N.J.)	1,050.00
18 tubes No. 12 and 11 tubes No. 24 Dacron thread	199.65
92-1/2 hours for sewing and use of 2-needle machine at $6.50 (additional labor for cutting and handling material furnished by laboratory)	601.25
9-1/2 hours for sewing sleeves on side skirts at $5.00 (single-needle Government machine used)	47.50
810 lengths 3/4-inch galvanized standard pipe (GSA 4710-203-2905)	2,381.40
Freight on pipe	324.60
Assorted 3/4-inch slip-on fittings (Hollaender Mfg. Co., Cincinnati 23, Ohio)	1,316.66
120 50-foot rolls clothesline wire (GSA 4010-580-2963)	129.40
21 dozen No. 17 galvanized turnbuckles (eyes on both ends)	121.69
2-inch fir ripped for poles to roll panels	84.87
72 pounds 3/8-inch iron rods for anchor-post hooks	15.08
164 pounds 3-inch channel iron for panel storage rack	22.73
Total expenditures	$6,468.77
Estimated total cost	$10,000.00

Two 0.08-acre fiberglass screen cages 24 feet 8 inches by 133 feet (3,330 sq. ft.) (one 8- by 8-mesh; one 12- by 12-mesh)

	8- by 8-mesh	12- by 12-mesh
6,000 sq. ft. 8- and 12-mesh fiberglass screen (Owens-Corning Fiberglas Corp., Toledo, Ohio)	$235.00	$306.00
Assorted 3/4-inch slip-on fittings (Hollaender Mfg. Co.)	110.90	110.90
63-1/2 hours for sewing, adjusting zipper lengths, cutting, and handling material at $6.50	206.38	206.38
8 spools Nos. 12 and 24 Dacron thread	27.76	27.76
190 lengths 3/4-inch galvanized standard pipe (GSA 4710-203-2905)	296.40	296.40
	$876.44	$947.44
Turnbuckles, guy wire, and anchor posts (estimate)	23.56	27.56
Estimated total cost	$900.00	$975.00

3/ The cost of the cages is given for the convenience of those interested in similar facilities. Reference to companies indicates the type of materials found suitable but does not imply superiority or endorsement of their products by the U.S. Department of Agriculture. GSA numbers refer to stock items available from the U.S. General Services Administration.