

# TESTS OF CARGO FLOORING R AND S FOR AIRCRAFT

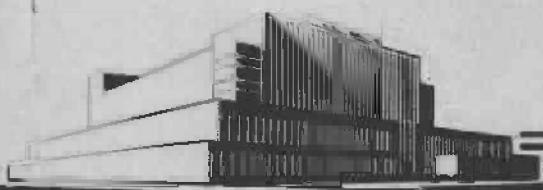
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UNITED STATES DEPARTMENT OF AGRICULTURE  
FOREST SERVICE

In Cooperation with the University of Wisconsin

# TESTS OF CARGO FLOORING R AND S FOR AIRCRAFT<sup>1</sup>

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## Summary

Tests of two additional types of floors proposed for use as flooring materials in cargo-carrying aircraft were made at the Forest Products Laboratory as a part of the cooperative program with the Air Materiel Command, U. S. Air Force (Wright-Patterson Air Force Base), to evaluate the principal strength characteristics of these materials. Simulated-service and basic-strength tests were made in accordance with the procedures established previously,<sup>2</sup> and the test results are compared with those obtained on other floors tested under this program.<sup>2,4,5</sup>

The two floors tested, designated R and S, were aluminum-alloy floors having a flat sheet-aluminum upper or wearing surface that was riveted to a corrugated-aluminum undersurface. In both floors the wearing surface was 0.047 inch thick. The corrugated sheet of floor S was also formed from 0.047-inch aluminum, while in floor R this sheet was made from aluminum 0.040 inch thick. The floors differ from aluminum floors tested previously<sup>2</sup> in that the corrugations were small and spaced closely together, but since the floors were otherwise similar, general comparisons are made between floors R, S, H, and I.<sup>3</sup>

The weights of floors R and S, 1.67 and 1.86 pounds per square foot, respectively, class them with the lighter floors tested. Excepting only floor N,<sup>2</sup> cargo flooring S is from an over-all-performance standpoint the most satisfactory flooring material that has been studied in this program. Flooring R is also very satisfactory; and if the relative weight of the two floors is taken into account, it compares very well with floor S. The excellent performance of these

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<sup>1</sup>Original report issued June 1948.

<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

<sup>3</sup>"Methods for Testing and Evaluating Cargo Flooring for Transport Aircraft," Forest Products Laboratory Report No. 1550, April 1946.

<sup>4</sup>"Development of a Sandwich-Type Cargo Floor for Transport Aircraft," Forest Products Laboratory Report No. 1550-C, October 1947.

<sup>5</sup>"Tests of Cargo Flooring N and P for Aircraft," Forest Products Laboratory Report No. 1550-D, January 1948.

floors and the favorable comparisons with floors H and I indicate the advantage to be gained through the use of smaller closely spaced corrugations, probably due to better load distribution. The only cause for any concern is the relative ease with which the rivets are caused to project above the flooring surface, which slight projections could interfere with the movement of cargo.

### Introduction

As a part of the cooperative program with the Air Materiel Command, U. S. Air Force (Wright-Patterson Air Force Base), and at its request, tests were made on two aluminum flooring materials at the Forest Products Laboratory. These floors, designated R and S, were tested to evaluate some of their basic-strength properties as well as to determine their behavior under simulated-service tests. Tests were made in accordance with procedures already established<sup>2</sup> for investigation of the characteristics of cargo flooring materials to provide comparable data that would permit comparisons with results obtained on other floors tested under this program.

### Material

#### Floor R

The 0.047-inch-thick aluminum sheet that formed the wearing surface of this flooring was riveted to the 0.040-inch thick aluminum corrugated lower sheet by 1/8-inch countersunk rivets. The rivets were spaced approximately 1-1/4 inches on centers both ways, and the corrugations in the lower sheet were also spaced about 1-1/4 inches on centers. Over-all floor thickness was 13/16 inch. Figure 1 gives an edge view of this flooring.

#### Floor S

This flooring, figure 1, was identical with that of flooring R except that the aluminum used in the corrugated sheet was 0.047 inch in thickness.

### 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 flooring materials as described in an earlier report:<sup>2</sup>

Static bending: specimens 8 inches in width tested over an 8-and a 16-inch span  
Strip loading: under a 1-1/4- by 9-inch steel bar  
Concentrated loading: applied by a 1-inch-diameter steel cylinder  
Impact loading: under the drop of a 200-pound softwood box corner  
Rolling load: applied by an engine cradle wheel

The corrugations were parallel to the length of all except the strip-loading specimens.

### Presentation of Data

A summary of results obtained from tests of floors R and S is given in table 1. The results are averages of data on two or more specimens, except in the case of the rolling-load tests, where the results are based on tests of a single panel for each loading condition.

### Static Bending

Three static-bending specimens of each flooring material and span length were tested over 8- and 16-inch spans. Typical load-deflection curves for each span length and material are presented in figures 2 and 3. Top and edge views of typical failures for each material and span length show in figures 4 and 5 the shearing of rivets that was encountered in every test.

### Strip Loading

Load-deformation curves for strip-loading tests to simulate the effect of a floor beam on the under side of a loaded panel are plotted in figure 6. The appearance of the test specimens after having been loaded to produce this effect may be seen in figure 7.

### Concentrated-Load Tests

Because of lack of material, only the concentrated-load tests using a 1-inch-diameter steel cylinder were made. Two tests were made on each panel for each two conditions, one when the cylinder was placed between the crests of the corrugations and the other when the specimen was loaded directly over the crest of a corrugation. The damage resulting from these tests is indicated in figures 8 and 9.

### Impact Loading

Impact tests, using a 200-pound softwood box corner dropped from 12 and 15 inches above the face of the panel, were made on each flooring material. The extent of the damage resulting from this impact loading is evident in figures 10 and 11. The deflection of the panels due to the impact loading and the permanent deformation resulting from the blow were measured directly below the point of load application. These values are given in table 1.

## Rolling-Load Engine Cradle

Three type R flooring panels and two type S panels were tested under the action of a continuously repeated rolling load applied by means of an engine cradle wheel. The magnitude of the applied load and the number of trips to cause the damage shown in the photographs are indicated in figures 12 to 16, inclusive.

### Analysis of Results

#### Weight

The weights of cargo flooring materials R and S, 1.67 pounds per square foot for floor R and 1.86 pounds per square foot for floor S, show that they are well within the limit of 2 pounds per square foot that is the assumed maximum for cargo flooring. The two floors are among the lighter floors investigated under the program and are from 0.1 to 0.4 pound lighter than floors H and I,<sup>2</sup> which are similar in construction but with larger corrugations.

#### Static Bending

The primary cause of failure in static-bending tests of specimens from flooring materials R and S was due to the failure of the rivets in shear over one-half of the span. This permitted the top wearing surface to slide over the corrugations as the specimen was deflected during test. The appearance of the specimens at failure can be seen in figures 4 and 5. In general, the load and deflection continued to increase up to the point where the first rivet failed, after which time the deflection increased, but the load decreased as more of the rivets failed in shear. The specimens continued to carry a large percentage of the ultimate load after most of the rivets in half of the span had failed; and when the test was continued, the load would tend to increase somewhat after the specimen had been deflected to the point where the load block was acting as a wedge. The specimen at this time, however, was not acting as an integrated unit of wearing surface and corrugations. Possibly because of the greater stiffness of the corrugations, floor S specimens tested over an 8-inch span behaved somewhat differently in test. As may be noted in figure 2, the load continued to increase, although somewhat erratically after the first rivet failure at a load of about 750 pounds until ultimate, where a greater portion of the rivets had failed.

In flexural stiffness, floors R and S compare favorably with the better of the floors tested in this program. When comparisons of load-carrying capacity per inch of width are made of these floors with others which have been tested, it is readily apparent that floor S on an 8-inch span is far superior to the others. This indicates a high shearing strength. Specimens from floor R and those from floors H and I,<sup>2</sup> constructed similarly to R and S but with deeper and wider corrugations, were about equal in strength on short spans but inferior to those of floor S. When tested over a 16-inch span, the static-bending specimens of floors R and S exhibited good strength properties, although they were about 80 percent as strong as those from floors H and I, possibly because of a smaller over-all depth.

The shock resistance of floors R and S, as measured by work to maximum load, was generally superior to that of the other floors previously tested. In tests over an 8-inch span, floor S had a greater shock resistance, but the greater deflection of floor R specimens over a 16-inch span before failure permitted them to absorb a greater amount of energy than those of floor S.

### Strip Loading

The small, closely spaced corrugations of floors R and S make them much more resistant to crushing, as measured by results of strip-loading tests, than the floors of similar construction but with larger corrugations H and I.<sup>2</sup> Floor S was shown, figure 7, to be about 40 percent stronger than floor R in this property and gave comparable results to those obtained on the strong sandwich honeycomb-type floors, N and P.<sup>2</sup> In all cases the corrugations under the loading bar fractured, as shown in figure 7, at the maximum recorded load. At this point the support offered by the corrugations to floor areas adjacent to the fracture would be reduced, but the corrugations would still carry a considerable load as they are crushed further.

