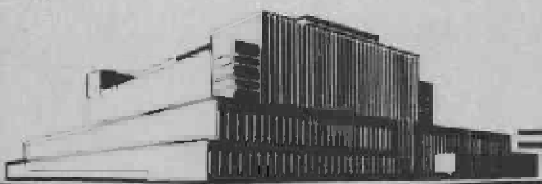
TESTS OF CARGO FLOORING

Pp AND U FOR AIRCRAFT

Information Reviewed and Reaffirmed

March 1956

No. 1550-G



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

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

TESTS OF CARGO FLOORING Pp AND U FOR AIRCRAFT[1]

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Summary

Simulated service and strength tests of two types of cargo aircraft flooring were made at the Forest Products Laboratory in cooperation with and at the request of the Air Materiel Command, U. S. Air Force (Wright-Patterson Air Force Base). The tests were made in accordance with methods previously established[3] for the evaluation of cargo flooring materials, and the results are compared with those of other floors tested previously.[4]

The cargo aircraft flooring panels designated Pp and U were sandwich-type materials having metal facings bonded to a 3/4-inch-thick resin-impregnated cotton-fabric honeycomb core. The upper or wearing surface of floor Pp was FS-1A magnesium alloy 0.090 inch thick, and that of floor U was the same alloy 0.081 inch thick. The lower surface of both floors was FS-1H magnesium alloy 0.032 inch thick.

Floor U was the lighter of the two floors, weighing 1.62 pounds per square foot compared to 1.71 pounds per square foot for floor Pp.

Both floors had the same rating when compared according to tentative method A and compared favorably to floors of similar construction tested previously.

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[1]The work here reported was done under U. S. Air Force Order No. (33-038)49-1875E. Original report issued April 1949.

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

[3]"Methods for Testing and Evaluating Cargo Flooring for Transport Aircraft," Forest Products Laboratory Report 1550, April 1945.

[4]"Development of a Sandwich-type Cargo Floor for Transport Aircraft," Forest Products Laboratory Report 1550-C, September 1947;
"Tests of Cargo Flooring N and P for Aircraft," Forest Products Laboratory Report 1550-D, January 1948;
"Tests of Cargo Flooring Nn and T for Aircraft," Forest Products Laboratory Report 1550-F, October 1948.

These floors, however, are somewhat less satisfactory than floors of similar type faced with aluminum. Increasing the resistance of the core to crushing over supports would measurably increase the resistance of floors Pp and U to rolling loads.

Introduction

The tests on cargo floor types Pp and U were made by the Forest Products Laboratory as part of a cooperative program with the Air Materiel Command, U. S. Air Force (Wright-Patterson Air Force Base) to evaluate materials proposed for use as floors for cargo airplanes. Cargo floors Pp and U were made of resin-impregnated cotton-duck cores faced with a magnesium alloy. The basic strength tests and studies to evaluate performance under simulated service conditions were made in accordance with methods previously developed for testing and evaluating cargo flooring material,[3] and comparison is made to other sandwich-type floors tested previously.[4] The studies on floor Pp are essentially an extension and more complete evaluation of floor P, which was previously investigated. The magnesium alloy wearing surface of floor Pp is in the annealed condition, however, as contrasted to the hard-rolled state as used in floor P.

Material

Floor Pp

The sandwich-type floor Pp consisted of a honeycomb core faced with magnesium alloy. An edge view of floor Pp is shown in figure 1. The honeycomb core was made of resin-impregnated cotton fabric with hexagonal cells approximately 3/8 inch across the flats and weighed about 0.60 pound per square foot. The upper or wearing surface was FS-1A magnesium alloy 0.090 inch thick, and the lower face was FS-1h magnesium alloy 0.032 inch thick.

Floor U

Figure 1 shows an edge view of cargo flooring U. This flooring was of the same construction as floor Pp except that the wearing surface was 0.081 inch thick.

Method of Test

The panels were weighed, measured, and then prepared as required for use as specimens. The following tests were made in accordance with methods specified for evaluation of this material and described in an earlier report.[3]

Static bending.--Specimens 8 inches in width tested over 8- and 16-inch spans.

Strip loading.--Under a 1-1/4- by 9-inch steel bar.

Concentrated loading.--Applied by a 1-inch-diameter steel rod and by a 2-1/2-inch-wide maple block shaped to a 4-inch radius.

Impact loading.--Under the drop of a 200-pound softwood-box corner.

Rolling load.--Applied by an engine-cradle wheel.

The specimens were so oriented that the direction of the continuous strip of the cotton-duck core was parallel to the length of the specimens, except those for strip-loading tests.

In addition, compression tests loaded normal to the wearing surface, were made on 4- by 4-inch specimens in the condition in which they were received and after soaking in water for 24 hours.

Presentation of Data

A summary of results obtained from tests of floors Pp and U is given in table 1. Each tabular value is the average of two or more tests, except in the case of the rolling-load tests, where only a single panel was used for each loading condition.

Compression

To evaluate the effect of moisture on the crushing strength of these floors, 12 specimens of each type of floor were tested; six in the condition as received, and six after soaking in water at room temperature for 24 hours. The 4- by 4-inch specimens were loaded in compression normal to the wearing surface of the floor. The comparative strength values are given in table 1.

Static Bending

Eight static-bending specimens of each flooring material and span length, two from each of four panels of floors Pp and U, were tested over 8- and 16-inch spans. The average results of these tests are tabulated in table 1.

Typical load-deflection curves for specimens tested over 8- and 16-inch spans for floors Pp and U are presented in figures 2 and 3. Figure 4 shows the type of failure, shear of the glue bond between the core and facings that occurred when these flooring materials were tested over an 8-inch span. All of the specimens of type U and half of the type Pp specimens failed in tension of the lower face, as shown in figure 5, when tested over a 16-inch span. Some of the

Pp flooring materials, however, when tested over a 16-inch span, failed in shear in the glue bond between the core and the facings, and an example of this type of failure is also shown in figure 5.

Strip Loading

Strip-loading tests, simulating the action of a floor beam on the underside of a loaded panel, were made on five specimens of each of the floors Pp and U.

Typical load-deformation curves for specimens of floors Pp and U are shown in figure 6, and a photograph of the resultant failures in figure 7. The normal failure was crushing of the core at a deformation of about 0.03 inch as shown in figure 7, but one specimen of each material failed by shearing of the magnesium face in addition to crushing of the core. The type of failure is consistent with that obtained on sandwich-type floors tested previously.[4]

Concentrated Loads

The concentrated loads were applied to the panels through a 1-inch-diameter steel bar and a 2-1/2-inch wide maple block rounded to a 4-inch radius at exterior and interior positions, 4 and 12 inches from an unsupported edge of the panel. The normal failure under loads applied through the maple block was shearing of the glue bond between the core and the facings, which sometimes affected the results of later tests on the same panel. Therefore to present a more uniform measure of the performance of these floors, the load at 0.5-inch deflection was used as the criterion of quality and is the tabulated value in table 1. This method of analysis has been used for previous tests of cargo floors.[4] Photographs of typical failures and the positioning of the loads for floors Pp and U are shown in figures 8 and 9, which show as well the punching shear that results from loads applied with the steel bar.

Impact Loading

A measure of the resistance of floors Pp and U to impact loads was obtained by dropping a 200-pound softwood-box corner on the wearing surface of the panel from various heights. The deflection of the lower surface of the panel directly under the point of impact was measured at the time of impact and after the load was removed. The relation of the deflection under load and permanent set of the panel to the height of drop are presented in figure 10. Figures 11 and 12 show typical panels of floors Pp and U after they were subject to the impact tests. The heights of the various drops are indicated adjacent to the indentations made in the wearing surface.

Rolling Load (Engine-cradle wheel)

Six panels of each floor, Pp and U, were tested to failure under repeated rolling loads varying in magnitude from 800 to 1,600 pounds and applied through the wheel of an engine cradle. Semilogarithmic plots of load and number of trips to failure are shown in figure 13. Figures 14 to 19, inclusive, show photographs of typical failures of these floors after rolling-load tests.

Analysis of Results

Weight

The average weight of floors Pp and U was 1.71 and 1.62 pounds per square foot, respectively. Floor U is one of the lightest sandwich-type floors tested,[4] and both floors were well within the assumed upper limit of 2 pounds per square foot for cargo flooring material.

Compression

The results of the compression tests on these floors show that after soaking the compressive strength of floors Pp and U was about 30 percent less than the strength of the floors as received. The weight of the specimens increased 10 to 15 percent during the soaking period. The percentage weight increase would not be expected to be this large for the full-size floor panels, but some weight increase could be expected under adverse moisture conditions, and therefore some strength loss would result. The effect of moisture on floors Pp snd U resulted in a strength loss of the same magnitude as that for floors Nn and T tested previously,[4] although the compressive strength of the core material used in floors Pp and U was not as great as that employed in floors Nn and T.

Static Bending

Static bending tests on floors Pp and U gave results that showed them to be about equal in load-carrying capacity and that indicate good strength in comparison to other floors previously tested.[4] The energy-absorption qualities of both flooring materials, as measured by work per inch of width to ultimate strength, when tested over a 16-inch span, was satisfactory, although somewhat less than that obtained with the better aluminum-faced sandwich flooring materials. This same property, obtained from tests made over an 8-inch span, where the shear strength governs, was very much below that of floor P and was less than that for other sandwich floors tested. The glue bond of floors Pp and U appeared to be less plastic than that of floor P, and therefore to result in less deflection at maximum load and consequently lower work values to maximum load. The failures that result in the static-bending tests cause the load to decrease abruptly after the maximum load is reached, and result in a greatly reduced load-carrying capacity for these flooring materials.

Strip Loading

The resistance of cargo floors Pp and U to strip loading, simulating the reaction of a floor beam on the lower surface of a panel, was about 10 percent less that of other sandwich-type floorings investigated, but still would be considered very satisfactoy. The ultimate strength values of floors Pp and U were about the same as would be expected, since they have the same core and lower-face construction, and occurred at a deflection of about 0.03 inch. Failure was generally due to crushing of the core material, as shown in figure 7; and in one instance for each flooring material, this was accompanied by punching shear of the lower facing.

Concentrated Loads

Concentrated loads using a 1-inch-diameter steel bar and a curved maple block to simulate the loading under an engine-cradle wheel, were applied to panels of floorings Pp and U at exterior and interior positions 4 to 12 inches from an unsupported edge. Results of the tests using the 1-inch-diameter steel bar were better than those obtained from floor P, tested previously,[4] and showed the advantage of using an annealed magnesium alloy over one that is hard-rolled. The values obtained for floors Pp and U were somewhat below those obtained on sandwich floors with aluminum facings.[2] Floor Pp is about 10 percent stronger than floor U, as would be expected from the thickness of the wearing surface of the two materials. The results of the concentrated load tests on flooring materials Pp and U, using the maple block, where the typical failure was shear in the glue bond between the core and the faces, were not so good as those obtained with floor P tested previously. The lower results of floors Pp and U may be due to a somewhat lower bond strength in these panels, as indicated also by the decreased deflections obtained in short-span static-bending tests.

