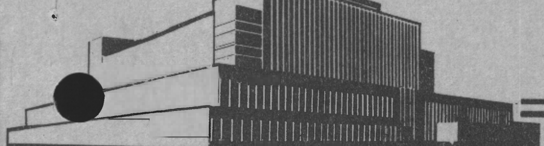
(Report) 2216

AN EVALUATION OF ELEVEN BIN-PALLET DESIGNS

March 1961

No. 2216



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

AN EVALUATION OF ELEVEN BIN-PALLET DESIGNS

By

T. B. HEEBINK, Engineer

Forest Products Laboratory,[1] Forest Service
U. S. Department of Agriculture

Summary

Eleven different designs of Washington State apple bin pallets were evaluated in two weathering cycles and six rough-handling tests. The weathering cycles consisted of a water spray followed by high-temperature drying to simulate the weather in off-season outdoor storage. The rough-handling tests were planned to simulate in an accelerated manner the ordinary handling expected to occur over a long period of the life of a bin pallet in use.

Three bin pallets failed to survive the complete series of tests. In each, the fastening or assembly method proved inadequate. An analysis of the best designs, based on performance in each test, led to the following conclusions: Vertical side and end boards, adequately fastened to horizontal framing members and diagonal braces in sides and ends, are desirable; and both hardwoods and softwoods are satisfactory for bin pallet construction.

Introduction

One of the most important developments in the fruit and vegetable industry is the new system of harvesting and storing crops in bin pallets. These bulk containers are being rapidly adopted in many parts of the country, but particularly in the apple-growing areas in Washington. Because the fiberboard box has replaced the wood shipping container for apples, the grower no longer has new standard apple boxes available for picking. Investigation showed that apples could be harvested and handled in bin pallets with no more injury than when harvested in picking boxes and with substantial savings, so the grower began to employ bins.

A need has developed for reliable information on the design, durability, and economics of these bulk containers for apple harvesting and handling. Many requests were being received by the U. S. Department of Agriculture Tree Fruit Experiment Station at Wenatchee, Wash., and the Forest Products Laboratory for information on bin pallets. It was decided that some help could be provided for prospective bin pallet users by conducting engineering studies on a variety of bin designs. In August 1959, a study was made of the various bin styles in use and available in the Wenatchee and Yakima, Wash., areas. Ten types were selected as being representative, and arrangements were made to ship three of each to the Forest Products Laboratory.

---

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

When the bins were received, one bin of each of the 10 different styles was tested. Because severe winter weather and other developments prevented immediate completion of the total project, tentative results were published by the Laboratory.[2]

In June of 1960, a second series of bin pallet tests was begun. The weathering cycle and rough-handling tests of this series were changed and made more severe in the light of the findings in the first series. Also, one new design was added and two of the original designs were modified.

Description of Bin Pallet Designs

All of the bin pallets were essentially open top boxes built of wood on a pallet base. They were approximately 47 inches square and 29 inches high (table 1). All were fabricated from Douglas-fir except bin I, which consisted of mixed hardwoods, and bin E, made of spruce plywood. Six were of lumber and five were made mainly of plywood. All had stringer-type pallets with two-way entry except bin E, which had six blocks, two bottom deck boards, and four-way entry. A detailed description of each design follows:

Bin A

Bin A, like two others, had vertical side and end boards fabricated at the top and bottom with horizontal 1- by 6-inch members (fig. 1). There were three 1-3/4-inch by 12-gage clinched nails at each crossing. The vertical boards were spaced about 1/4 inch apart. The vertical corner posts were 26 inches long and were obtained by cutting 4- by 4-inch members on the diagonal. The outer stringers in the pallet base were 3 by 4s, the center stringer was a 2 by 4, and there were three 1- by 6-inch bottom deck boards. The eight 1- by 6-inch top deck boards were spaced approximately 1/4 inch apart. They were fastened to the skids with three 2-inch by 11-gage spirally grooved nails at each crossing. Each side and each end was attached to the corner posts by driving three 3-1/2-inch by 9-gage spirally grooved nails, through the horizontal members and into the corner posts. The upper assembly was attached to the base at each corner with three 2-1/2-inch by 10-1/2-gage spirally grooved nails driven through the end board of the sides and into the stringer.

Bin B

Douglas-fir plywood 1/2 inch thick was used for sides, ends, and top deck of bin B (fig. 1). The sides were 1 inch short at the bottom, and the top deck was 1 inch narrow at the ends, to provide ventilation slots around the perimeter at the base. Sides and ends were fastened together at the corners with full-length 2-inch by 16-gage sheet-metal angle irons. Three stove bolts, 1/4 inch in diameter by 1/2 inch long, were used to attach sides and ends to the angle irons at each edge. T-nuts were used in the plywood. The angle-iron corner posts were attached to the pallet base at each corner with one 1/4- by 2-inch lag screw and one 5/16- by 1-1/2-inch machine bolt and T-nuts in the stringers. The center of each side and end were assembled to the pallet base

[2] U.S. Forest Products Laboratory. Rugged Tests for Bins. Produce Marketing Magazine, 3(3): 13-16, March 1960.

with 16-gage by 2- by 3-1/2-inch sheet metal brackets and No. 14 flathead screws, 1-3/4 inches long, into the stringer. The three stringers were 2 by 4s, and there were three 1- by 6-inch bottom deck boards. The top deck was attached to the stringers with 2-1/2-inch by 10-1/2-gage galvanized nails spaced about 6 inches apart along each stringer.

Bin C

Bin C was similar to bin B, but the sides and ends were made of 5/8-inch-thick Douglas-fir plywood and the top deck boards were 1 inch thick (fig. 1). The sides extended down over the 2 by 4 skids, and each side was assembled to the base with three 1/2- by 2-1/2-inch stove bolts that fastened into T-nuts in the stringers. The eight 1- by 6-inch top deck boards were spaced 3/8 inch apart and fastened with three 2-1/2-inch by 10-1/2-gage spirally grooved nails at each crossing. No slots other than those between deck boards were provided for ventilation.

Bin D

Bin D was different than the rest because it had two 4- by 4-inch stringers with three 2- by 6-inch crosswise subdeck boards (fig. 1). The two fork slides were 1 by 6s nailed to the bottoms of the subdeck boards. The top deck of the base was made of 3/8-inch Douglas-fir plywood nailed to the subdeck boards with only six 2-inch by 10-1/2-gage spirally grooved nails. The corner posts were 24 inches long and triangular in cross section, as in bin A. The sides and ends consisted of 5/8-inch Douglas-fir plywood, except for 1- by 6-inch boards around the perimeter of the top. The sides and ends were fabricated to the posts with 2-inch by 10-1/2-gage spirally grooved nails spaced about 3 inches apart. Casein glue was used between the sides and ends and corner posts, and at the bottom of the two ends where they contacted the subdeck board.

Bin E

Spruce plywood 1/2 inch thick was used in the sides and ends of bin E and 3/4-inch spruce plywood for the top deck of the base (fig. 2). The sides and ends were nailed into triangular corner posts (approximately 3 by 3 inches) with 2-1/8-inch by 12-gage square stock Swedish-type nails spaced about 4-1/2 inches apart. The pallet base had three wood blocks (6-inch lengths of 4 by 4s) and one 1- by 4-inch bottom deck board on each edge. Straps of 16-gage metal, 1-1/4 by 6 inches in size, were used for assembly at each top corner and at the center of the bottom of sides and ends. Two 2-inch by 11-1/2-gage galvanized nails were used in each leg of the straps. Sheet metal angle irons, 16 gage by 2 by 4-1/2 inches, were added at the corners to reinforce the upper-assembly-to-base attachment. These latter angle irons were not on the bins tested in the first series previously reported. The plywood deck was attached at each block location with 1/4- by 5-inch flat-headed elevator bolts down through the 1- by 4-inch bottom deck boards. The nuts were countersunk in the bottom deck boards. Casein glue was used between the plywood panels and the corner posts, the top deck and the blocks, and the blocks and the bottom deck boards. Bin E had been dipped in a water-repellent preservative.