### Concentrated Loading

Concentrated-load tests using a 1-inch-diameter steel bar to apply loads at exterior and interior positions (4 and 12 inches from an unsupported edge) and above and between crests of corrugations were made on each flooring material. Positioning of loads and evidence of damage may be seen in figures 8 and 9. The limited data obtained did not indicate any definite trend of load relative to position with respect to the edge of the panel, but did show a 20 to 35 percent increase when the load was applied above rather than between corrugation crests. When the load was applied over a corrugation, floor S was the stronger, but the floors were about equal in strength, as would be anticipated when the top surface alone carried the majority of the load. Floors R and S rate well in comparison with other floors, although they are somewhat less strong than floors H, I, and N.<sup>3,5</sup>

### Impact Loading

Preliminary tests indicated that there was little difference in measured deflection or set of the panels under impact loading when the load was applied above or between crests of corrugations. Since fracture of the top surface was more likely when the blow fell on an unsupported surface, all panels were loaded between crests of corrugations. Impact tests with a 200-pound softwood box corner dropped from heights of 12 and 15 inches revealed that floors R and S are high in impact resistance. No damage that would make the floors unserviceable was noted after these tests, figures 10 and 11. Floor S deflected less under impact than did floor R and had less permanent deformation, but based on these tests the floors gave as good a performance as any tested previously. The deflection caused by the impact loading was sufficient to pull the wearing surface away from the rivets adjacent to the indented area, with the result that some of the rivets protrude slightly above the panel surface.

## Rolling Load

The rolling-load test panels were oriented so that the center of the path of the engine cradle wheel would lie along the crest of a corrugation, and this corrugation and the ones adjacent to it on either side carried the major portion of the test load. This wheel load, of a chosen magnitude, was repeated until failure of the test panel occurred, and the magnitude of the load, extent of damage, and number of load repetitions to failure are presented for each panel in figures 12 to 16 inclusive. The number of tests was restricted by the amount of flooring available, so it was not possible to determine a relationship between wheel load and number of repetitions to failure for floors R and S, but general observations on behavior may be made.

Early in each test the deflection of the panel due to the passage of the rolling load caused the top surface to pull away from the rivets with the result that the rivets adjacent to the wheel path projected slightly above the panel surface. Directly in the wheel path the rivets were flattened out, but after a relatively small number of load repetitions, a number of loose rivets were noted in this area. The next evidence of damage was a crushing of the corrugations directly over the supports. While the failures that subsequently occurred in all panels were due to a combination of failure in the wearing surface through or adjacent to a line of rivet holes and of tensile fractures in the corrugations, normally near the supports, the order of failure was not always the same. Under the 1,450-pound wheel load the failure began in the wearing surface, while under the lesser loads first evidence of damage was apparent in the corrugations.

Cargo flooring S gave the more satisfactory demonstration of resistance to the action of the rolling load, and in this respect equaled the performance of the better of the panels tested similarly. The flooring, as given in table 1, withstood 614 trips of a 1,450-pound rolling load and 3,668 trips of a 1,000-pound load. Flooring R was able to carry the same loads for 250 and 2,652 repetitions, respectively, and required 525 trips of a 1,300-pound load to cause failure. This is evidence of a good flooring material, although one that is less satisfactory than type S. The number of trips or repetitions of load to cause sufficient damage to render the flooring unfit for service may be taken as 5 to 10 percent less than the trips to give the failures shown in figures 12 to 16 inclusive.

## Conclusions

While the conclusions are based on a limited amount of data because of lack of material, it is quite evident that cargo flooring panels R and S are from an over-all standpoint among the better flooring materials investigated.<sup>2,4,5</sup> When judged according to the standards of "tentative method A" for rating cargo flooring materials, as given in table 2, floors R and S are shown to be equal in performance. This is true, even though floor S has a greater capacity for resistance to damage due to rolling load, if the relative difference in weights of the floors is taken into account.

The floors exhibited satisfactory performance in all of the strength tests and were generally better than average in resistance to rolling load. From this standpoint it is noted that the smaller closely spaced corrugations provide a better flooring material than the larger corrugations of floors H and I.<sup>3</sup> Of all the floors tested, floor S seems to be over all the most satisfactory with the exception of the sandwich honeycomb-type floor N.<sup>2</sup> The floors R and S have one minor defect in common, and that is the ease with which the top surface pulls away from the rivets and causes slight projections above the floor surface that may be objectionable from the cargo-handling standpoint.

#### APPENDIX A

##### Comparative Ratings of Floors R and S

Results of Forest Products Laboratory tests and ratings by tentative method A as described in Forest Products Laboratory Report No. 1550<sup>2</sup> are presented for floors N and P in table 2.



Table 1.--Summary of results of tests of cargo flooring panels R and S

Property	Panel type	
	R	S
Weight of panel.....Lb. per sq. ft.:	1.67	1.86
<u>Static bending</u>		
8-inch span - Ultimate load per inch of width...Lb.:	790	1,020
Work to ultimate per inch of width.....In.-Lb.:	600	1,060
16-inch span - Ultimate load per inch of width...Lb.:	330	350
Work to ultimate per inch of width.....In.-Lb.:	550	440
<u>Strip loading</u>		
Load at 0.05-inch deformation.....Lb. per sq. in.:	970	1,350
Load at failure of corrugations.....Lb. per sq. in.:	1,540	2,060
Deflection at failure of corrugations.....In.:	0.24	0.19
<u>Concentrated load</u>		
1-inch steel cylinder centered over corrugations.Lb.:	3,750	4,390
Deflection at ultimate.....In.:	0.76	0.87
1-inch steel cylinder centered between corrugations.....Lb.:	3,100	3,200
Deflection at ultimate.....In.:	0.60	0.62
<u>Impact loading -- 200-pound box corner</u>		
15-inch drop		
Deflection.....	0.661	0.587
Set.....	.291	.245
12-inch drop		
Deflection.....	.596	.514
Set.....	.232	.183
<u>Rolling load -- Engine cradle wheel</u>		
Load.....Lb.:	1,450	1,450
Trips.....	250	614
Load.....Lb.:	1,300	
Trips.....	525	
Load.....Lb.:	1,000	1,000
Trips.....	2,652	3,668

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	Floor	
	R	S
Weight per square foot.....Lb.:	1.67	1.86
Engine-cradle rolling load sustained for 500 trips.....Lb.:	<u>1</u> ,300	<u>1</u> ,450
Allowable height of drop of 200-pound box corner.....In.:	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

Criteria	Percentage rating of floors based on criteria	
	R	S
Weight.....	85	76
Rolling load.....	90	100
Impact.....	100	100
Sum.....	275	276
Rating.....	92	92

<sup>1</sup>Values are only approximate since the number of panels tested was insufficient to establish a curve.

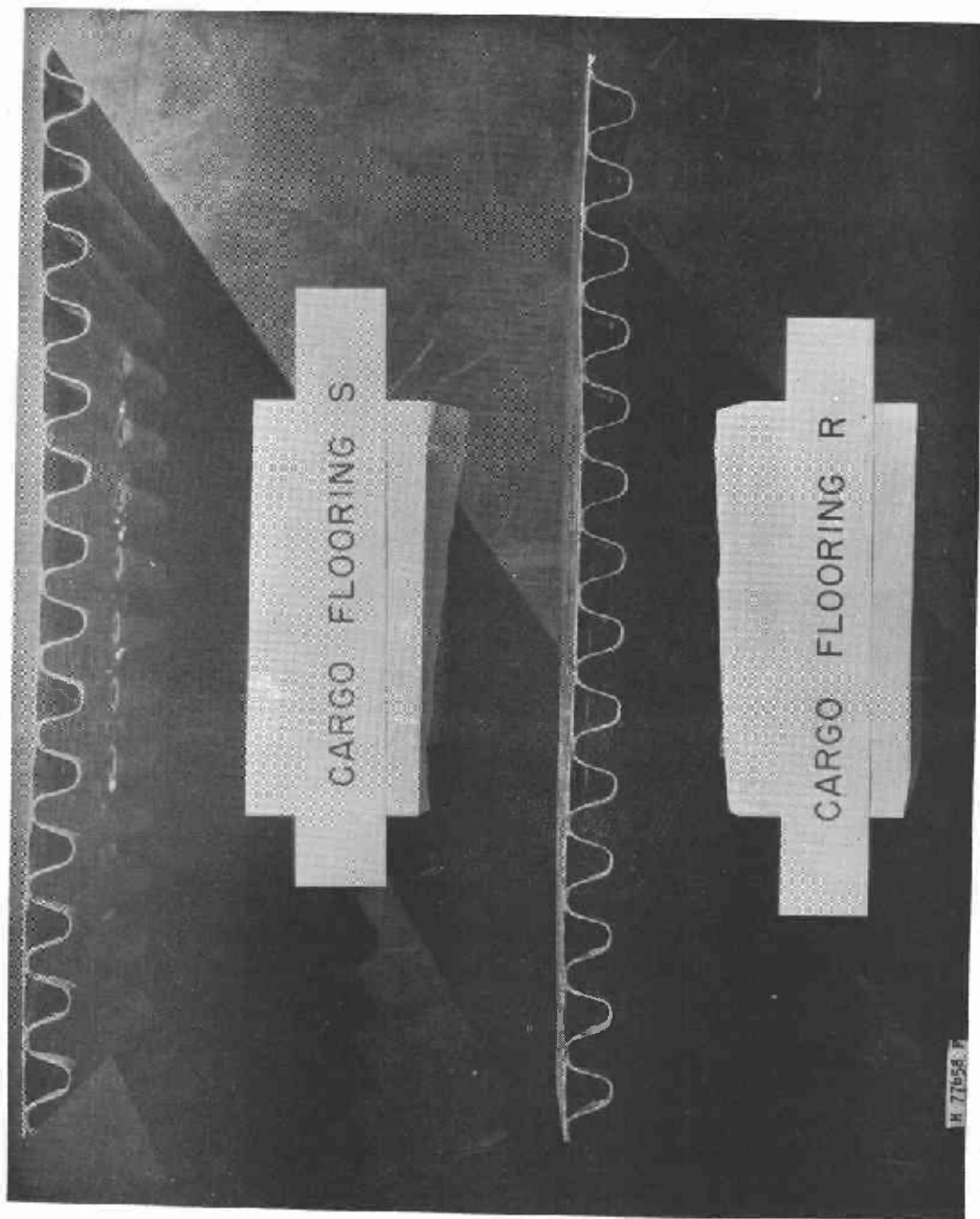


Figure 1.--Edge view of cargo flooring panels R and S showing similarity of construction. The corrugations are spaced about 1-1/4 inches on centers and the corrugated sheet is riveted to the wearing surface at 1-1/4-inch intervals.