Impact Loading

The greater shock resistance of magnesium in the annealed instead of the hard-rolled condition is evident from the superior performance of cargo floors Pp and U in the impact-loading tests when compared to the results obtained previously on floor P.[4] The maximum height of drop, 21 inches, of the 200-pound softwood-box corner did not rupture the wearing surface of floors Pp and U, nor did it damage the surface of these panels to the extent that they would be no longer serviceable. One panel of floor Pp failed in the glue bond between the core and the faces at heights of drop of 8 inches and above, indicating that the bond on that particular panel was exceedingly poor. Generally, flooring type U did not deflect as much under load, nor was the residual deformation as great, as with floor type Pp, although the surface damage was about the same for both floors.

Rolling Load

Cargo flooring type U did not stand up under repeated trips of the weighted engine-cradle wheel an well as did type Pp, and both types of floors rated lower than type P, tested previously,[4] particularly under the higher loads. In all of the rolling-load tests on flooring materials Pp and U, the first indication of failure was crushing of the core over the supports, which thus transferred a large percentage of the load to the wearing surface. Initial failure of the magnesium was evidenced by a crack over one of the supports that would grow progressively larger as the load was repeated and would ultimately result in complete failure of the panel. These flooring materials were not as good in rolling-load resistance as were similar sandwich panels faced with aluminum; nevertheless, they would be quite satisfactory, particularly at lower loads. The values reported in table 1 are for complete failures and would have to be reduced about 10 percent to indicate the relative serviceable life of the panel.

Conclusions

The results of the tests made on magnesium-faced cargo flooring Pp and U, when compared to results of tests of floors obtained previously,[2,3,4] show that these floors are among the better floors tested, but are less satisfactory than sandwich flooring materials faced with aluminum. These flooring materials might be improved by using a glue bond between the core and the facings that would have more plasticity and thus allow more deflection before failure, which would increase their ability to absorb energy before shear failures occurred in the glue bond. As with the sandwich-type floors previously tested, increasing the crushing strength of the core over supports would increase the rating of the panel substantially.

APPENDIX A

Comparative Ratings of Floors Pp and U

Results of Forest Products Laboratory tests and ratings by tentative methods A and B as described in Forest Products Laboratory Report No. 1550[2] are presented for floors Pp and U in tables 2 and 3. Since the original impact test permitted a maximum height of drop of 15 inches and this maximum was used in rating other floors, the same maximum will be used in rating floors Pp and U, although these floors will take greater impact loads without damage. A floor will be given a rating of 100 in impact if no serious damage results from a drop test from heights of 15 or more inches.

Table 1.--Summary of results of tests of cargo flooring panels Pp and U

Property	Unit	Panel type: Pp	Panel type: U
Weight of panel	Pounds per square foot	1.71	1.62
Compression(perpendicular to face of panel)			
Ultimate load			
As received	Pounds per square inch	870	900
Soaked in water 24 hours		620	630
Static bending			
8-inch span			
Ultimate load per inch of width	Pounds	460	460
Work to ultimate per inch of width	Inch-pounds	55	60
16-inch span			
Ultimate load per inch of width	Pounds	300	310
Work to ultimate per inch of width	Inch-pounds	250	270
Strip loading			
Ultimate load	Pounds per square inch	1,360	1,350
Deflection at ultimate	Inch	0.030	0.030
Concentrated loading			
1-inch steel cylinder interior position	Pounds	3,680	3,300
Deflection at ultimate	Inch	0.500	0.450
1-inch steel cylinder exterior position	Pounds	3,450	2,940
Deflection at ultimate	Inch	0.600	0.520
Maple block, 4-inch radius, interior position, load at 0.5-inch deflection	Pounds	4,470	4,400
Maple block, 4-inch radius, exterior position, load at 0.5-inch deflection	Pounds	3,540	3,460

(continued)

Table 1.--Summary of results of tests of cargo flooring panels Pp and U (continued)

Property	Unit	Panel type Pp	Panel type U
Impact loading -- 200-pound box corner			
21-inch drop			
Deflection	Inch	0.608	0.462
Set	Inch	.128	.090
18-inch drop			
Deflection	Inch	.547	.413
Set	Inch	.091	.080
15-inch drop			
Deflection	Inch	.418	.493
Set	Inch	.075	.104
12-inch drop			
Deflection	Inch	.420	.334
Set	Inch	.083	.052
10-inch drop			
Deflection	Inch	.325	.271
Set	Inch	.052	.025
8-inch drop			
Deflection	Inch	.306	.311
Set	Inch	.048	.052
Rolling load -- engine-cradle wheel			
Load	Pounds	1,600	1,600
Trips		78	57
Load	Pounds	1,450	1,450
Trips		311	195
Load	Pounds	1,300	1,300
Trips		470	291
Load	Pounds	1,100	1,100
Trips		2,329	724
Load	Pounds	1,000	1,000
Trips		4,317	2,386
Load	Pounds	800	800
Trips		10,004	5,060

(concluded)

Table 2.--Comparative ratings of air-cargo floors based on best results obtained from Forest Products Laboratory weight, impact, and rolling-load tests according to tentative method A

Type of Test	Units	Floor Pp	Floor U
Weight per square foot	Pounds	1.71	1.62
Engine-cradle wheel rolling load sustained for 500 trips	Pounds	1,320	1,230
Allowable height of drop of 200-pound box corner	Inches	15	15

Criteria for satisfactory floors, based on best results

Weight = 1.42 pounds per square foot Rolling load = 1,450 pounds
Impact = 15 inches

Percentage of rating of floors, based on criteria

		Pp	U
Weight		83	88
Rolling load		91	85
Impact		100	100
Sum		274	273
Rating		91	91

Table 3.--Comparative ratings of air-cargo floors based on best results obtained from Forest Products Laboratory weight, impact, and rolling-load tests according to tentative method B

Type of Test	Units	Floor Pp	Floor U
Weight per square foot	Pounds	1.71	1.62
Engine-cradle wheel rolling load sustained for 1,000 trips	Pounds	1,210	1,110
Allowable height of drop of 200-pound box	Inches	15	15

Criteria for satisfactory floors based on best results

Weight = 1.42 pounds per square foot Rolling load = 1,300 pounds
Impact = 15 inches

Percentage rating of floors, based on criteria

		Pp	U
Weight		83	88
Rolling load		93	85
Impact		100	100
Sum		276	273
Rating		92	91

CARGO FLOORING Pp

CARGO FLOORING U

Figure 1. --Edge view of cargo floorings Pp and U showing the relative thickness of the magnesium facings and the cotton-fabric honeycomb core. The two floors are identical except for the thickness of the wearing surface, which is 0.090 inch thick in floor Pp and 0.081 inch thick in floor U.

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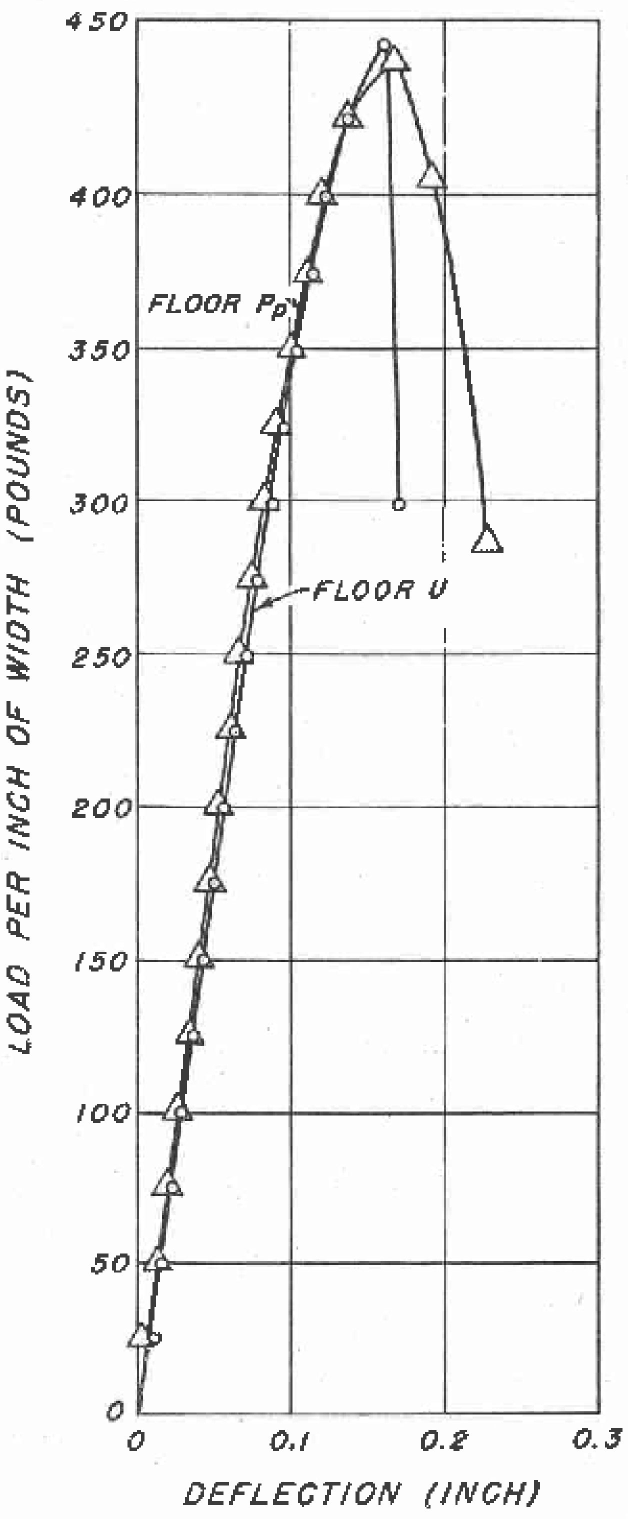


Figure 2. --Typical load-deflection curves for static-bending test of cargo floorings Pp and U, tested over an 8-inch span.