Bin F

Bin F was one of the two designs with diagonal members and the only one assembled with four long rods and nuts (fig. 2). The rods were 47-1/2 inches long and 3/8 inch in diameter and were located in the sides 2-3/4 inches down from the top and 3 inches up from the pallet floor. These tied the ends together and attached them to the sides. The upper assembly was fastened to the pallet base at the four corners with 3/8- by 4-inch flat-headed elevator bolts. The sides and ends were made up of five horizontal 1-inch boards, three 4 inches wide and two 6 inches wide, spaced about 5/8 inch apart. They were attached to the vertical corner 2- by 3-inch members with clinched nails 2-3/8 inch by 11-gage, and two nails per crossing.

Each side and end was braced with a 1- by 6-inch diagonal member nailed to each horizontal board with two 1-5/8-inch by 15-gage clinched nails. Each pallet had two 2- by 4-inch stringers at each edge and one center stringer of the same size. There were three 1- by 6-inch bottom deck boards and eleven 1-inch top deck boards, seven 4 inches wide and four 6 inches wide. These were attached to all stringers with two 1-15/16-inch by 11-gage spirally grooved nails at each crossing. Two forkslide members were fastened under the bottom of the top deck boards.

Bin G

Bin G was unique because the interior corner posts were built up of two members (fig 2). The horizontal side boards were nailed to 1- by 4-inch vertical boards, and the horizontal end boards were nailed to diagonally cut, triangular 3- by 3-inch vertical posts. Spaces approximately 1/4 inch wide were left between the boards. The side-to-end assembly was made with 3-inch by 10-1/2-gage spirally grooved nails, five to a corner, which fastened the two post members together. Three 1-1/2-inch by 11-gage spirally grooved nails were used to fasten 6-inch side boards to the 1- by 4-inch vertical members, and two were used in the 4-inch-wide side boards. End boards were attached to the triangular corner posts with 2-inch by 10-1/2-gage spirally grooved nails. In addition, one 2-1/2-inch by 11-gage spirally grooved nail was used through each end board into the 1- by 4-inch vertical side member.

Two 3-inch by 10-gage spirally grooved nails were used to fasten the upper assembly to the base at the bottom of each 1- by 4-inch corner post. The pallet base had two 3- by 4-inch stringers and one center 2- by 4-inch stringer, three 1- by 6-inch bottom deck boards, and one 1- by 8- and seven 1- by 6-inch top deck boards spaced about 3/16 inch apart. The deck boards were nailed to the stringers with three 2-inch by 10-1/2-gage nails at each crossing. Two ventilation openings 7/8 by 10-1/4 inches in area were provided at the bottom of each bottom side and end board.

Bin H

In bin H, vertical side and end boards, spaced approximately 5/16 inch apart, were fastened at the top to 2 by 4 horizontal members that had 2 inches of the depth routed out to receive the ends of the boards (fig. 2). The bottoms of the vertical boards were fastened to horizontal 1- by 4-inch members. One diagonal 1- by 4-inch member was used to brace each side and end. Fabrication of sides and ends was by means of clinched 1-3/4-inch by 14-gage nails; two were used at each crossing for 1- by 4-inch boards and three for 1- by 6-inch boards. The top horizontal members were notched at their ends so as to fit together at the corners. The three stringers were 3 by 4s. There were three 1- by 6-inch bottom deck boards. The top deck boards were 1 by 4s or 1 by 6s, spaced about 5/16 inch apart, and fastened with 3-inch by 10-gage spirally grooved nails. Two nails were used at each 1- by 4-inch crossing and three at each 1- by 6-inch crossing. The sides and ends were assembled together with eight 20-gage galvanized sheet metal brackets. The bottom four brackets also attach the upper assembly to the pallet base. Spirally grooved nails, 1-3/8 inch by 12-gage, were used for the brackets in the upper assembly and 2-1/4 inch by 10-1/2-gage into the base. Bin H had been dipped in a water-repellent preservative.

Bin I

Bin I was the only bin fastened with wire ties at the corners and metal U-clips at the base (fig. 3). The wire in the ties was 11 gage. There were 12 ties in all, and they had been twisted together during assembly. The sides and ends had 3/8-inch vertical hardwood boards 24 inches long. The board widths were random but the spaces between boards were 5/16 inch. The horizontal framing consisted of three exterior hardwood cleats. The top two were 15/16 by 2-9/16 inches, and the bottom cleat was 15/16 by 1-3/4 inches. The side and end boards were attached to the horizontal cleats with 16-gage staples 1-1/4 inches long. The pallet base had three 3 by 4 inch hardwood stringers, no bottom deck boards, and top deck boards of random width and full 15/16-inch thickness, laid together without spaces. These boards were fastened to the skids with three 2-1/2-inch by 11-gage spirally grooved nails at each crossing. There was a 15/16- by 1-1/8-inch rim cleat around the outside perimeter of the base to hold the sides and ends in at the bottom. The four metal U-clips holding the sides and ends to the base were 1/8 by 3/4 inch.

Bin J

Bin J had 2 by 4 interior corner posts and the upper assembly was fastened to the pallet base with three 3-1/2-inch by 7-gage annular-grooved nails through each post into the stringers (fig. 3). There were two 1- by 6-inch and three 1- by 4-inch horizontal boards on each side and end. They were spaced apart about 5/8 inch. The side boards were attached to the posts with 1-7/8-inch by 12-gage spirally grooved nails, three in 1- by 6- and two in 1- by 4-inch boards. The same number of 2-inch by 12-gage nails were used to attach the end boards. The two edge stringers were 3 by 4s and the center stringer was 2 by 4s. The three bottom deck boards were 5/8 inch thick by 7-1/2 inches wide. Six of the top deck boards were 1 by 6s and three were 1 by 4s; all were spaced 3/8 inch apart. The deck boards were attached to the stringers with three 2-inch by 12-gage spirally grooved nails per 6-inch board and two per 4-inch board at each crossing.

Bin K

Bin K had not been included in the first series of tests. The sides and ends were 5/8-inch Douglas-fir plywood fastened together at the corners to triangular corner posts, 24 inches long, obtained by diagonally cutting 3 by 3s lengthwise (fig. 3). The outer stringers were 3 by 4s, the center stringer a 2 by 4, and the three bottom deck boards were 1 by 6s. The eight top deck boards also were 1 by 6s and were spaced 3/8 inch apart; each was fastened with three spirally grooved nails 2-1/2 inches by 11-gage at each crossing. The upper assembly was fastened to the base with 1/4- by 28-inch vertical step bolts. Triangular plates, galvanized 16-gage sheet metal, were used top and bottom to tie the side and end panels together. The plates had bent over lips that fit over the outside edges and into saw kerfs in the top edges of the sides and ends, and these held the top assembly together. Bin K had been dipped in a water-repellent preservative.

Test Procedures

All 11 bin designs were given a simulated weathering test and then six rough-handling tests. Racking and rollover tests were conducted on empty bins, while the sag, vibration, pendulum-impact, and cornerwise-drop tests were conducted on the bins loaded level full with from 1, 100 to 1, 300 pounds of potatoes. The different loads were due to the varying capacity of the bins, ranging from 21 to 24 bushels. Load density was about 50 pounds per bushel, or 40 pounds per cubic foot. This is closely comparable to a load of apples.

Weathering Cycle

Two cycles of weathering were applied to each bin pallet; each cycle consisted of 16 hours of water spray and 4 days of kiln drying. One each of the 11 experimental bin designs was subjected to a 16-hour water spray to simulate severe rainfall. They were stacked in one row, two high, as shown in figure 4. A sprinkler with 21 rotating heads was placed on top of the stack, and the spray was adjusted to distribute the falling water uniformly over an area 7 feet wide by 30 feet long. The top and bottom bins were interchanged every 4 hours to insure even moisture distribution on each bin. The output of the sprinkler was 28 gallons per square foot--the equivalent of 72 inches of rainfall--in 16 hours.