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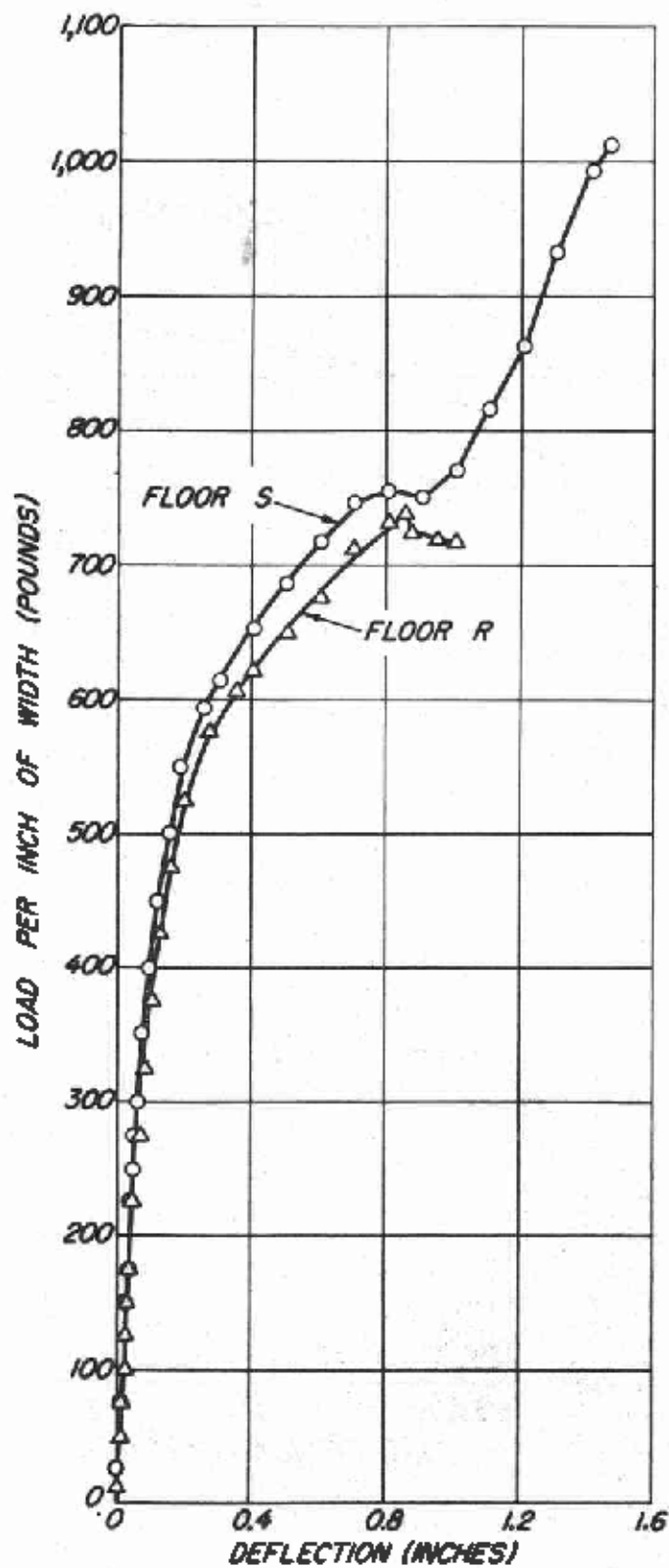


Figure 2.--Typical load-deflection curves for static-bending tests of cargo floorings R and S, tested over an 8-inch span.

2X 77934 R

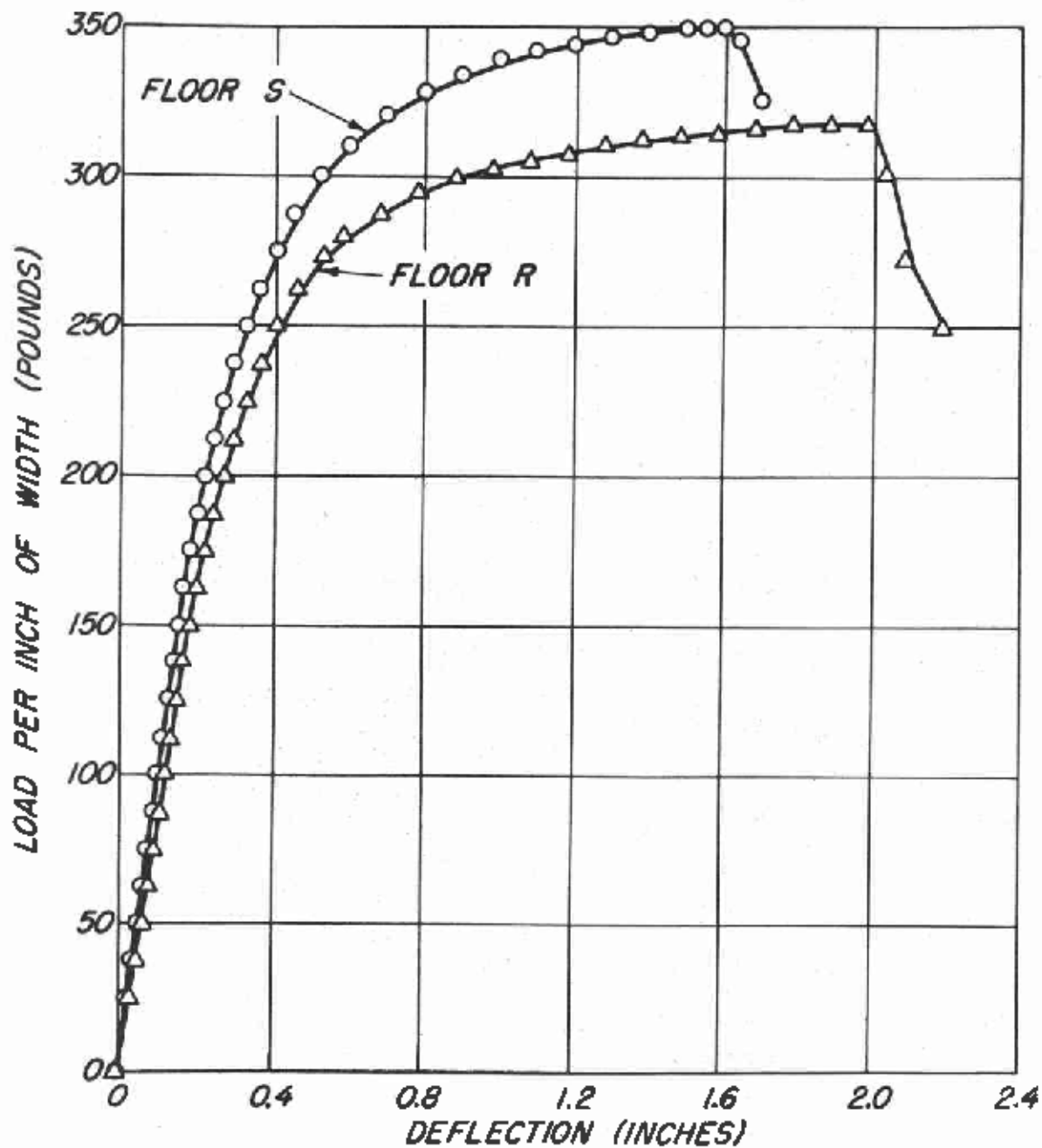


Figure 3.—Typical load-deflection curves for static-bending tests of cargo floorings R and S, tested over a 18-inch span.