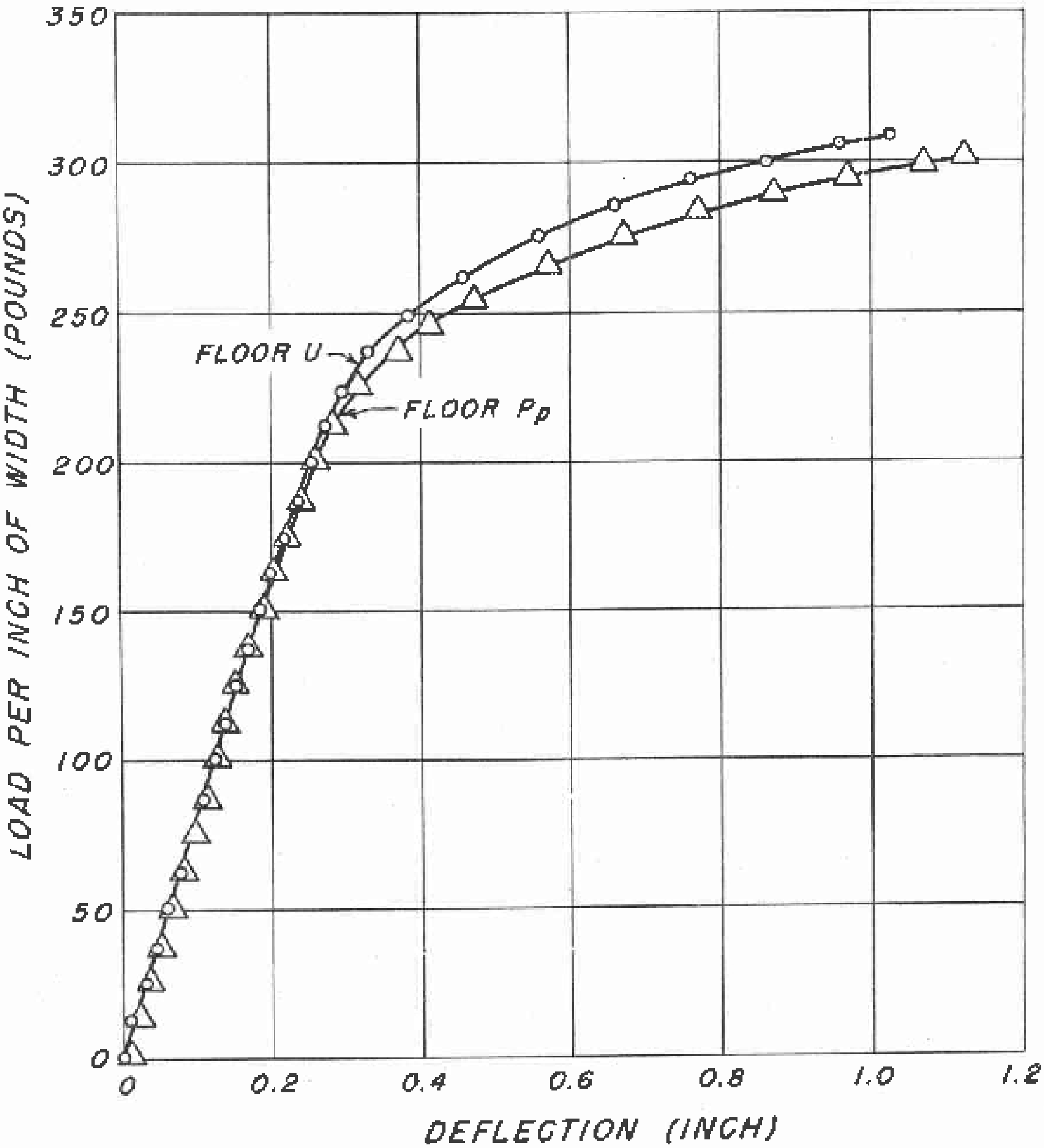
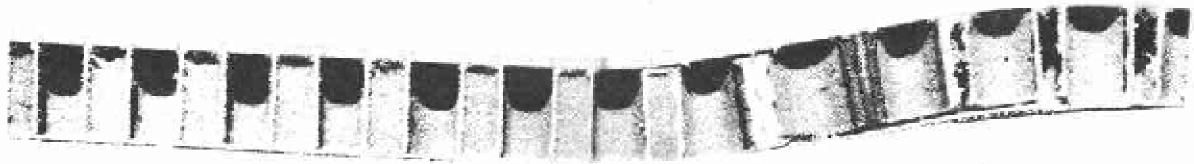
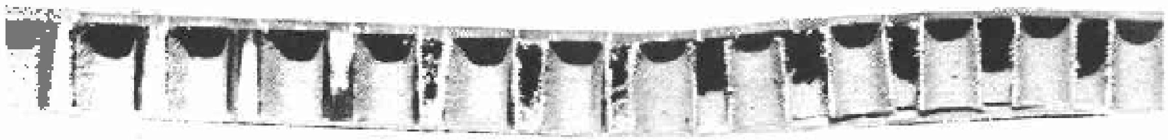


Figure 3.--Typical load-deflection curves for static-bending tests of cargo floorings Pp and U, tested over a 16-inch span.



CARGO FLOORING Pp



CARGO FLOORING U

Figure 4. --Typical shear failures that occur in the bond between the core and face material of floors Pp and U when tested in static bending over an 8-inch span.

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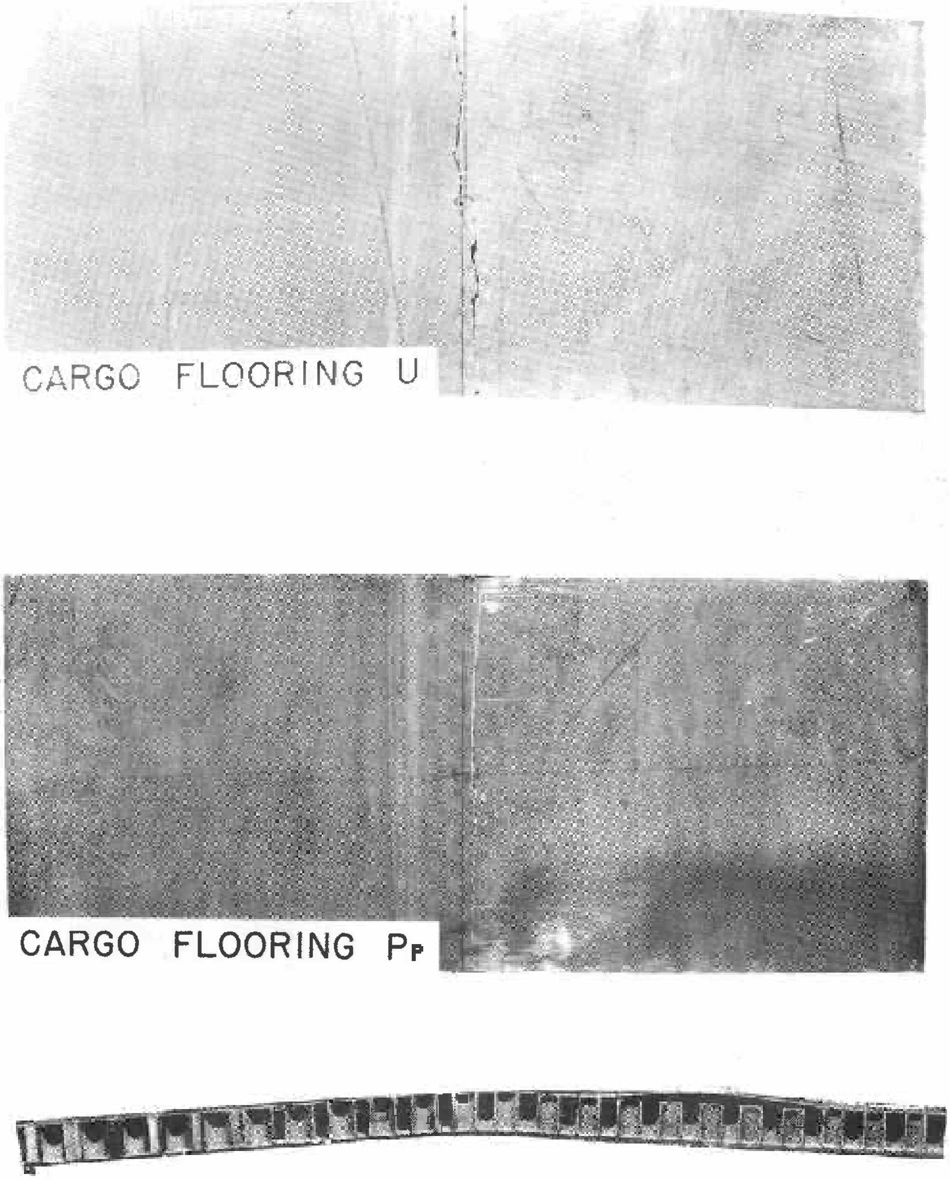

Figure 5.--Typical tension failure in the lower face of floor U and the tension and shear failures that occurred with floor Pp when tested in static bending over a 16-inch span.