Following the 16-hour water spray, the bins were placed for 4 days in a kiln maintained at 130° F. During this period no moisture was introduced and the water vapor drawn from the bins was carried away with fans. This conditioning simulated a severe drying period in hot, sunny weather.

Racking Test of Open Top of Bin

The racking test, conducted both before and after the rollover test, gave a measure of the stiffness of each bin in the horizontal plane. Holes were drilled in each top corner, and 1/4-inch-diameter steel rods were inserted as shown in figure 5. The rods had hooks on one end that engaged a dynamometer at the center of the container. The other ends of the rods were threaded, so that nuts could be turned on and a pull exerted by tightening them. The dynamometer recorded the amount of pull in pounds. The distance from corner to corner was measured before any pull was exerted and again at 150 pounds. Then the rods were removed, placed across the other diagonal, and similar measurements taken. The average change in these two diagonal measurements was recorded. This test had been used in the first series and was unchanged in the second series.

Rollover Test

Each bin was subjected to a side-to-end rollover test on a strip of concrete pavement. The container was tipped upon its side, raised to just past the point of balance as shown in figure 6, and permitted to fall freely to the concrete. This procedure was repeated until 16 falls were produced, or through 4 complete revolutions of the container. This test simulates the manner in which empty bins are positioned in orchards by rolling them side over end over side. In the first series of tests, the rollover test had consisted of only 12 falls, or 3 revolutions of the bin pallets.

Sag Test

For the sag test (fig. 7), each loaded bin pallet was placed on a 4- by 4-inch timber so that the bin was oriented diagonally across the length of the timber. This allowed the two unsupported corners to sag or deflect with respect to the others. A test of this sort simulates placing full bins on irregular ground.

The amount of sag was measured with a straightedge and taut string (fig. 7). The loaded bin was then rotated 90° so that the other two corners were unsupported and the sag readings were obtained. An average was recorded of the two readings. Each container was evaluated by the sag test just after it was loaded and before the vibration test. This test was used in first series.

Vibration Test

The vibration test was conducted on the Laboratory vibration tester (fig. 8), which operates approximately at a frequency of 9 cycles per second and a peak-to-peak amplitude of 1/4 inch. It simulates the type of vibration caused by truck or rail transportation over rough roads. Each loaded bin was vibrated for 10 minutes, measured for bulge, vibrated for 10 minutes, measured again, and so on for 30 minutes. The bulge measurements were taken on the sides or ends (whichever exhibited a greater tendency to deflect) by using a beam and a micrometer dial as shown in figure 9. Generally, but not always, the deflection was progressive and the maximum was recorded after 30 minutes. In the first series, the vibration test had a total duration of only 10 minutes.

Pendulum-Impact Test

Each loaded bin was subjected to the pendulum-impact test to evaluate its resistance to severe lateral impacts. The filled container was placed on a suspended platform, as shown in figure 10, so that its front end projected 10 inches beyond the platform. The platform was then pulled back horizontally until it was elevated 9 inches vertically, then suddenly released and allowed to swing freely until the bin struck the large concrete bumper. The speed at the point of impact was 7 feet per second. The area of contact with the bumper is about 4 inches high across the bottom of the container. Sides and ends of the bins tend to rack out of square and the resistance to this stress is determined by measuring the diagonals of the side or end (whichever was in the plane of racking stress) and calculating the change in dimensions due to the impact. Four impacts were inflicted on each bin--one against each side and end. In the first series the pendulum-impact test had been conducted similarly but only one impact against each end had been made.

Cornerwise-Drop Test

The last test, and probably the most severe, was the cornerwise-drop test. The loaded bin was placed with one edge on a 6-inch-high timber. Then one of the supported corners was further blocked up with another 6-inch-high block. This put the bin in a strained condition as shown in figure 11. Next, the corner diagonally opposite the highest corner was lifted up and set upon a block 6 inches high. Then the 6-inch block was suddenly jerked away and the unsupported side of the container fell freely, striking a steel plate embedded in a large mass of concrete in the floor. The impact of the drop placed dynamic racking stresses in all panels of the bin.

After the first fall the bin was rotated 90° and the adjacent corner dropped in a similar manner. Then the other two corners were tested similarly. The test was repeated from 12-inch heights and then 18 and 24 inches. After 16 of these cornerwise drops, 4 additional edgewise drops were made. They consisted of 24-inch falls of one bottom edge while the other bottom edge was supported on just the 6-inch-high timber only. Following each of the cornerwise (and edgewise) drops, evidence of deterioration or failure was recorded and measurements were taken of the amount of sag of the two unsupported corners as illustrated in figure 12. The cornerwise-drop test was used unchanged in both series of tests.

Results of Tests

The moisture content of the wood in the bins changed considerably during the weathering cycles. Originally the wood was at a moisture content of 8 to 12 percent. After the 16-hour spray period, the wood in the bins not dipped in preservatives picked up an average of 20 percent to a moisture content of 24 to 30 percent. Of the preservative-treated bins, K and M increased by only 12 percent but bin L increased by 22 percent. After the drying periods, moisture content returned very closely to the original.

The weathering cycles caused some degrade to the parts of the bins. Checking of both wood and plywood members was observed. Loosening of bolts and slight nailhead protrusions were also noticeable. Those bins that had been dipped, including bin L, were less affected by these defects than the unpreserved bins. It was not possible, however, in the subsequent testing, to determine if the performance of any bin was affected by the degrade caused by weathering. It is the consensus of the observers that the weathering cycles had very little influence on the performance of the bins.

The results of the rough-handling tests are presented in table 2. Three designs failed to survive the complete series of tests. Bin B failed in the 11th fall of the cornerwise-drop test from a deficiency that started during the fifth drop. The two wood screws that attach the midpoints of each side to the pallet base pulled out of the stringers. These failures allowed the sides to deflect outward and the potatoes to spill out of the containers (fig. 13). Before this, bin B had been very flexible in the racking test and bulged more than any other in the vibration test.

Bin F failed during the fourth pendulum-impact. The forward thrust of the potatoes caused one of the 2- by 3-inch corner posts to split at the top where the assembly rods were attached (fig. 14). The force due to the thrust was too concentrated at the position of the holes through the 2- by 3-inch vertical post. Up to that time, bin F had performed fairly well. In the first series of tests, bin F had survived the pendulum test because the impacts were made on only the ends of the containers. Thus, no impacts were produced perpendicular to the rods. Following the pendulum test, another sample of bin F design was substituted and subjected to the cornerwise-drop test. It did not have the previous rough handling represented by weathering, racking, roll-over, sag, vibration, and pendulum-impact.

Bin K failed in the first drop of the pendulum-impact test when an end panel separated from the sides (fig. 15). The lip on the top corner bracket bent and slid out of the saw kerf in the side panels. Bin K had also been very flexible in the racking tests. This side-to-end assembly method apparently was not positive enough to resist the thrust. After this failure, a new bin K was substituted and subjected to the cornerwise drops. Like bin F, this new bin had not had the previous testing. In the fifth drop, the metal bracket failed in the same manner, causing the side-to-end assembly to open at the corner.

Bin A survived all of the tests but exhibited a weakness in the cornerwise-drop test. During the 19th drop, which was edgewise, the assembly nails pulled at a bottom corner, causing the end to separate from the side (fig. 16). Close examination revealed that the three assembly nails had been driven at the wrong angle and had not been imbedded properly in the triangular corner post. Bin A survived a similar series of cornerwise drop tests very well in the first series. It was the best bin with respect to racking in both series, but performed poorly in the pendulum-impact test.

The bins that performed best in this series were D, H, and I. Bin D was very good in racking and cornerwise drop. Its only weakness was its excessive deflection in the sag test.

Bin H was good in all respects and seemed to have little weakness. The addition of diagonal members to the sides and ends and the other minor design changes had improved the performance tremendously over that of the first series of tests. Bin H had been very poor in racking, sag, and cornerwise drop before the changes.