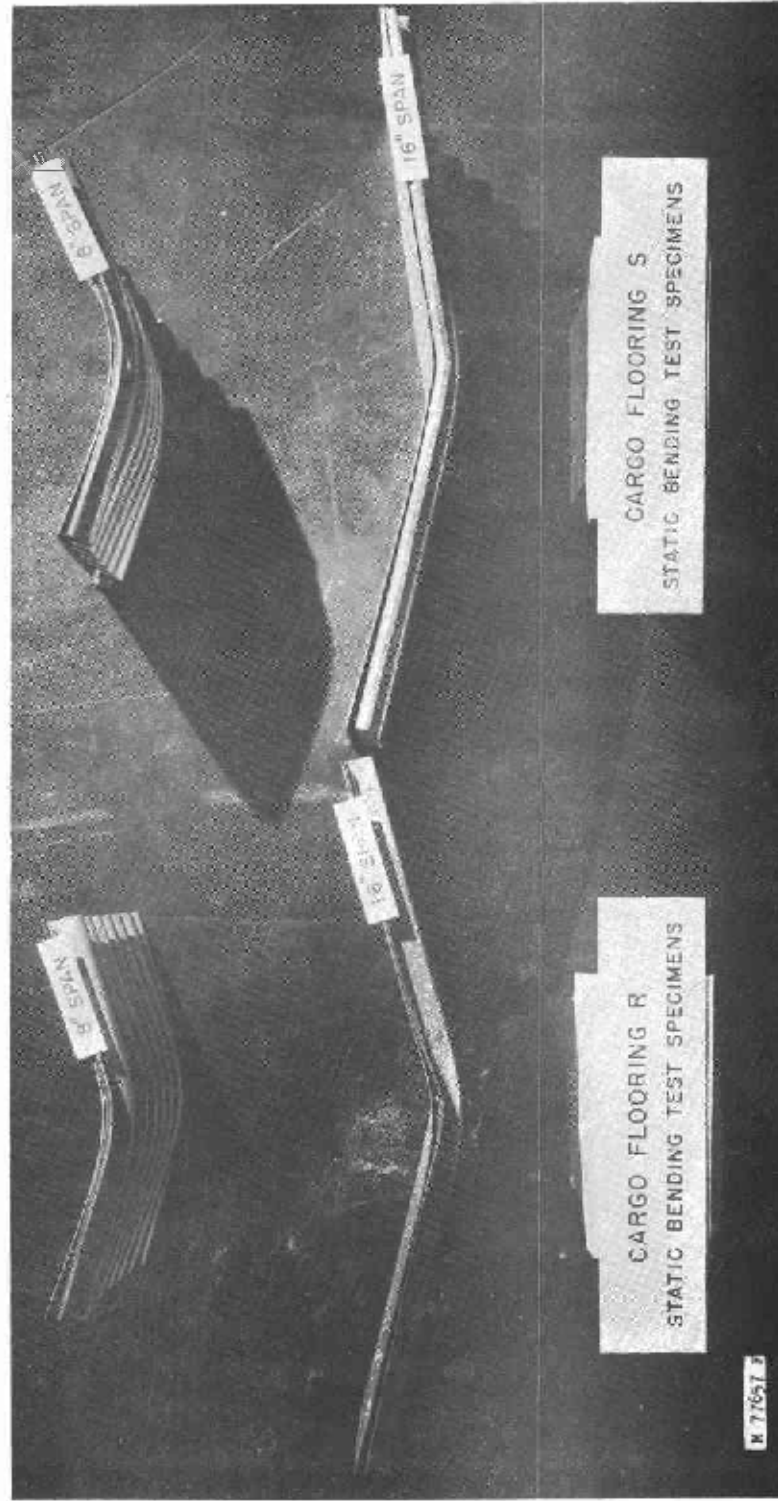


Figure 4.--Edge view of typical failures of static-bending test specimens of cargo flooring R and S.

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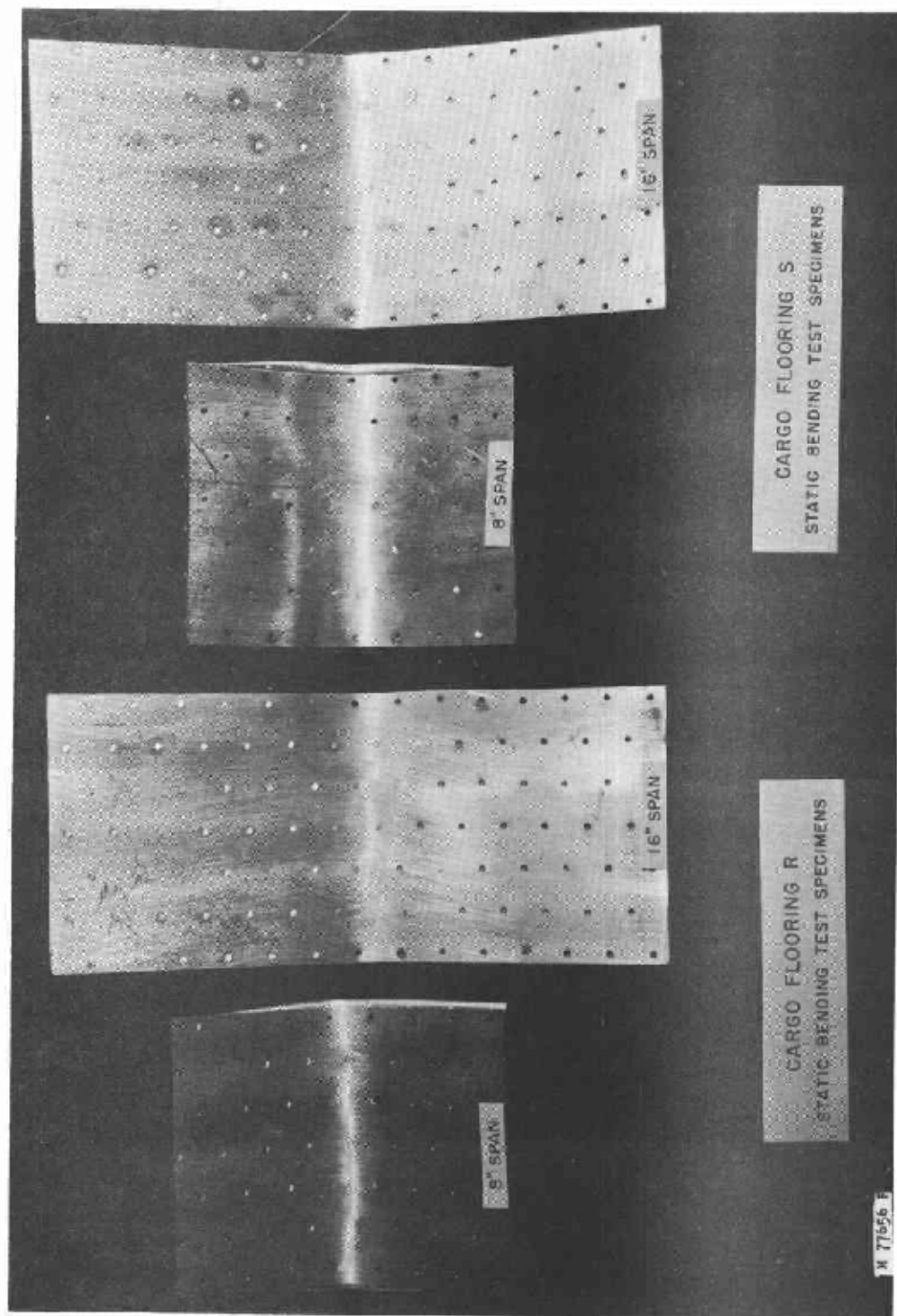


Figure 5.--Top view of static-bending test specimens of cargo flooring R and S.  
Note that on one-half of each specimen the rivets have failed in shear, which is typical of all tests on these flooring materials.

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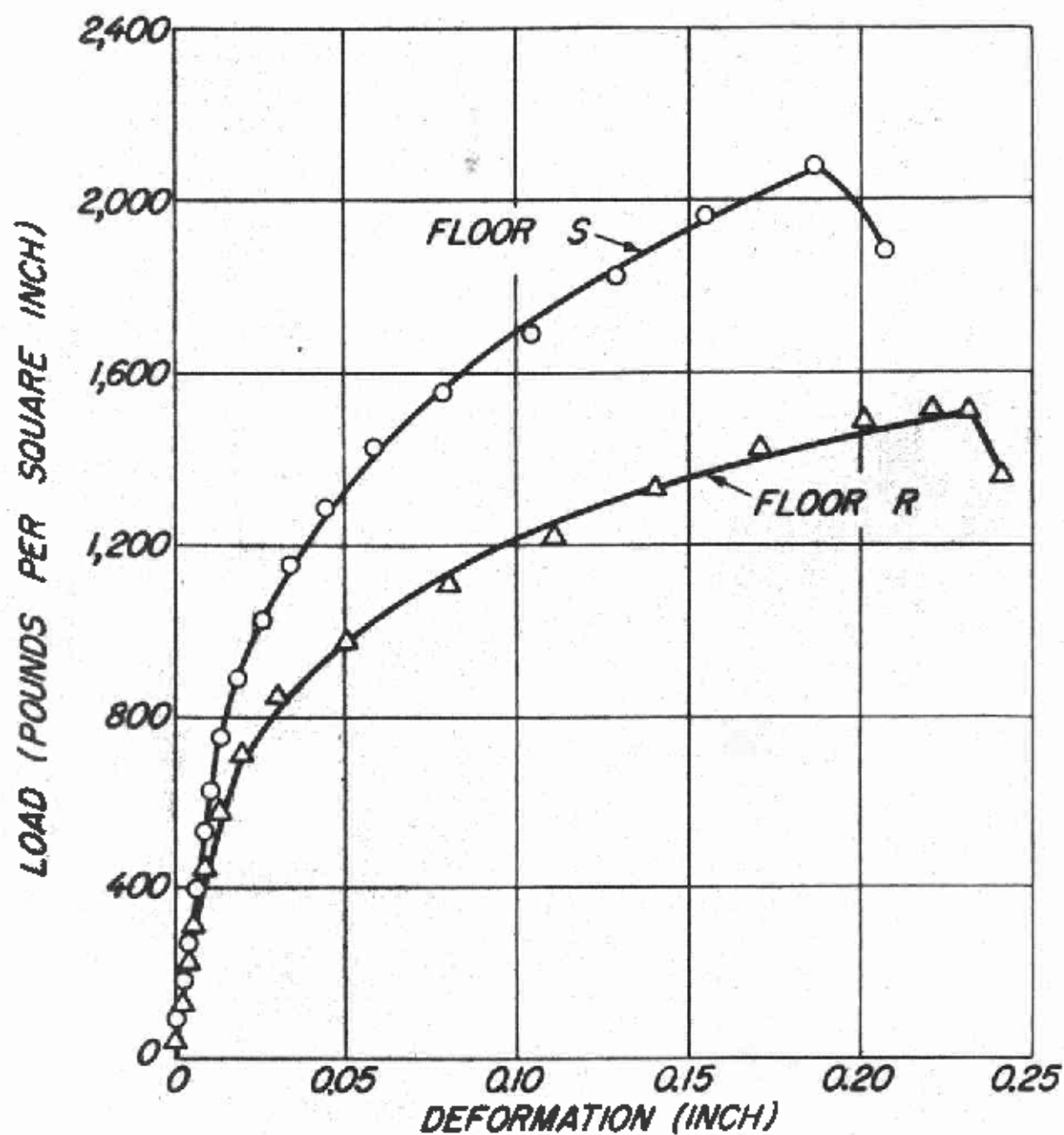


Figure 6.--Typical load-deformation curves for strip-loading tests on cargo floorings R and S.