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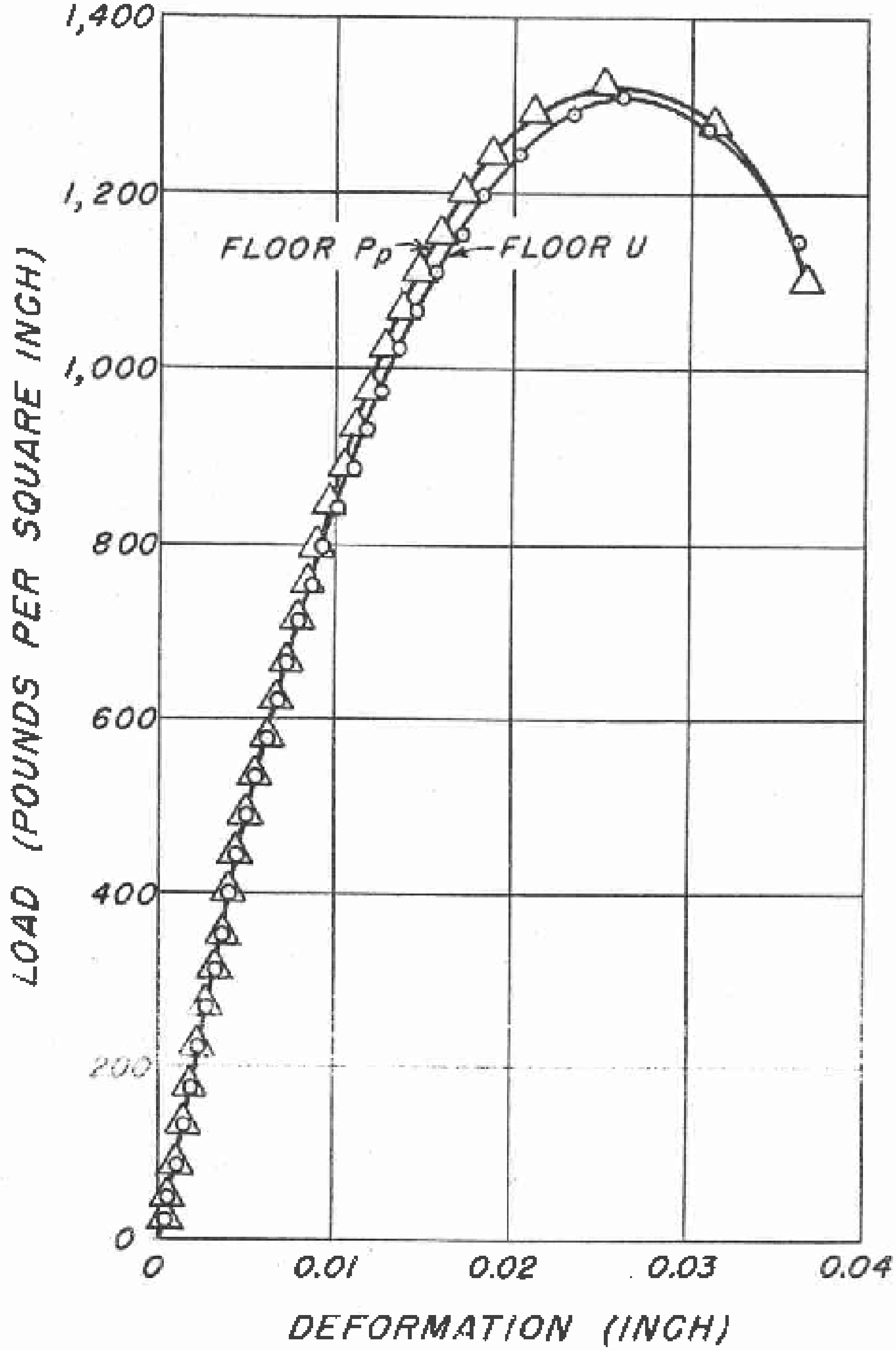

Figure 6. --Typical load-deformation curves for strip-loading tests on cargo floorings Pp and U.

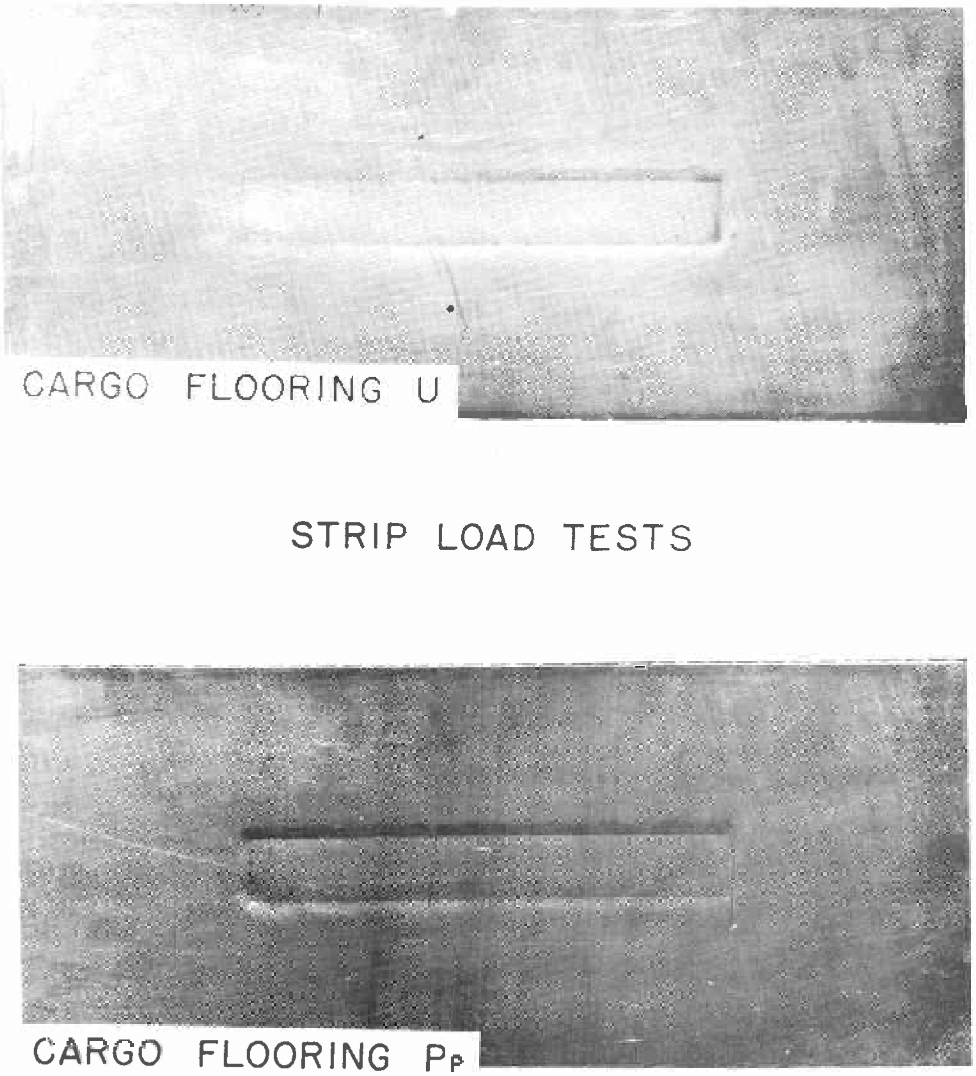

Figure 7.--Typical failures of cargo floorings Pp and U when tested in strip-loading on the lower face.

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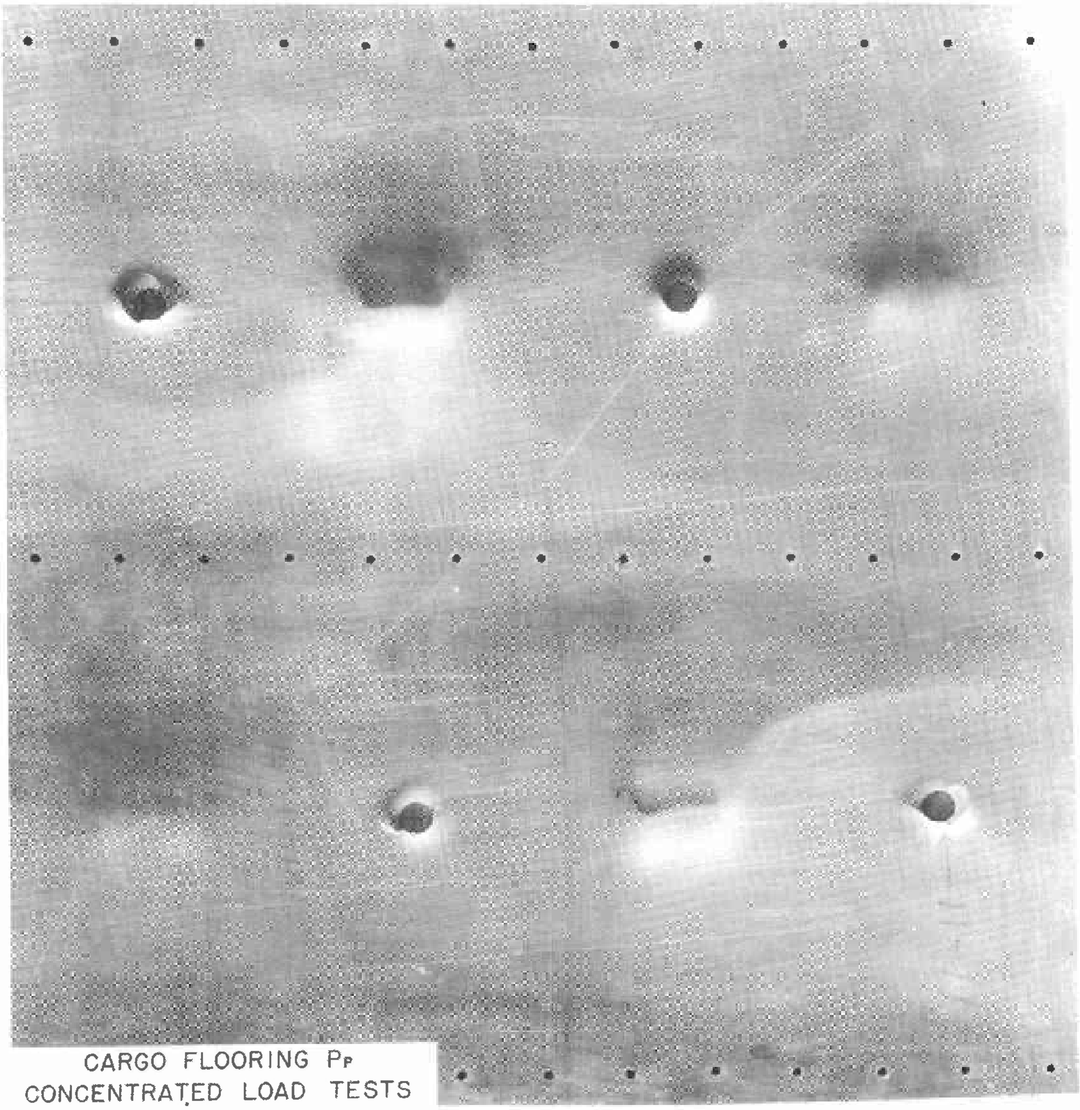

Figure 8.--Cargo flooring Pp showing damage resulting from concentrated-load tests.