Bin I was best of all in sag, vibration, and cornerwise drop. Its only weakness was flexibility in the racking test. Similar results had been observed in the first series.

Bins C, E, G, and J survived the rough-handling test cycle without failure but their performance was below average. Bins C and E had relatively thin plywood sides and ends and, therefore, were very flexible in the racking and cornerwise-drop tests. Bins G and J both had horizontal side and end boards and no diagonals. They performed poorly in the pendulum impact and cornerwise drop.

Conclusions

The following conclusions can be drawn from the results of this study:

(1) Vertical side and end boards, adequately fastened to horizontal framing members, are desirable. Two of the best three binpallet designs are in this category.

(2) Diagonal framing in sides and ends is desirable. Bin H performed as well as or better than any, and bin F performed well except for an obvious assembly weakness.

(3) Both hardwoods and softwoods are satisfactory for bin pallet construction.

Plywood bin pallets without large corner posts are very flexible with respect to the racking test. Bins B, C, E, and K deflected more than the average. The same bins also bulged excessively in the vibration test. Secondly, the plywood bins included in this evaluation were generally inadequately assembled. Bins B and K failed at assembly points.

No one single test accurately represented the bins' performance. The cornerwise-drop test was closest. Any bin that successfully passes the cornerwise-drop test should probably be acceptable.

Table 1.--Dimensions, capacities, and tare weights of 11 experimental bin pallets

Bin No.	Inside dimensions	Capacity	Outside dimensions	Capacity efficiency[1]	Tare weight
	Inches	Cubic feet	Inches	Percent	Pounds
A	43-7/8 x 43-5/8 x 26	28.8	47 x 47 x 31	73	157
B	46-1/4 x 46-1/8 x 24-1/4	29.9	47-1/4 x 47-1/4 x 29-1/8	80	102
C	45-3/4 x 45-3/4 x 23-7/8	28.9	47-1/4 x 47-1/4 x 29	77	124
D	43-5/8 x 43-5/8 x 23-7/8	26.3	47-1/16 x 47-1/16 x 29-3/8	70	125
E	46-7/8 x 41-7/8 x 23-7/8	27.1	47-3/4 x 42-3/4 x 29	79	80
F	43-1/8 x 43-1/8 x 23-7/8	25.7	47-3/4 x 47-3/4 x 29	67	153
G	45-3/4 x 45-1/2 x 23-3/4	28.6	47 x 46-7/8 x 28-5/8	78	138
H	43-3/4 x 43-3/4 x 24-3/4	27.4	47-1/8 x 47 x 29-7/8	72	157
I	43-11/16 x 43-5/8 x 24-1/16	26.5	46-1/2 x 46-3/8 x 28-1/2	75	151
J	46-1/2 x 46 x 24-1/4	30.0	48 x 47-1/2 x 29-1/16	78	138
K	45-5/8 x 45-5/8 x 24	28.9	47 x 46-7/8 x 29	78	120

[1] Inside capacity of bin divided by the outside cubic displacement.

Table 2.--Results of rough-handling tests of 11 designs of bin pallets for apples

Bin No.	Racking test (Average change in diagonal corner-to-corner measurement at 150-pound pull)		Sag test (Average vertical deflection of two unsupported top corners)	Vibration test (Maximum bulge in sides and ends of bins)	Pendulum-impact tests (Average change in diagonal measurements of two sides of bins)	Cornerwise-drop tests (Maximum vertical deflection of two unsupported top corners)	Remarks
	Before rollover	After rollover					
	Inches	Inches	Inches	Inch	Inches	Inches	
A	1.73	1.88	0.47	0.21	0.83	3.66	Serious nailpull, two split side boards, and end loose from side at bottom corner
B	4.25	4.45	.44	.33	.01	Failure	Two assembly screws pulled out of stringers
C	3.14	3.52	.41	.30	.04	3.77	Two bottom deck boards split
D	1.78	2.09	1.95	.20	.09	3.38	Side pulled away slightly from post
E	3.36	3.53	2.31	.20	.05	3.94	Slight nailpull and opening at top corners
F	2.03	2.48	.44	.26	Failure	[1]2.94	Top of 2- by 3-inch corner post split off at assembly rod
G	2.11	2.42	.47	.20	1.09	3.77	One side board and two bottom deck boards badly split
H	1.94	2.12	.44	.11	.23	3.02	Side-to-end assembly slightly open at top corner
I	2.88	3.18	.22	.11	.16	2.88	
J	2.83	3.06	.69	.13	.82	3.78	
K	2.81	3.06	.50	.14	Failure	Failure[1]	Metal bracket failed to hold end to side at top

[1] New bin that was not subjected to other tests.

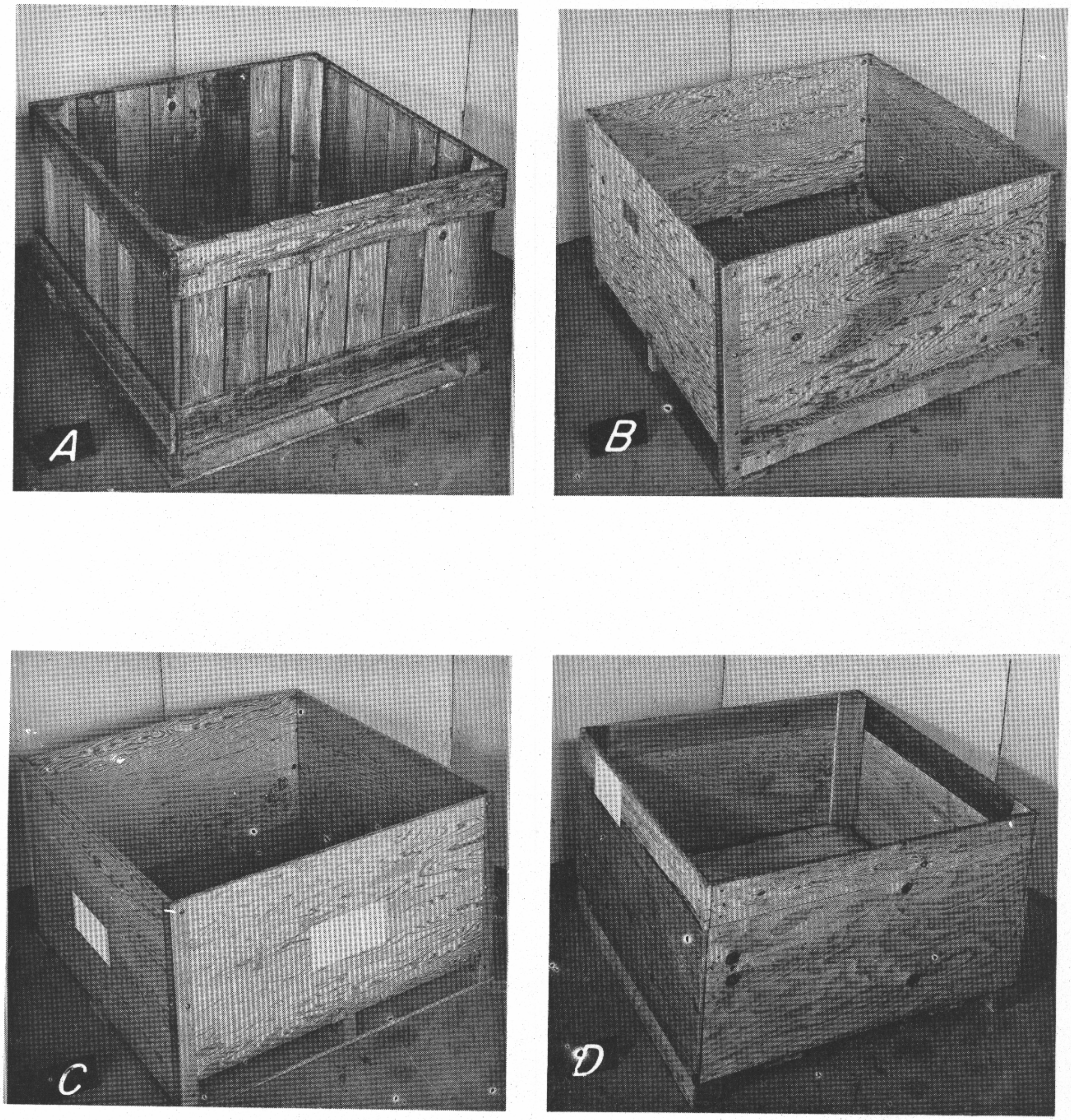


Figure 1.--Upper, left to right, bin pallets A and B; lower bins C and D.