2 x 77936 F



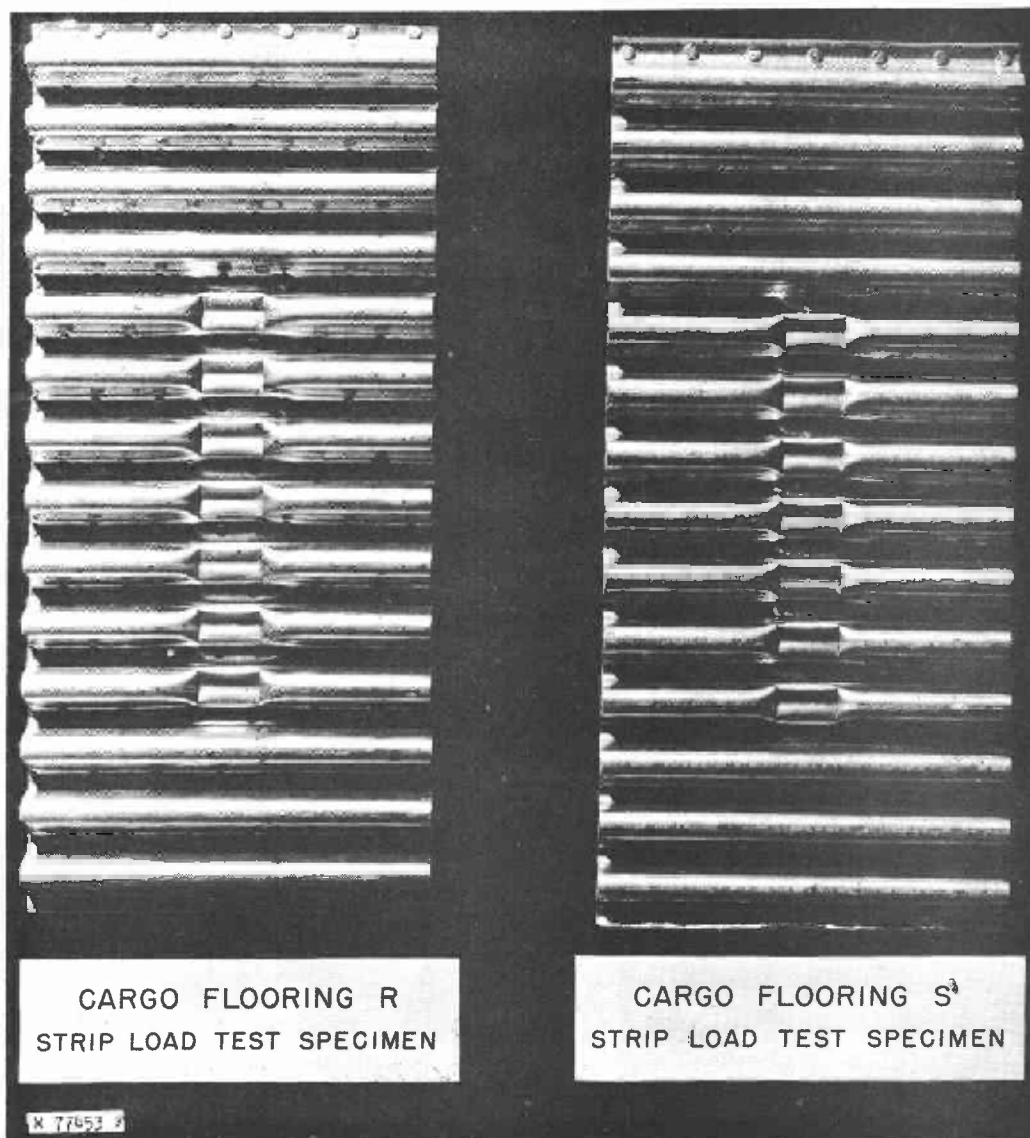


Figure 7.--Appearance of tested surface of cargo flooring R and S strip-loading specimens. Note the failures in each corrugation that occurred as the maximum test load was reached.

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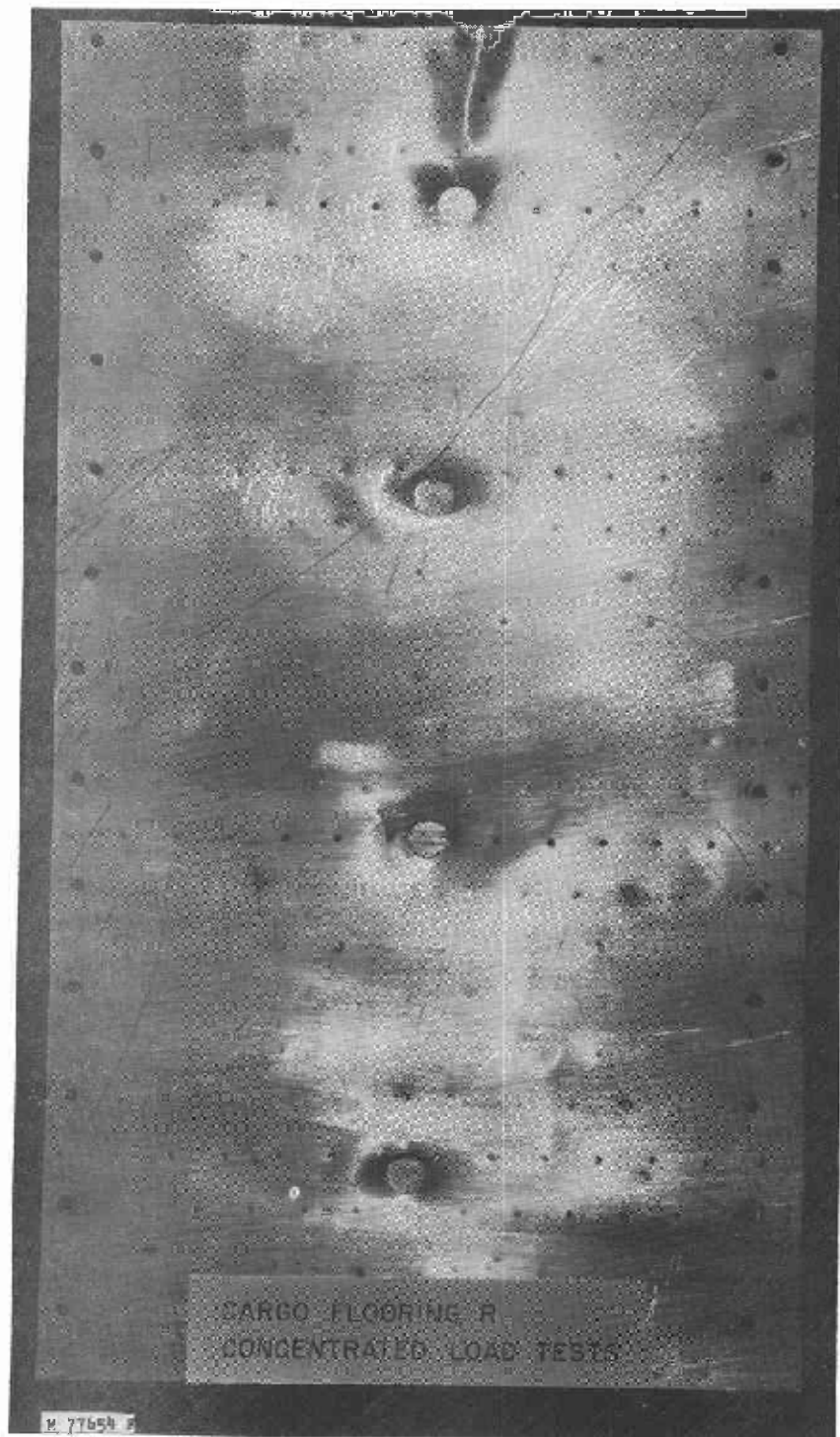


Figure 8.--Concentrated-load test panel of cargo flooring R showing load positions on and between crests of corrugations as indicated by rows of rivets. Type of failure is much the same in each case.