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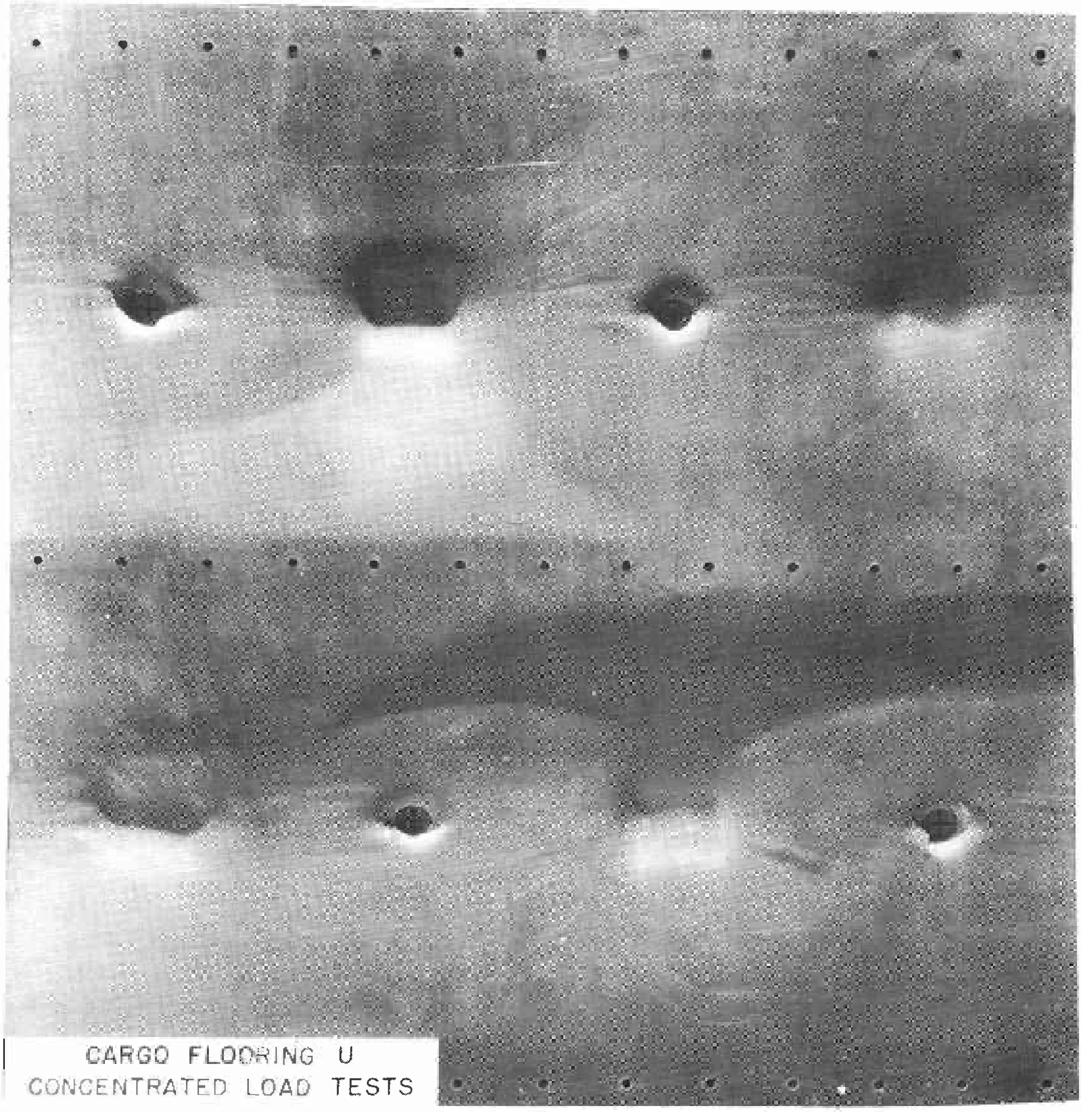

Figure 9.--Cargo flooring U showing damage resulting from concentrated-load tests.

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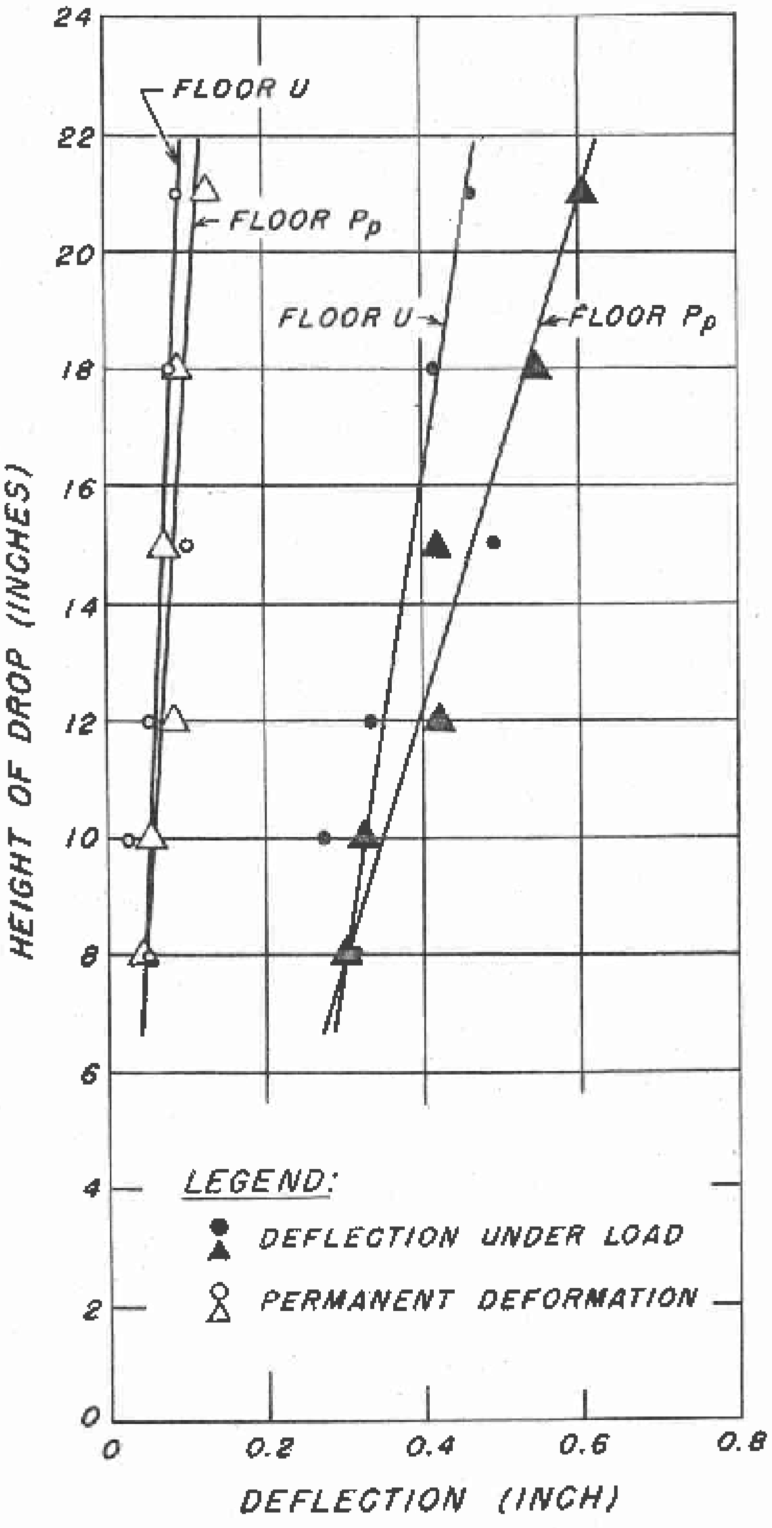

Figure 10. --Relationship between height of drop of a 200-pound softwood-box corner and the deflection and permanent deformation at point of impact for cargo floorings Pp and U.

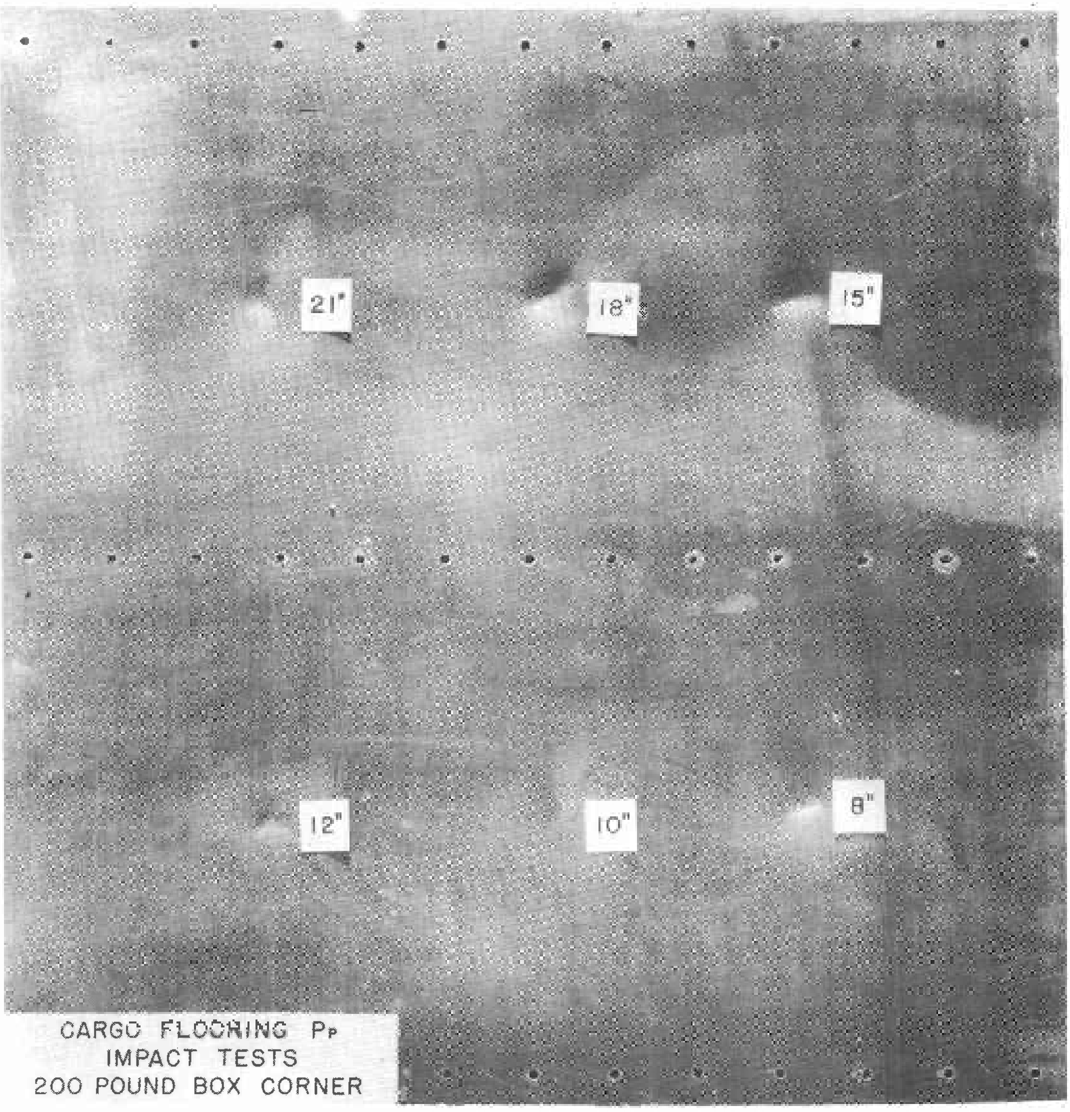

Figure 11.--Loaded surface of cargo flooring Pp showing position of blow, height of drop, and extent of damage that occurred under impact tests with a 200-pound softwood-box corner.