Z M 119 020

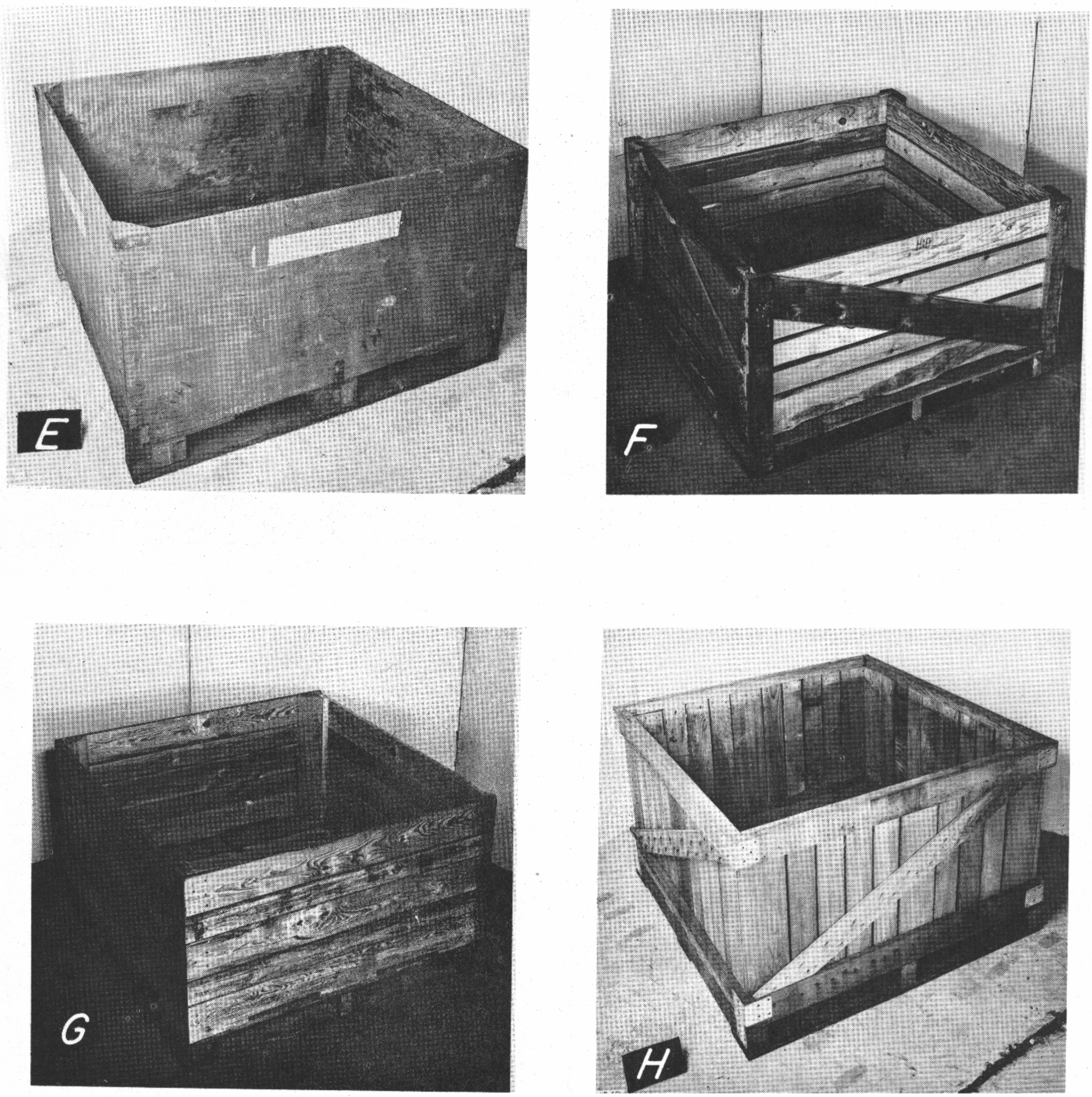


Figure 2. --Upper left, bin E, with sheet-metal assembly brackets at the bottom corners. Upper right, bin F; lower, left to right, bins G and H. Note diagonals on bin H.

Z M 119 022

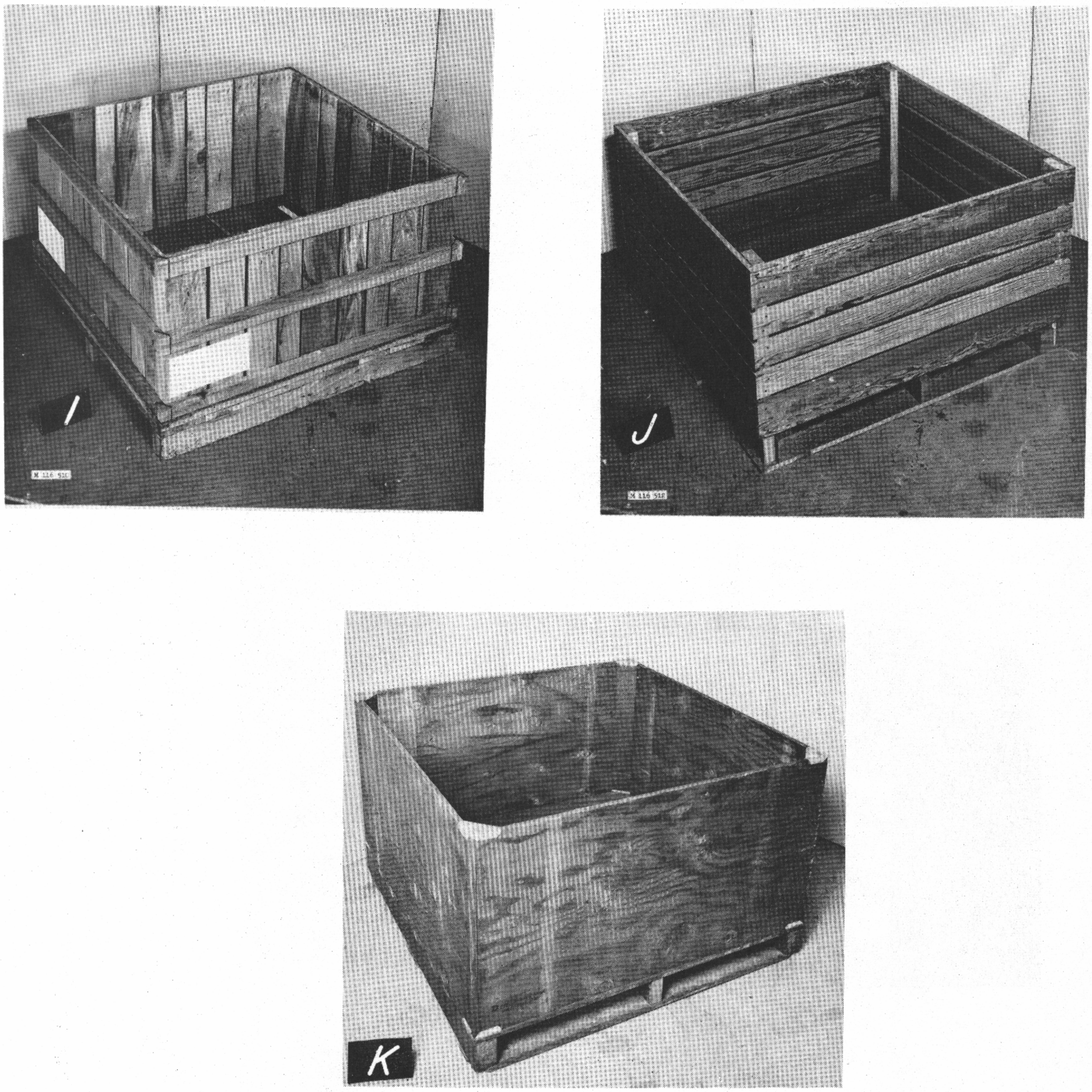


Figure 3. --Upper left to right, bin pallets I and J; lower, bin K.