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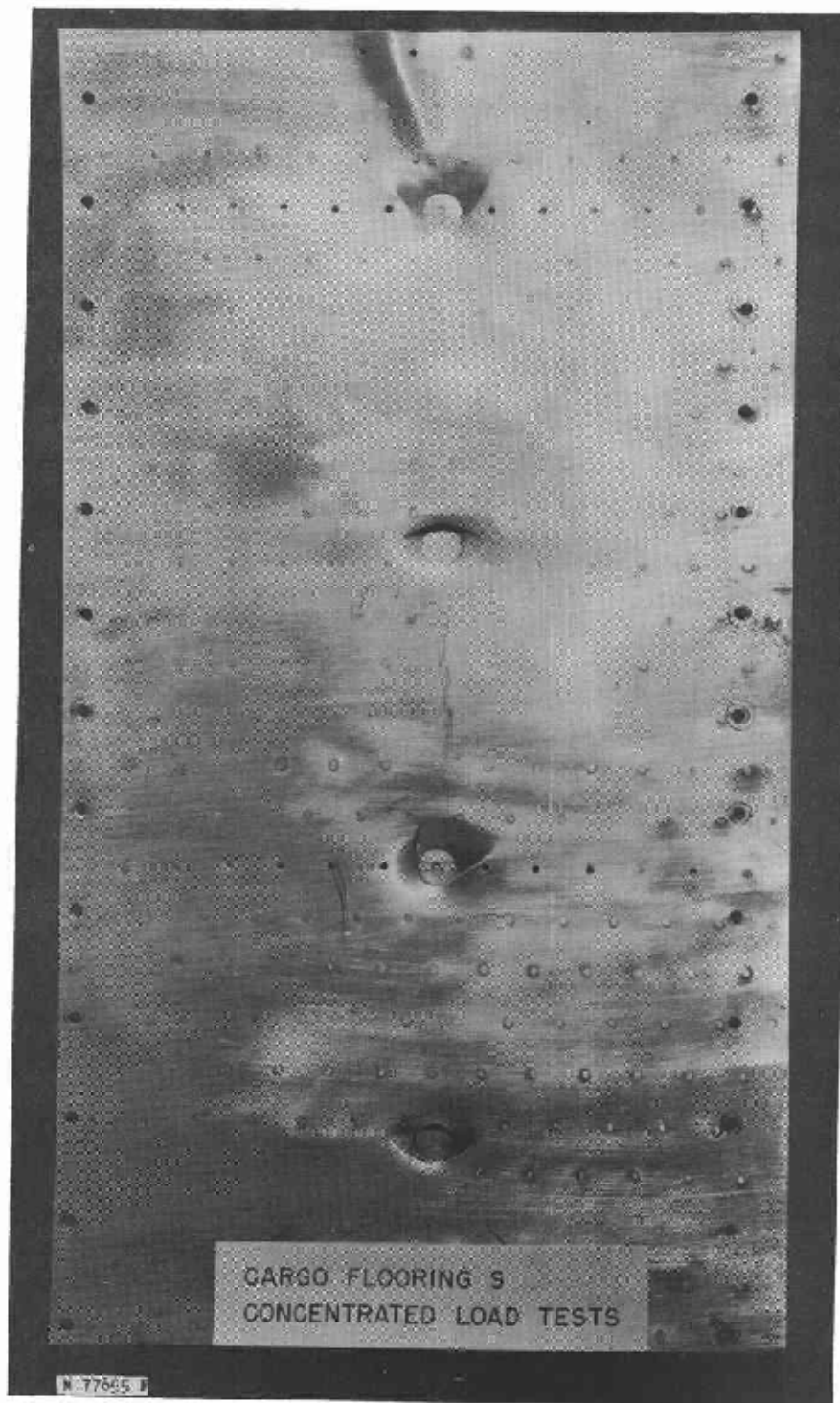


Figure 9.--Concentrated-load test panel of cargo flooring S showing load position on and between crests of corrugations as indicated by rows of rivets. Failures in each case were similar.

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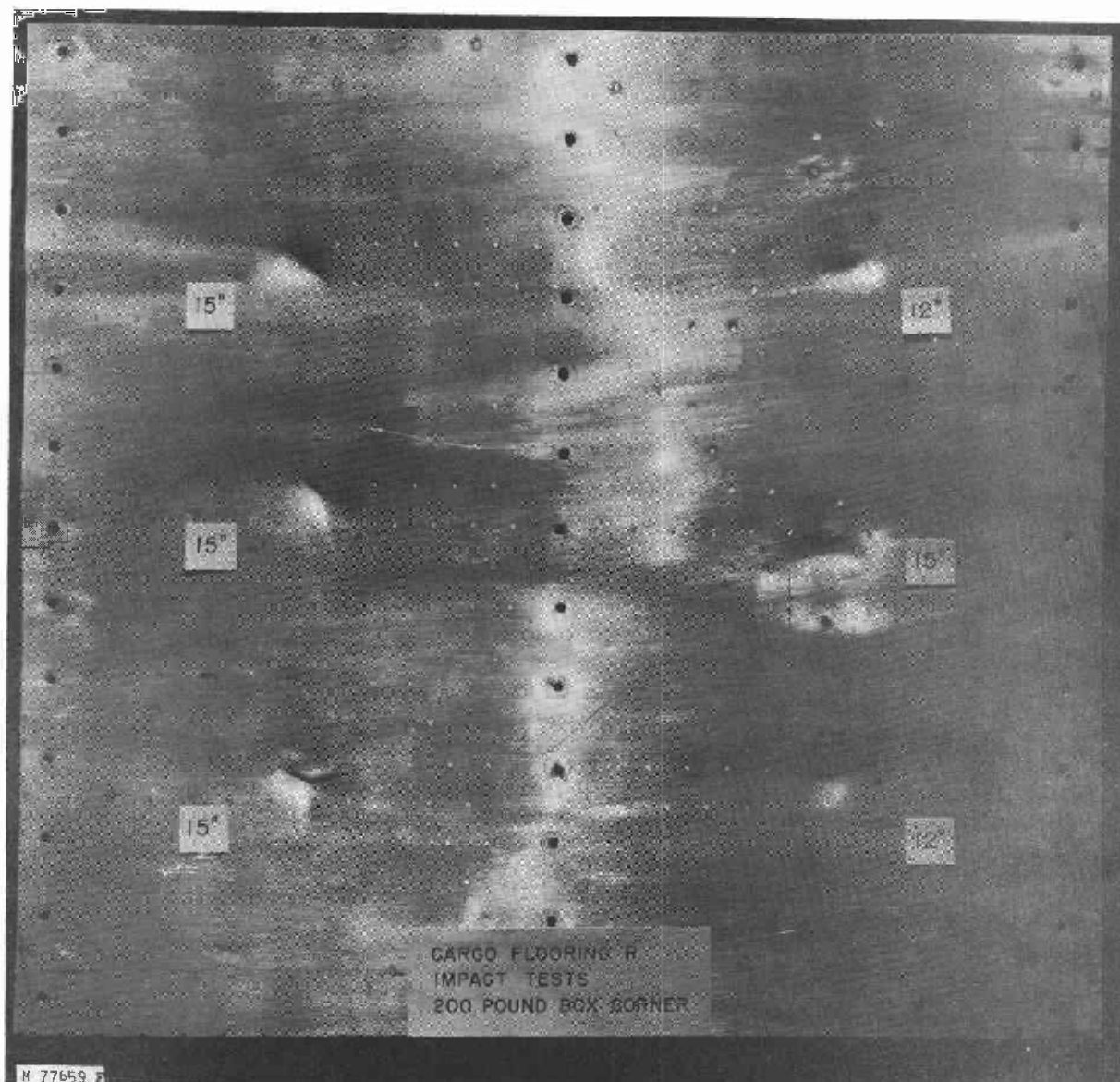


Figure 10.--Loaded surface of cargo flooring R impact-test panel that shows the position of blow, height of drop, and extent of damage due to test with a 200-pound softwood box corner.