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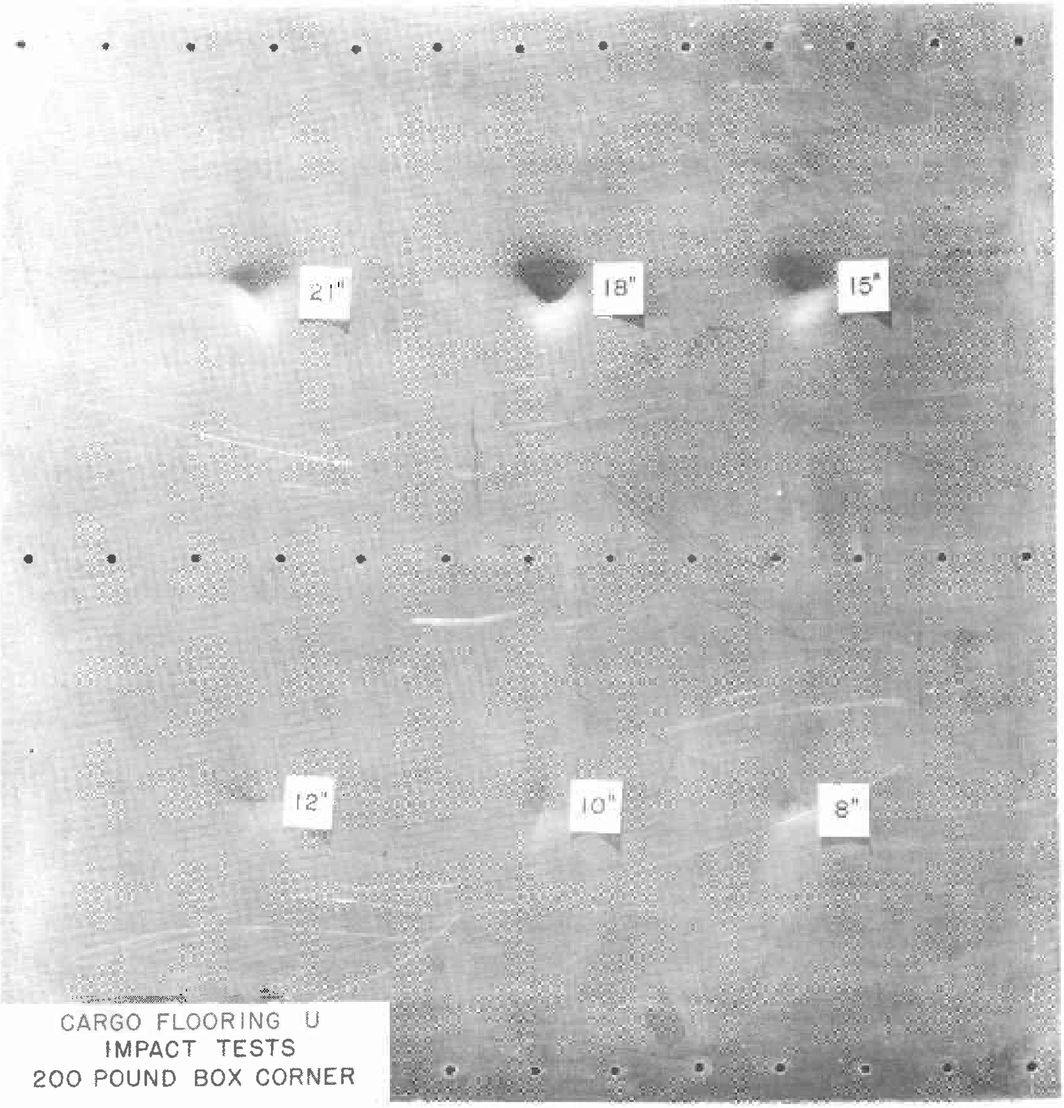

Figure 12.--Loaded surface of cargo flooring U, showing position of blow, height of drop, and extent of damage that occurred under impact tests with a 200-pound softwood-box corner.

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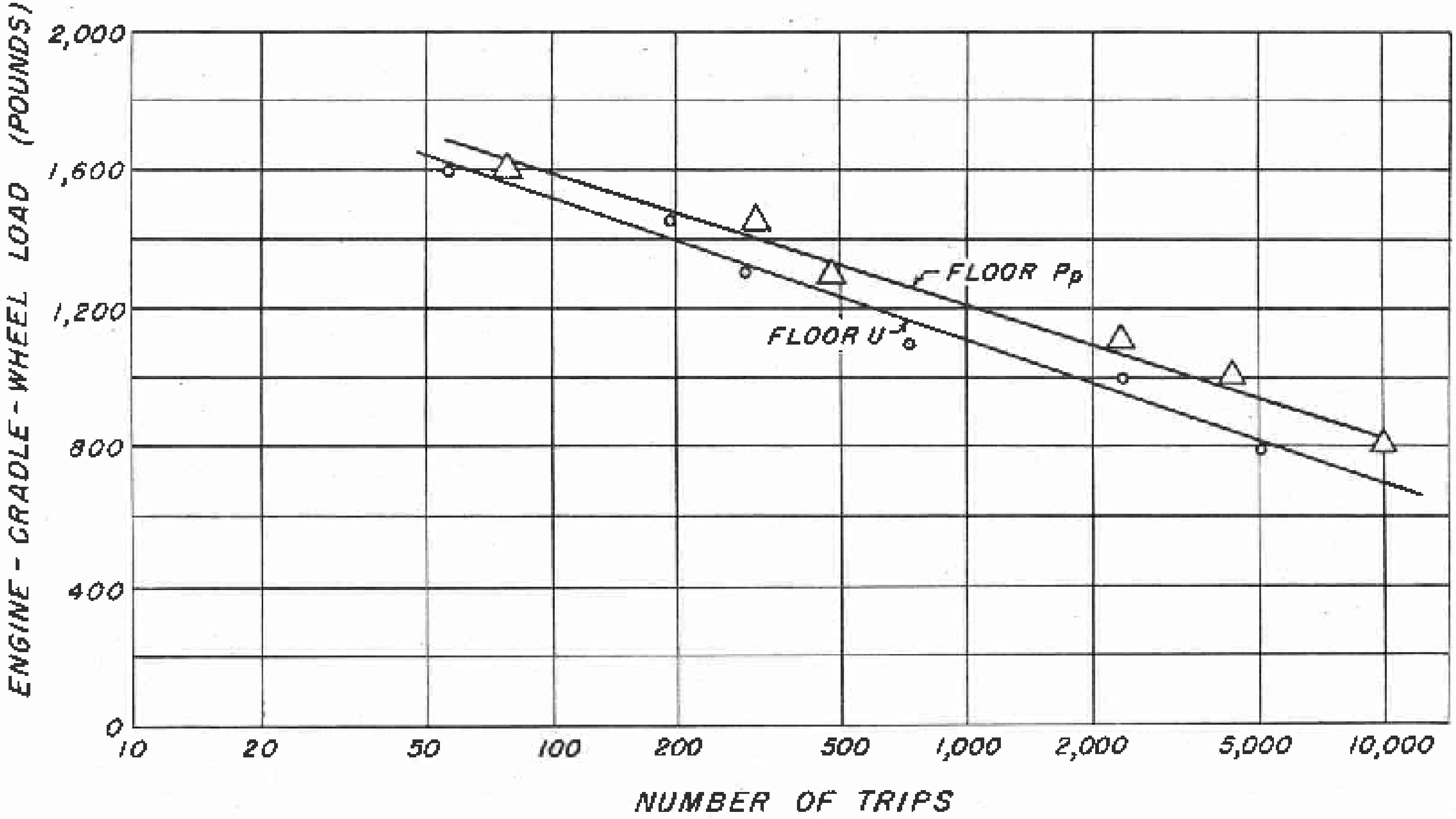

Figure 13. --Relation of number of trips to wheel load sustained by cargo floorings Pp and U when tested by a rolling load simulating that imposed by an aircraft engine-cradle wheel.

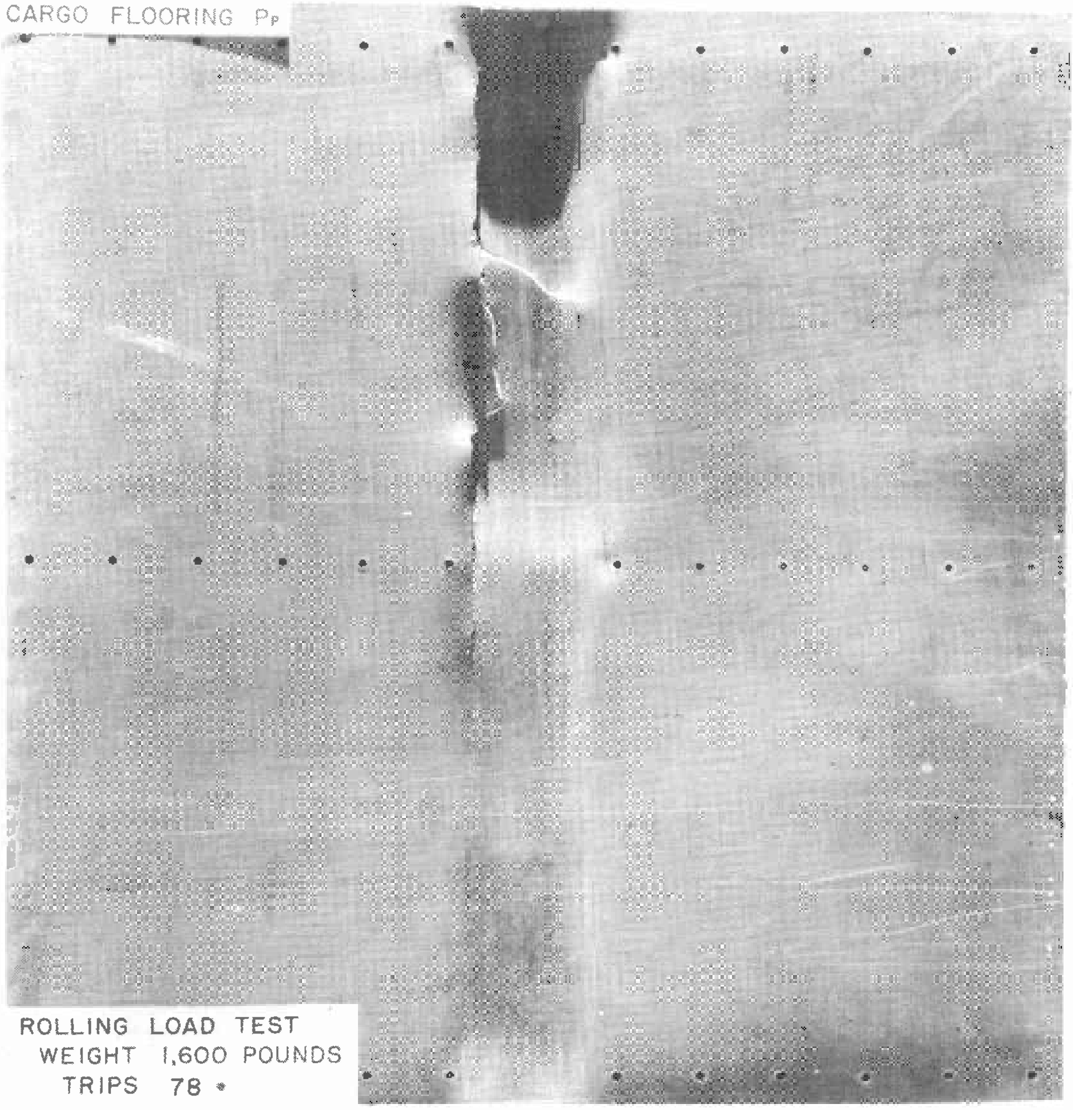

Figure 14.--Loaded surface of cargo flooring Pp after 78 repetitions of a 1,600-pound rolling load.