Z M 119 021

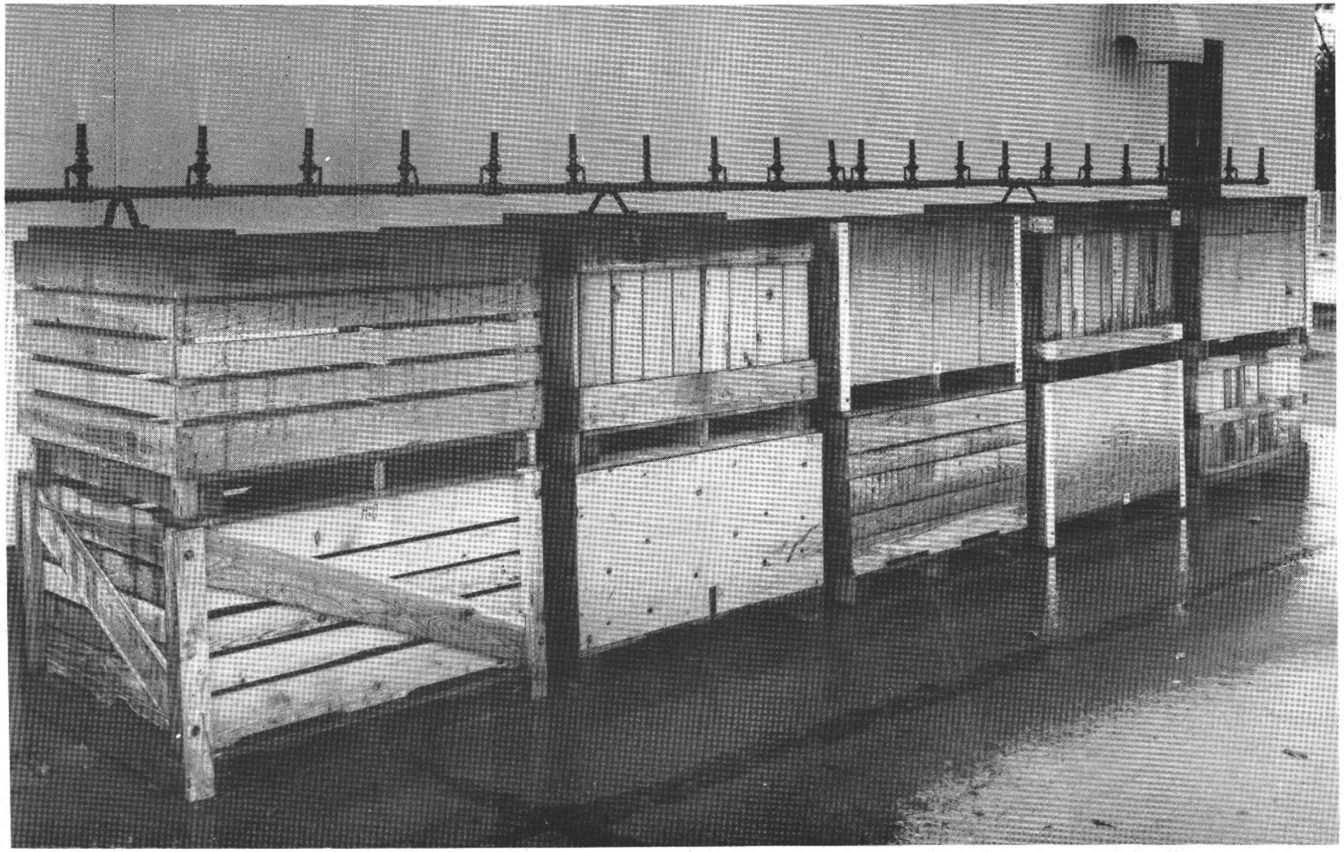


Figure 4. --Spray test for apple bin pallets. Sixteen hours of water spray is followed by 4 days' drying in a kiln.

ZM 116 507

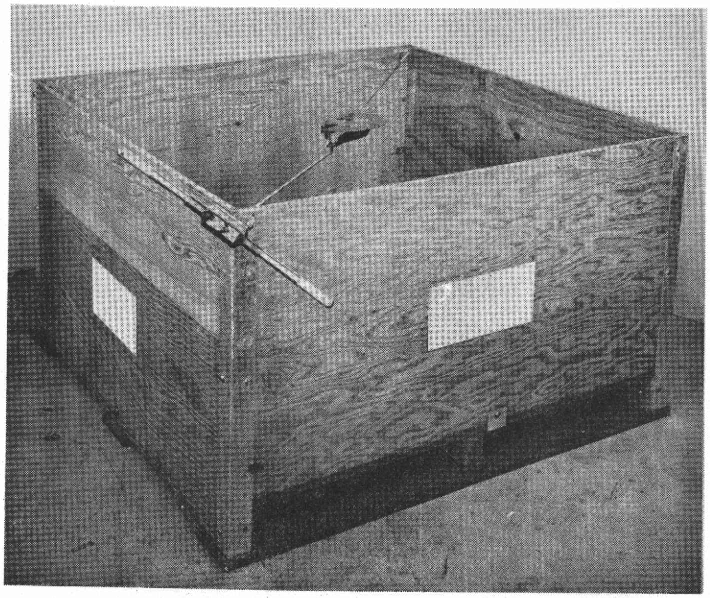


Figure 5. --Racking test of bin pallets. Diagonal pressure is applied to the top diagonal by turning up nuts on the rod. The magnitude of the force is measured by the dynanometer at the center.

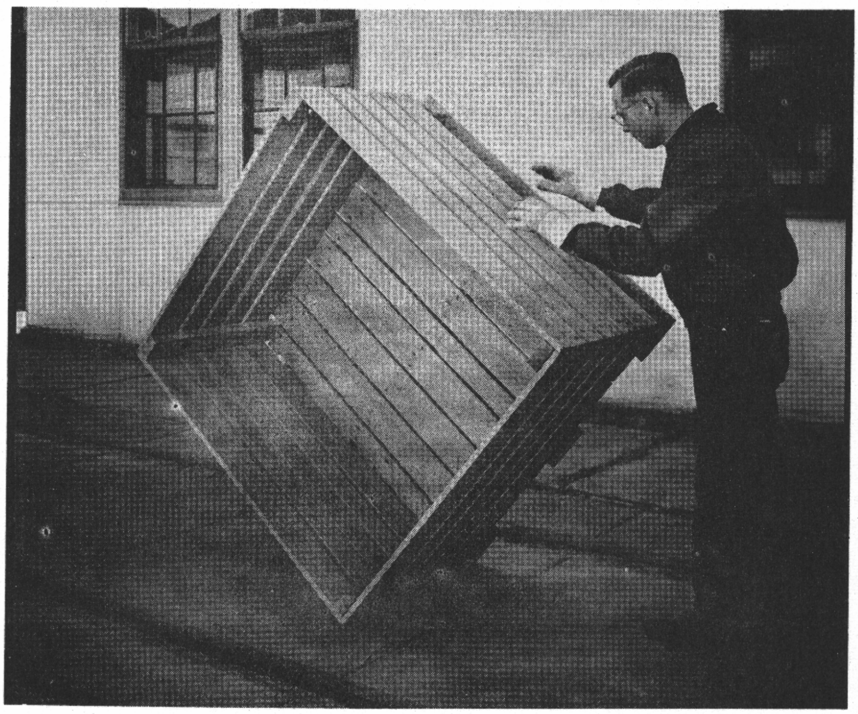


Figure 6. --Rollover test for bin pallets. This sort of rough handling simulates the impacts imparted by rollovers in the orchards to place bins in proper locations for filling.