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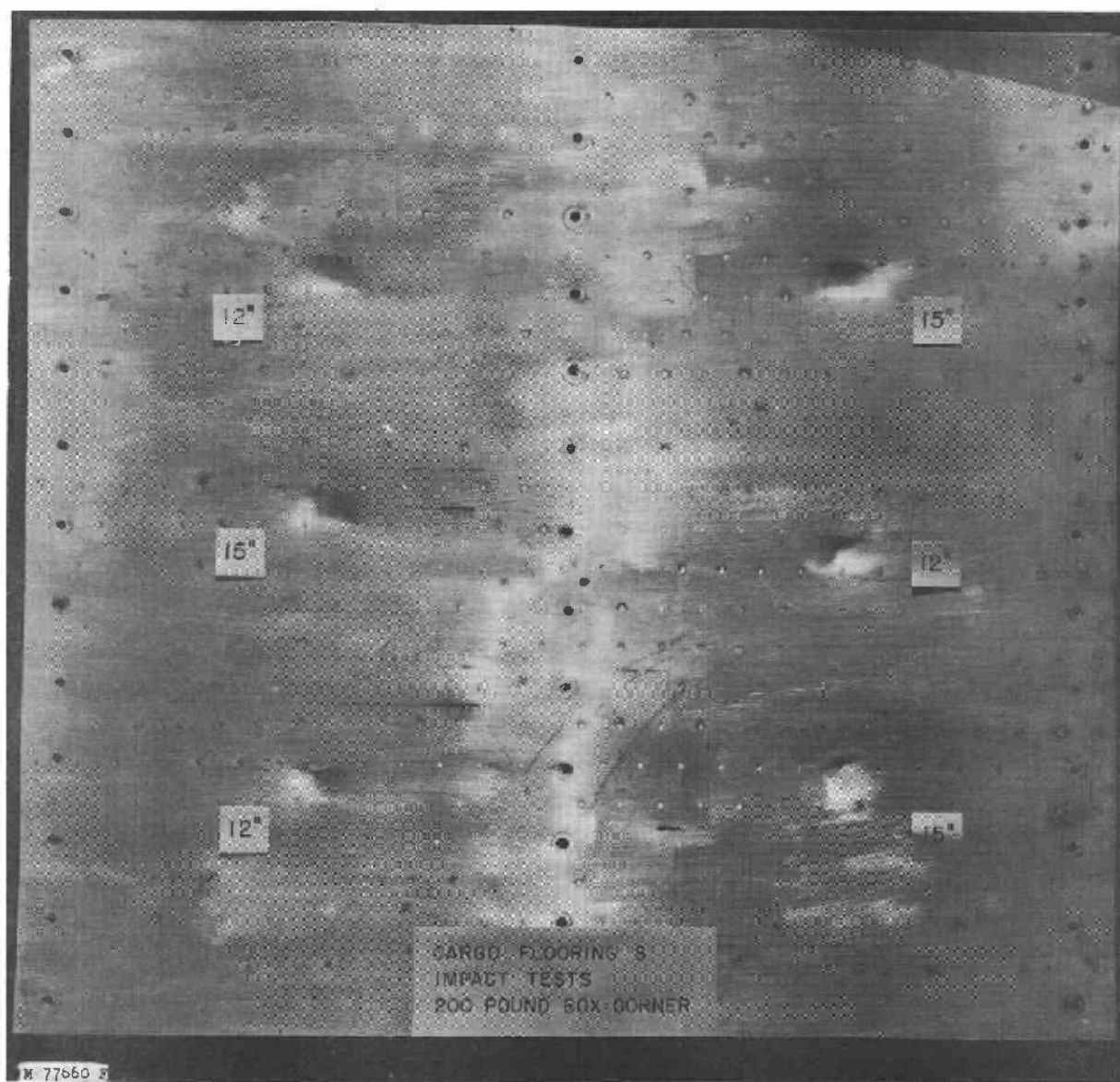


Figure 11.--Loaded surface of cargo flooring S impact-test panel that shows position of blow, height of drop, and extent of damage due to test with a 200-pound softwood box corner.

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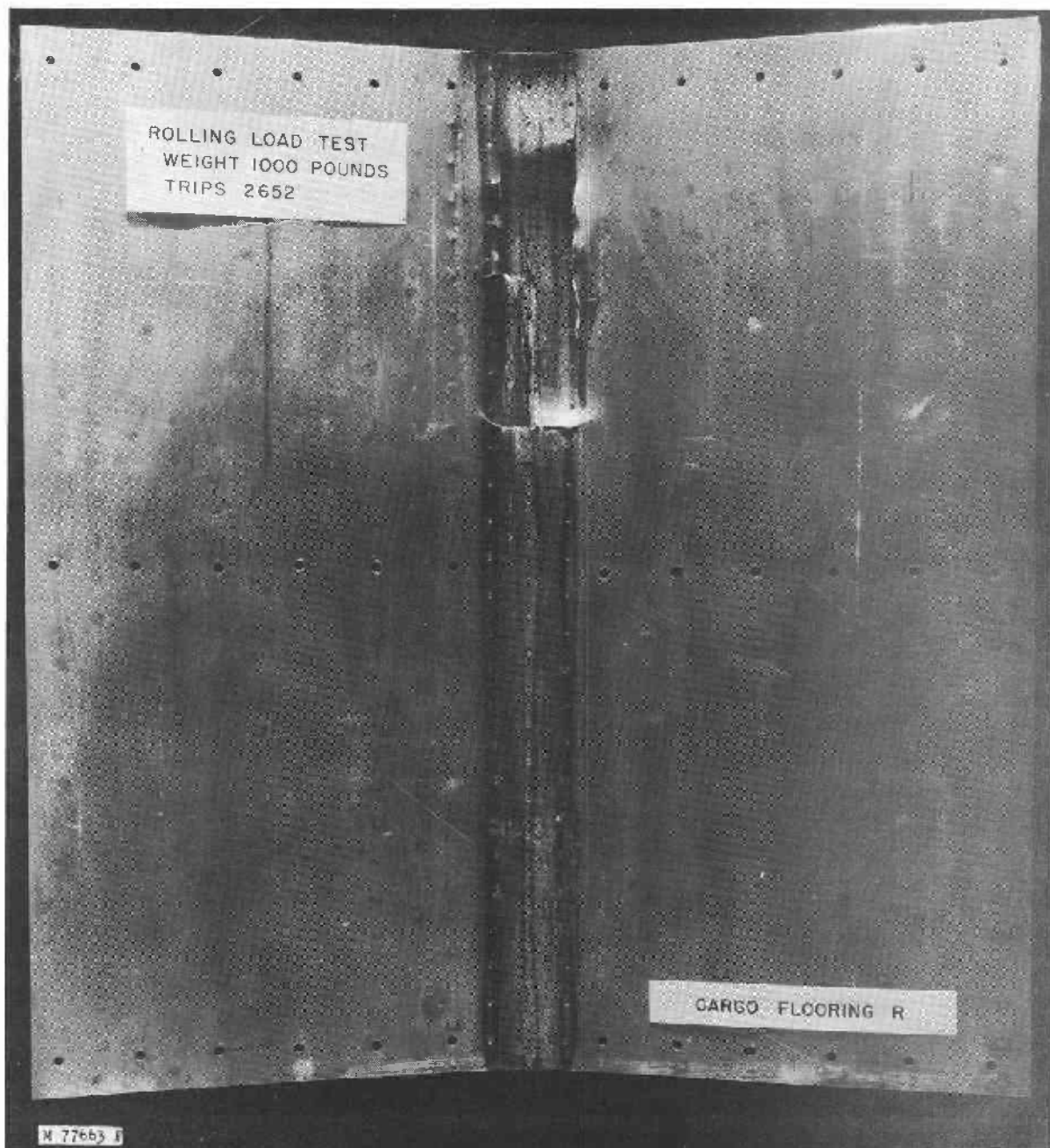


Figure 12.--Loaded surface of cargo flooring R rolling-load test specimen showing damage caused by 2,652 repetitions of a 1,000-pound engine-cradle-wheel load. Fracture of upper surface is generally along line of rivet holes. The corrugations have also failed in tension at the midpoint of the damaged span and have been crushed over all supports

z M 78625 F under the wheel path.

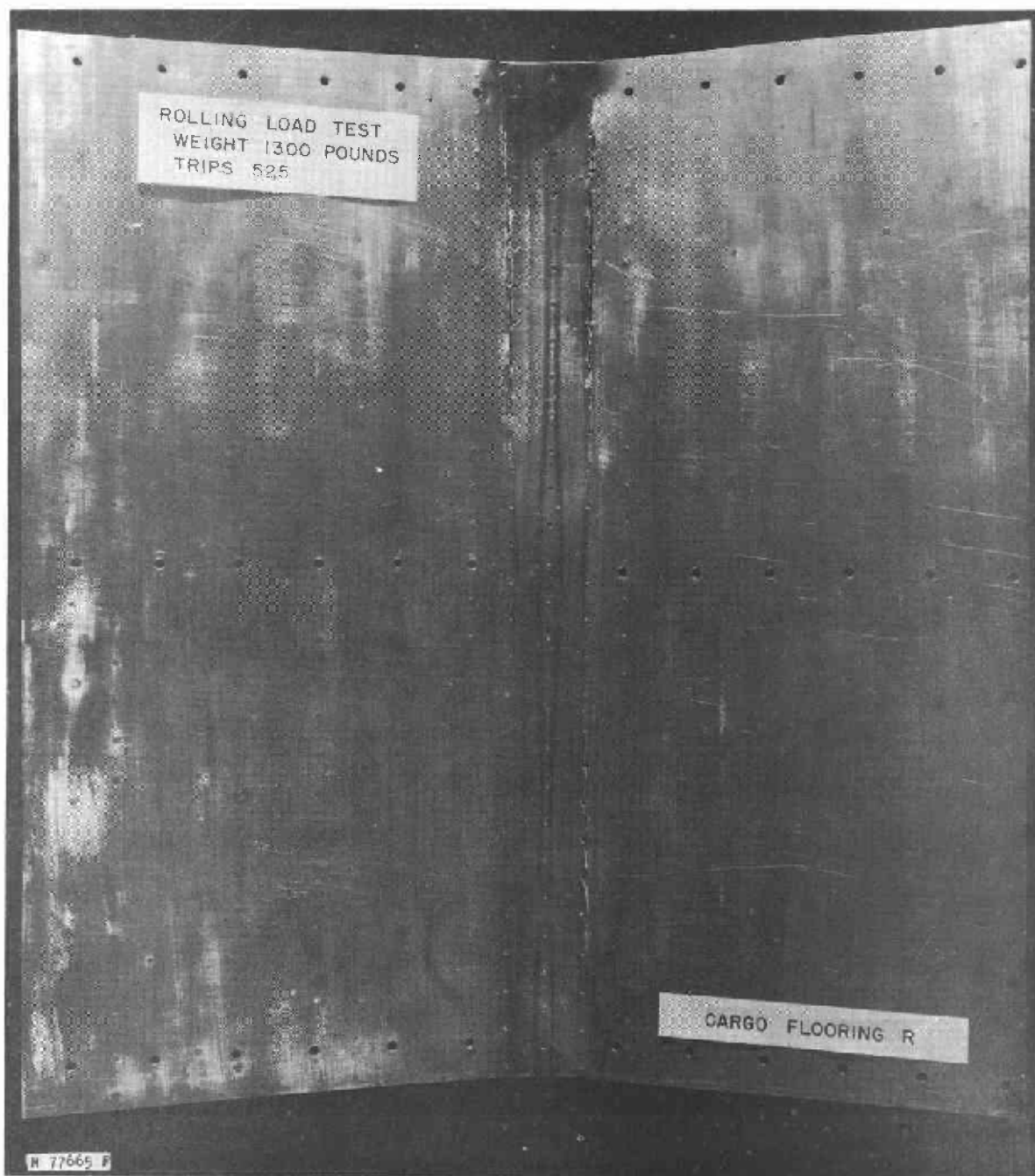


Figure 13.--Loaded surface of cargo flooring R rolling-load test specimen showing damage caused by 525 repetitions of a 1,300-pound engine-cradle-wheel load. The top surface has failed along the line of rivet holes and the corrugations have been crushed and split over all supports under the wheel path.