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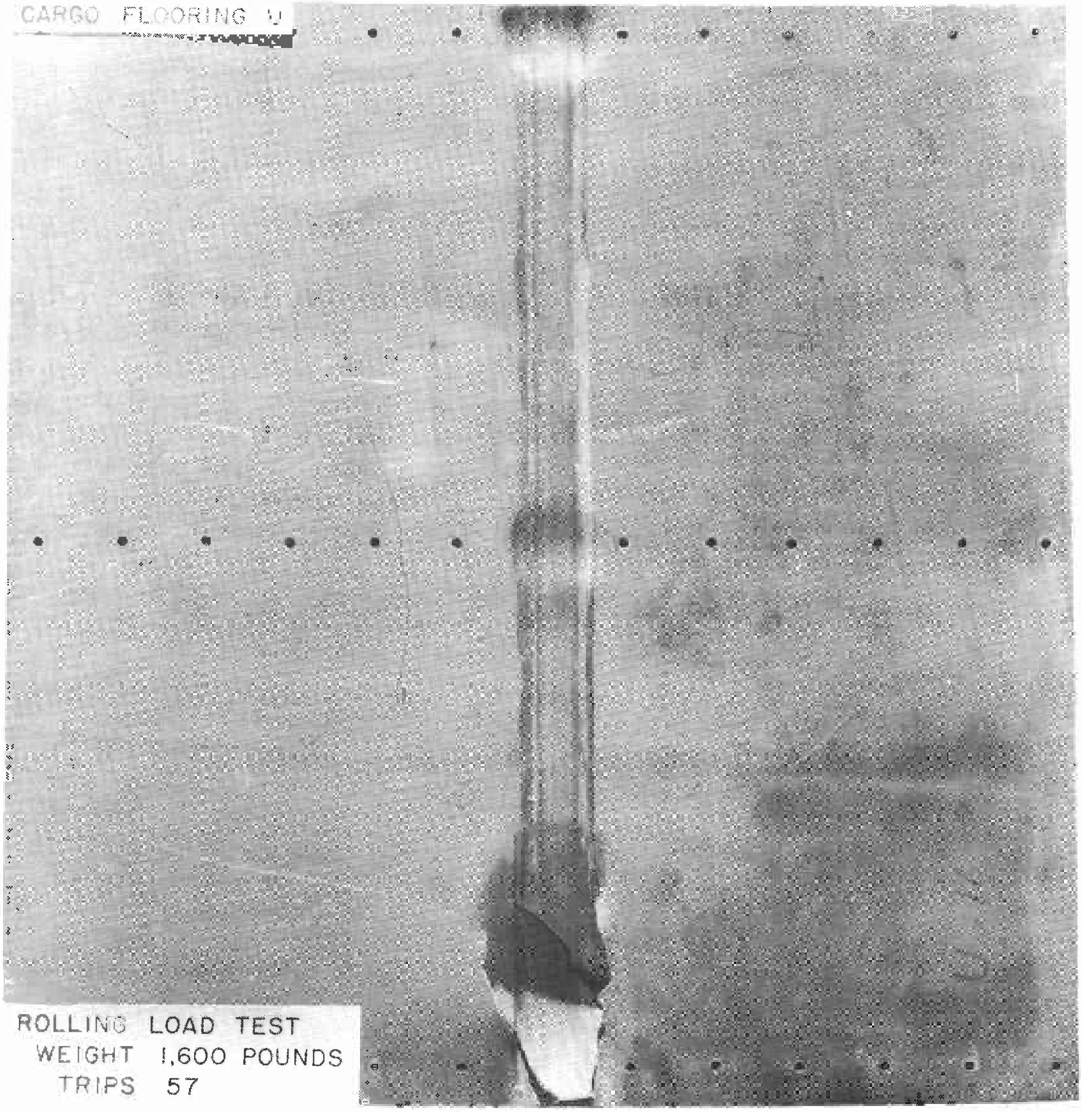

Figure 15.--Loaded surface of cargo flooring U after 57 repetitions of a 1,600-pound rolling load.

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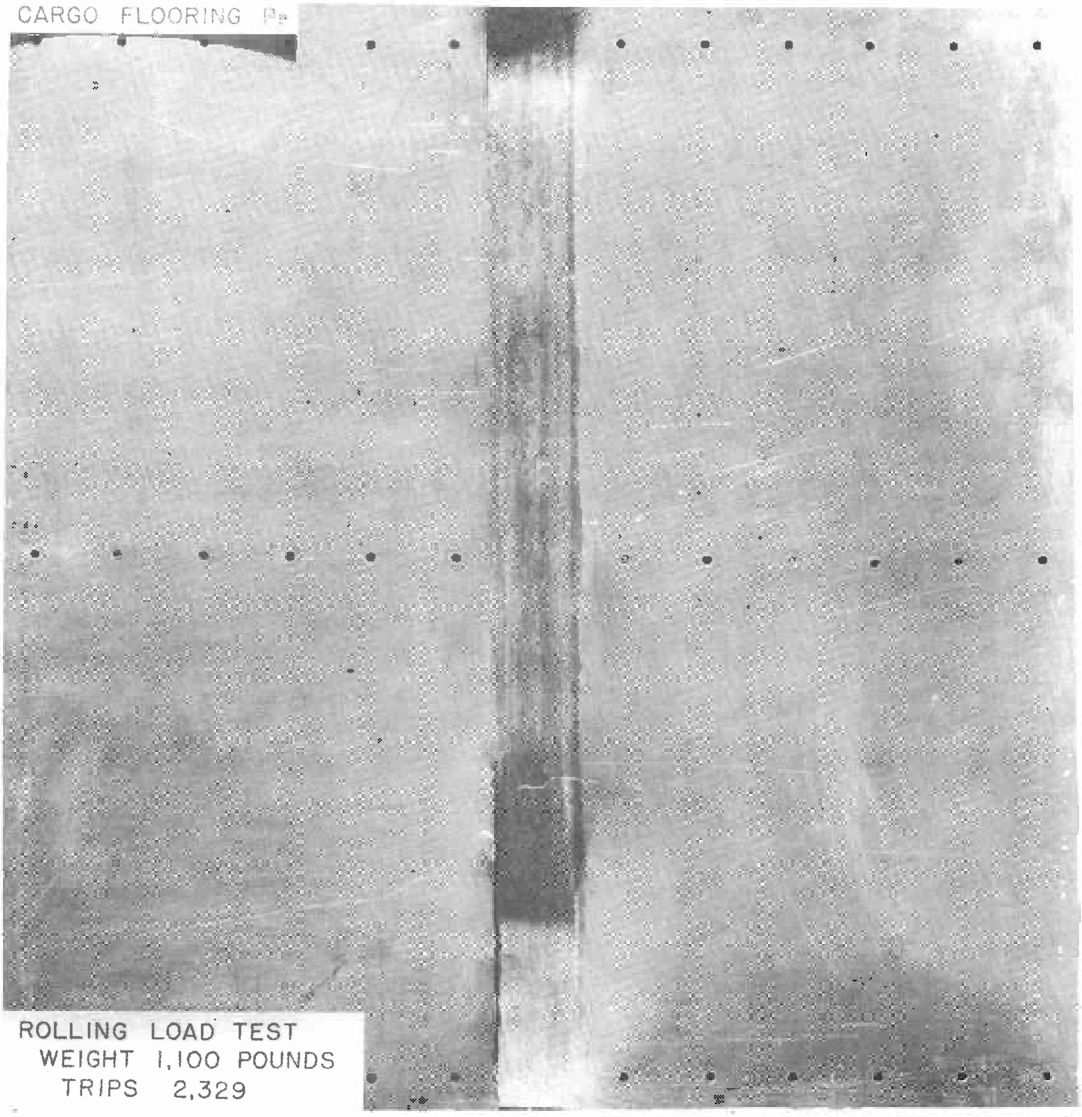

Figure 16.--Loaded surface of cargo flooring Pp after 2,329 repetitions of a 1,100-pound rolling load.