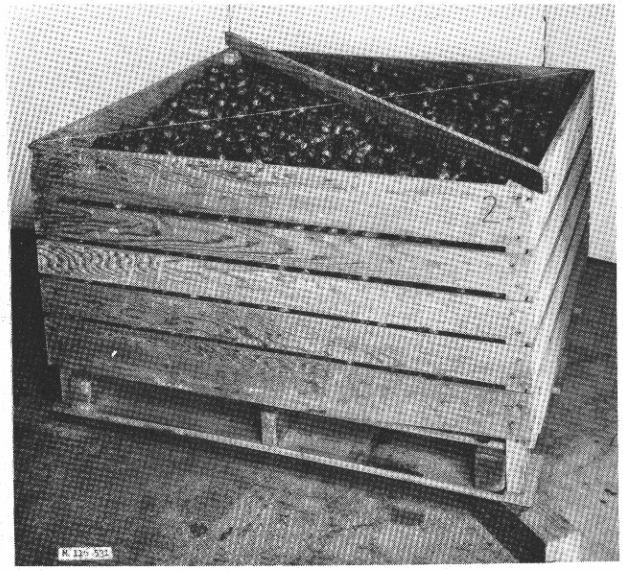


Figure 7. --Sag test for bin pallets. The deformation in the bin is similar to that caused by placing loaded bins on rough terrain.

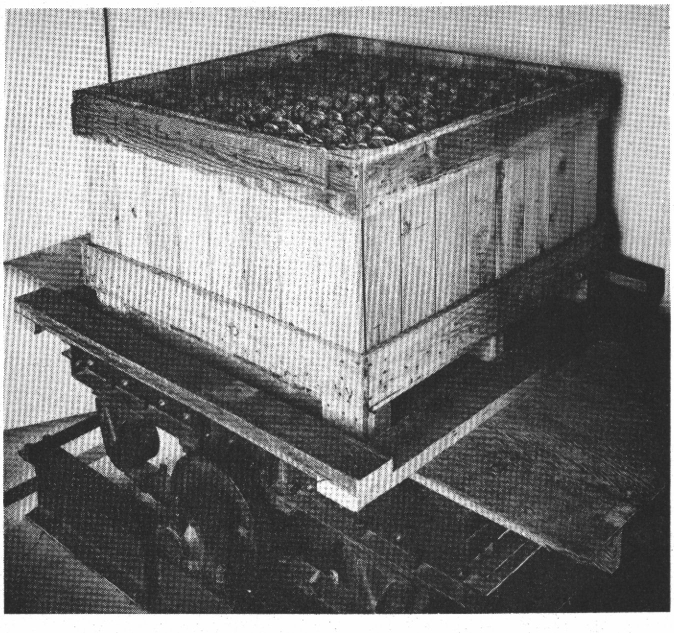


Figure 8. --Vibration test of bin pallets. Movements are produced that simulate those induced by transport over rough roads.

Z M 119 019

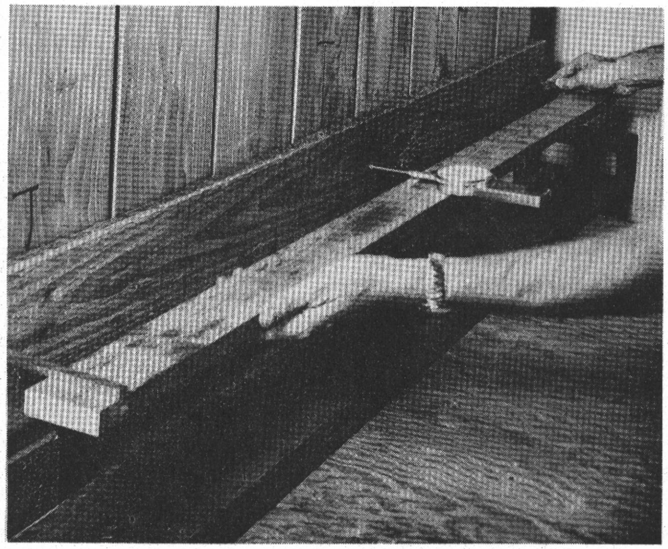


Figure 9.--Method of measuring the bulge caused by vibrating in bin pallet sides and ends. The potatoes settle and produce an outward pressure on the sides.

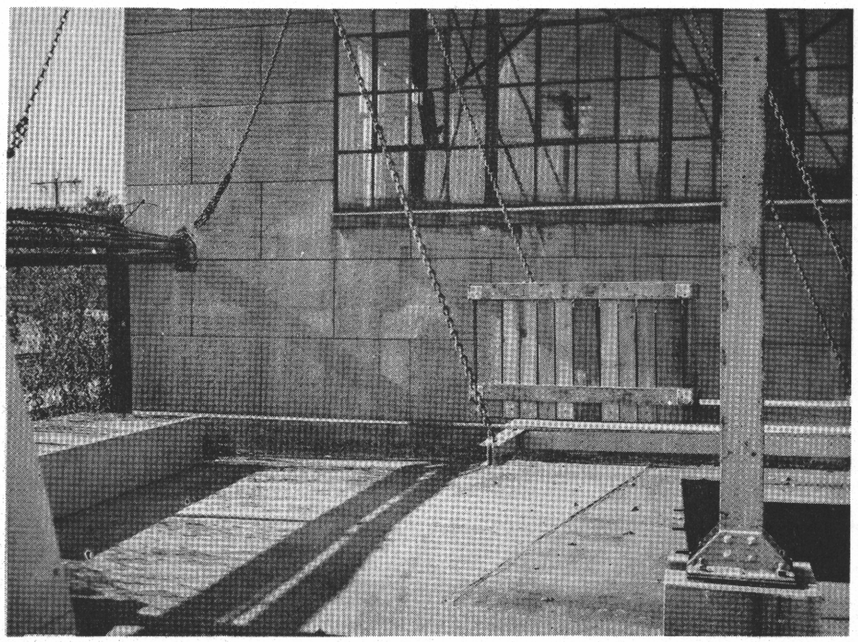


Figure 10.--Pendulum-impact test of bin pallets. Severe lateral impacts are imparted to the container when it contacts the concrete bumper on the left.

Z M 119 024

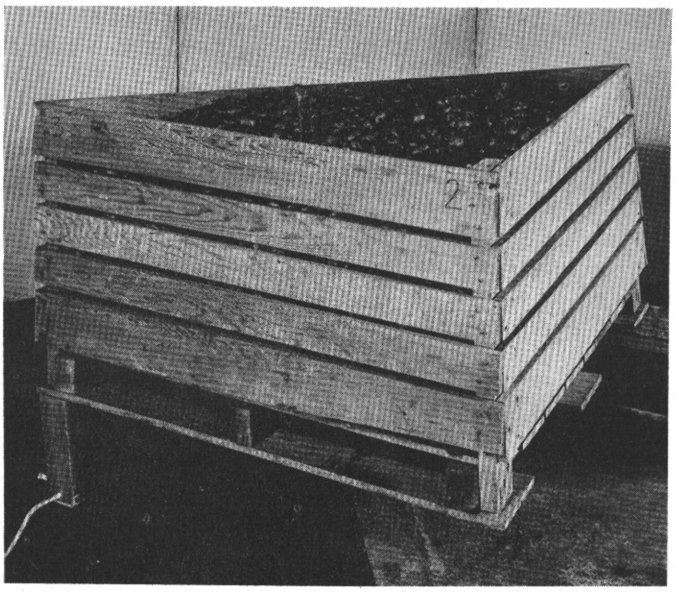


Figure 11. --Cornerwise-drop test for bin pallets. This test simulates rough handling on uneven ground.