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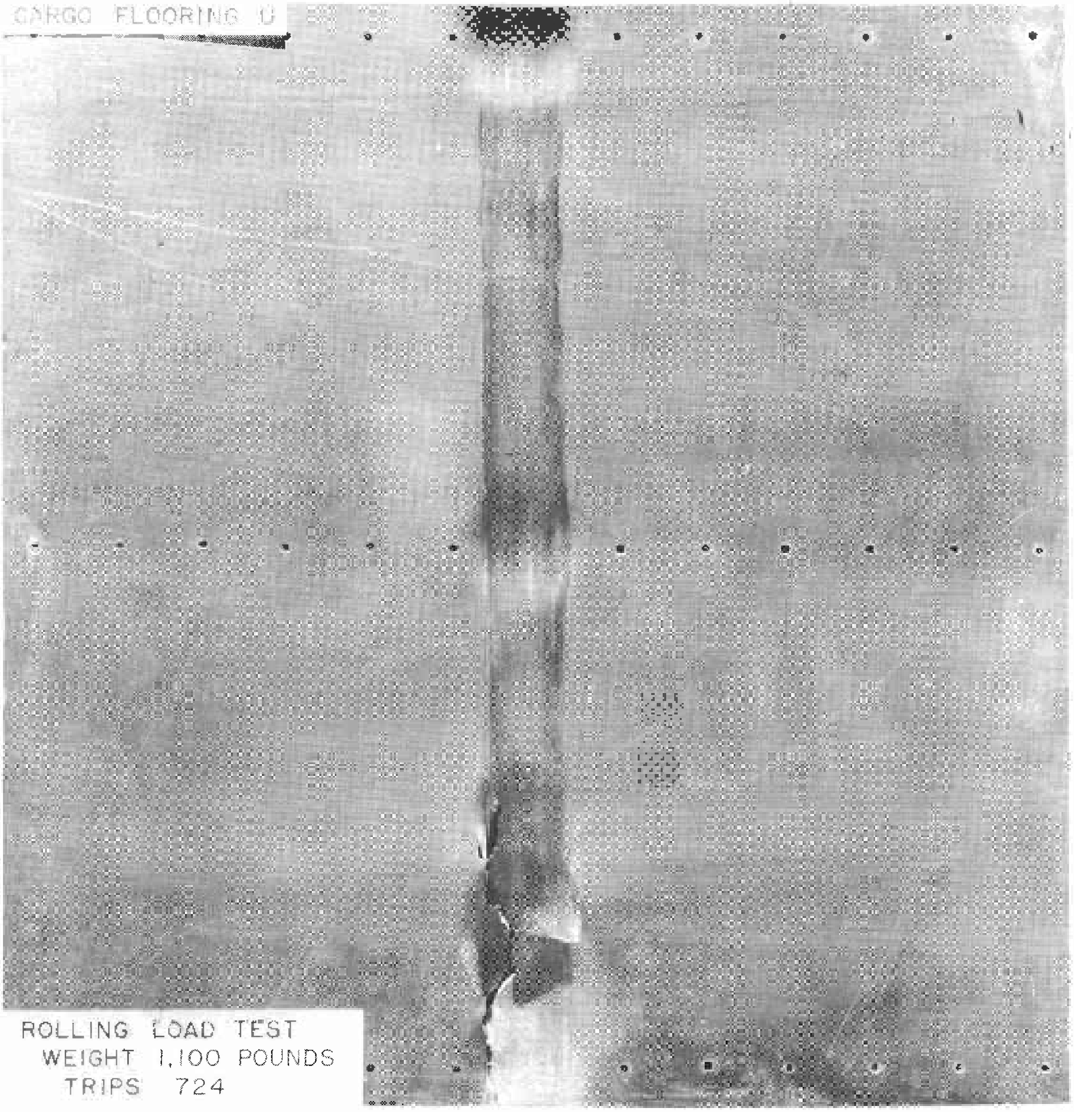

Figure 17.--Loaded surface of cargo flooring U after 724 repetitions of a 1,100-pound rolling load.

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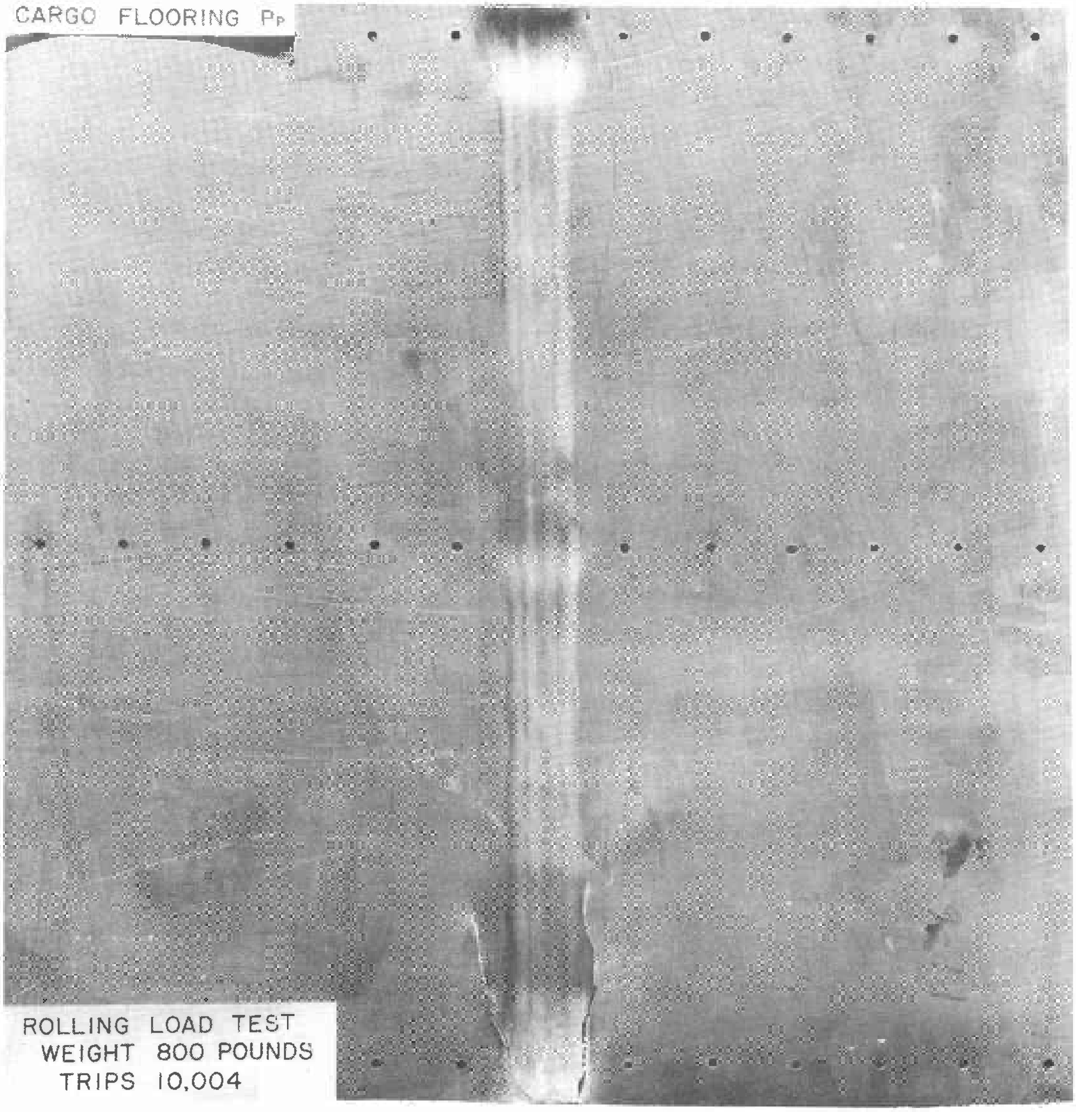

Figure 18.--Loaded surface of cargo flooring Pp after 10,004 repetitions of an 800-pound rolling load.

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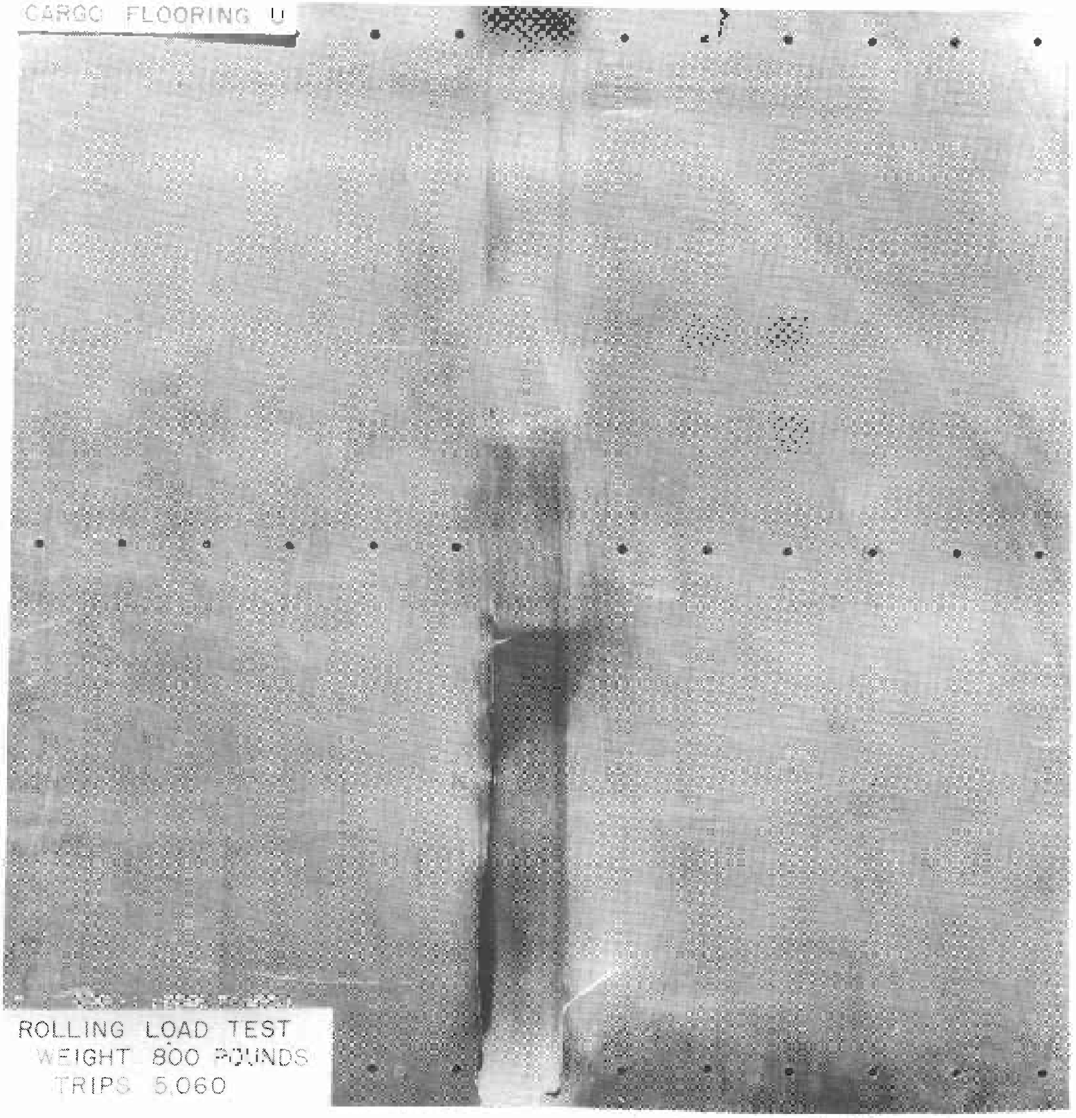

Figure 19.--Loaded surface of cargo flooring U after 5,060 repetitions of an 800-pound rolling load.

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- List of publications on Glue, Glued Products, and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
- Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen
- List of publications on Fire Protection
- List of publications on Logging, Milling, and Utilization of Timber Products
- List of publications on Pulp and Paper
- List of publications on Seasoning of Wood
- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

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