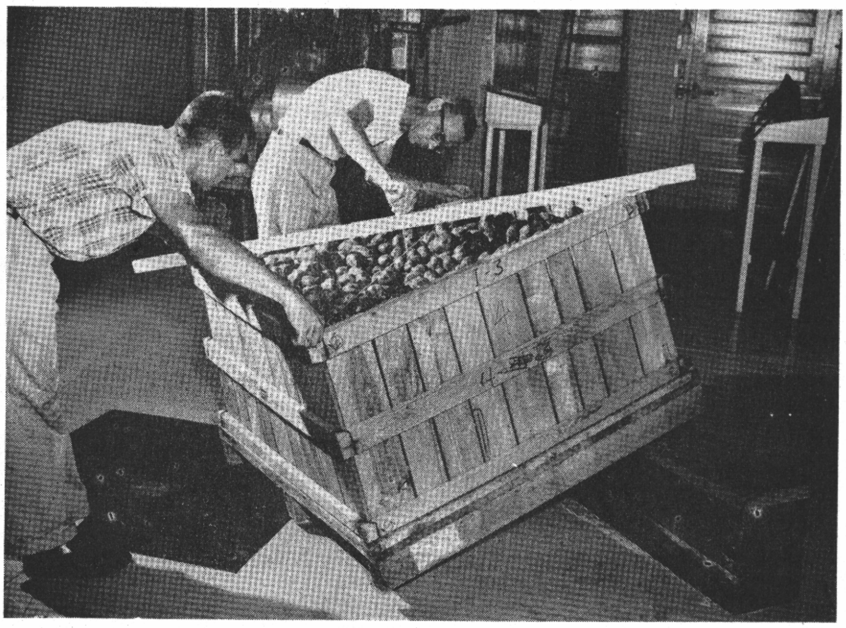


Figure 12. --Method of measuring sag of bin pallets after each drop in the cornerwise-drop test.

Z M 119 023

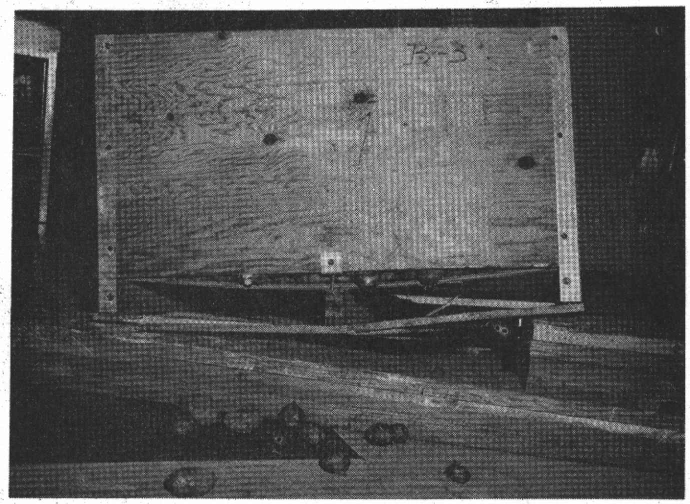


Figure 13. --Bin pallet B after cornerwise-drop test. The wood screws, assembling top assembly to base, have pulled loose from the stringers.

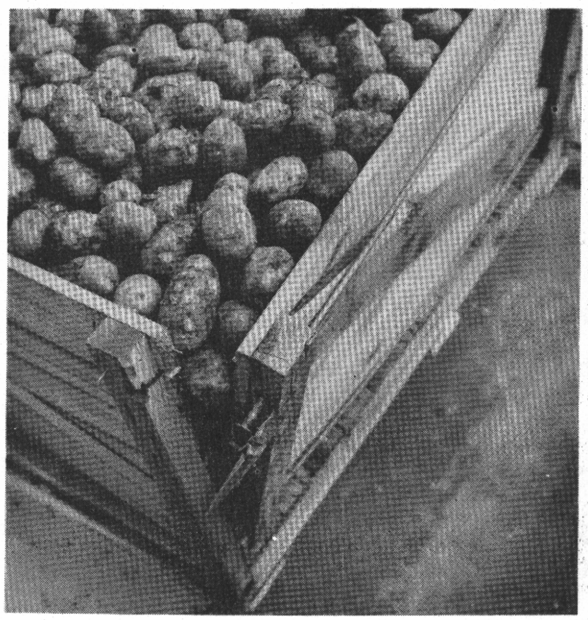


Figure 14. --Bin pallet F after pendulum-impact test. The 2- by 3-inch corner post has been split by the forward thrust of the load.

Z M 119 016

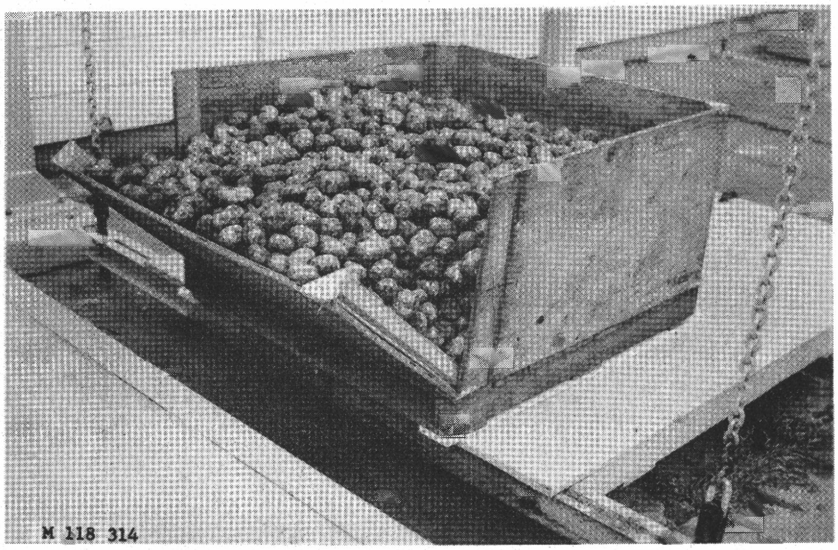


Figure 15. --Bin pallet K after the pendulum-impact test. The triangular assembly plate at the top corners failed to hold the end panel to the sides.

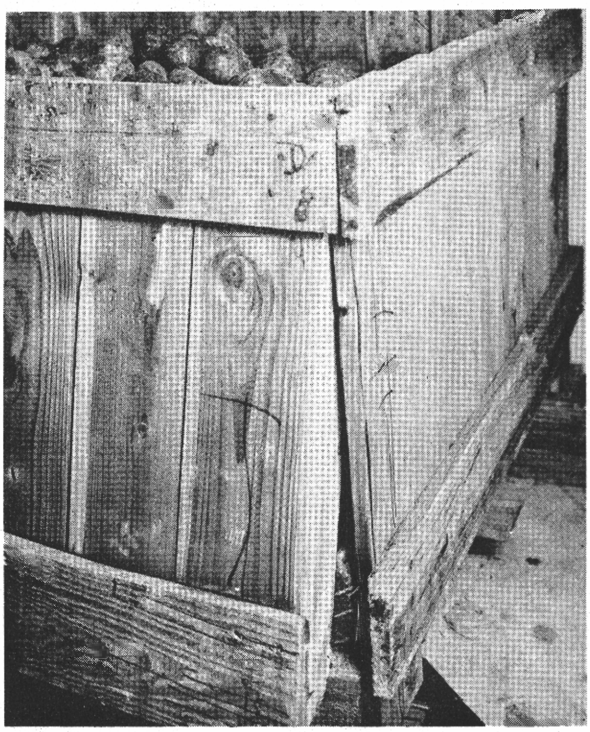


Figure 16. --Bin pallet A after the cornerwise-drop test. The three assembly nails at the bottom corner were incorrectly driven so that they did not penetrate the corner post.

Z M 119 017