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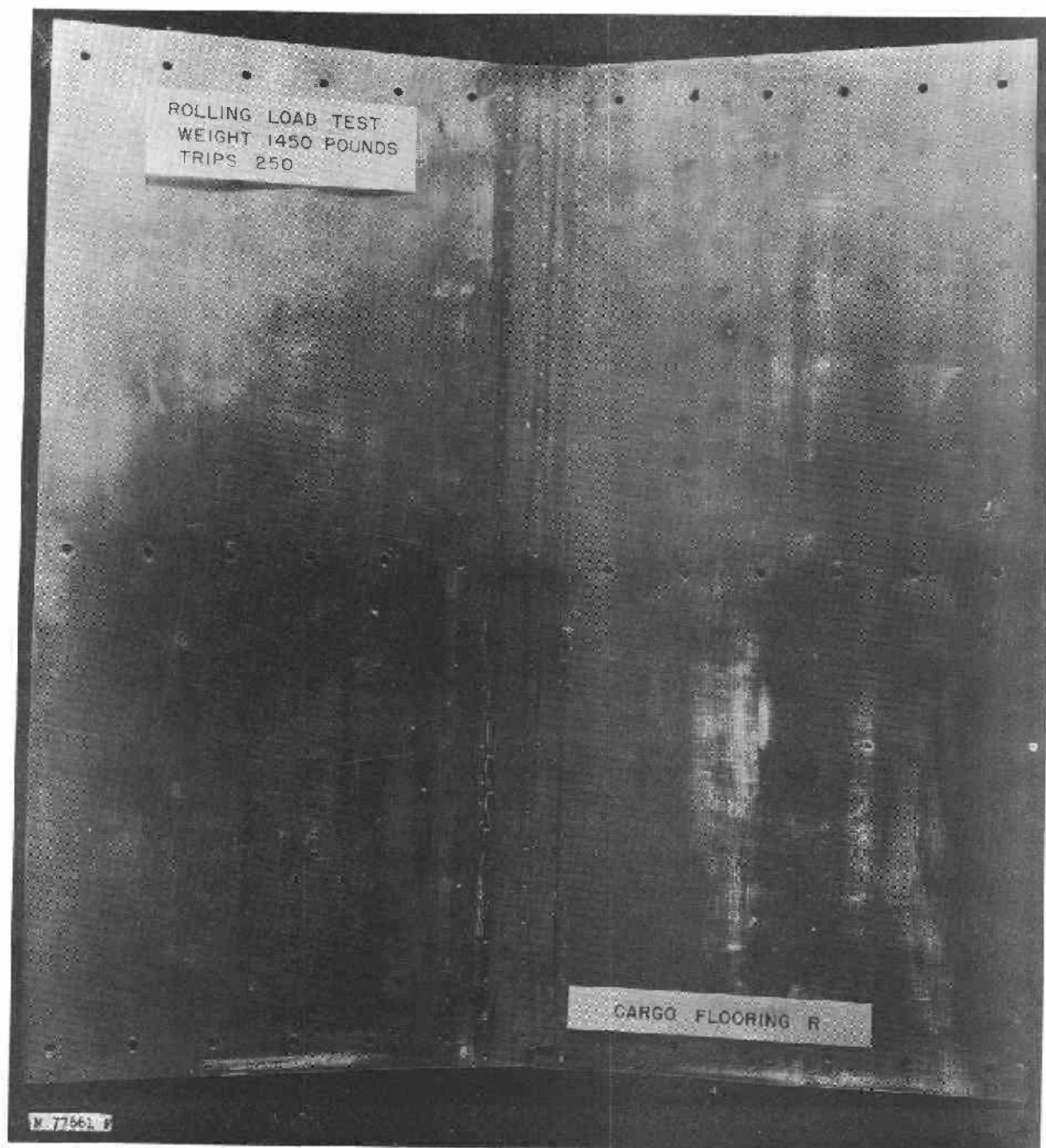


Figure 14.--Loaded surface of cargo-flooring R rolling-load test specimen showing damage caused by 250 repetitions of a 1,450-pound engine-cradle-wheel load. One edge of wearing surface fracture is along line of rivet holes. The corrugations under the wheel path have been crushed over all supports and have failed in tension adjacent to center support.

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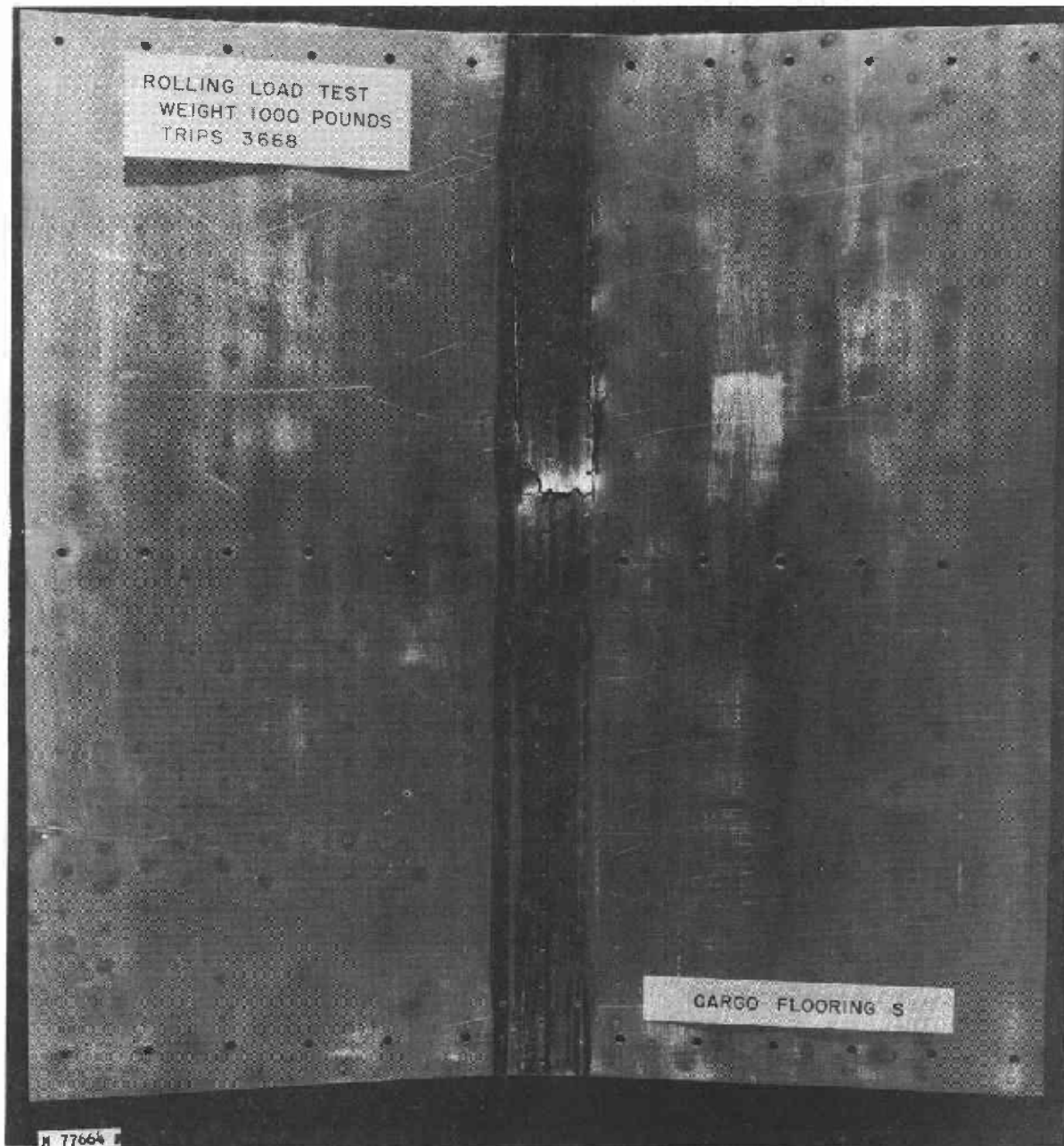


Figure 15.--Loaded surface of cargo-flooring S rolling-load test panel showing damage caused by 3,668 repetitions of a 1,000-pound engine-cradle-wheel load. The wearing surface has been fractured along the lines of rivet holes. The corrugations under the wheel path have been crushed over the supports and failures in tension occurred adjacent to the center and one end support.

4 ZM 78629 F

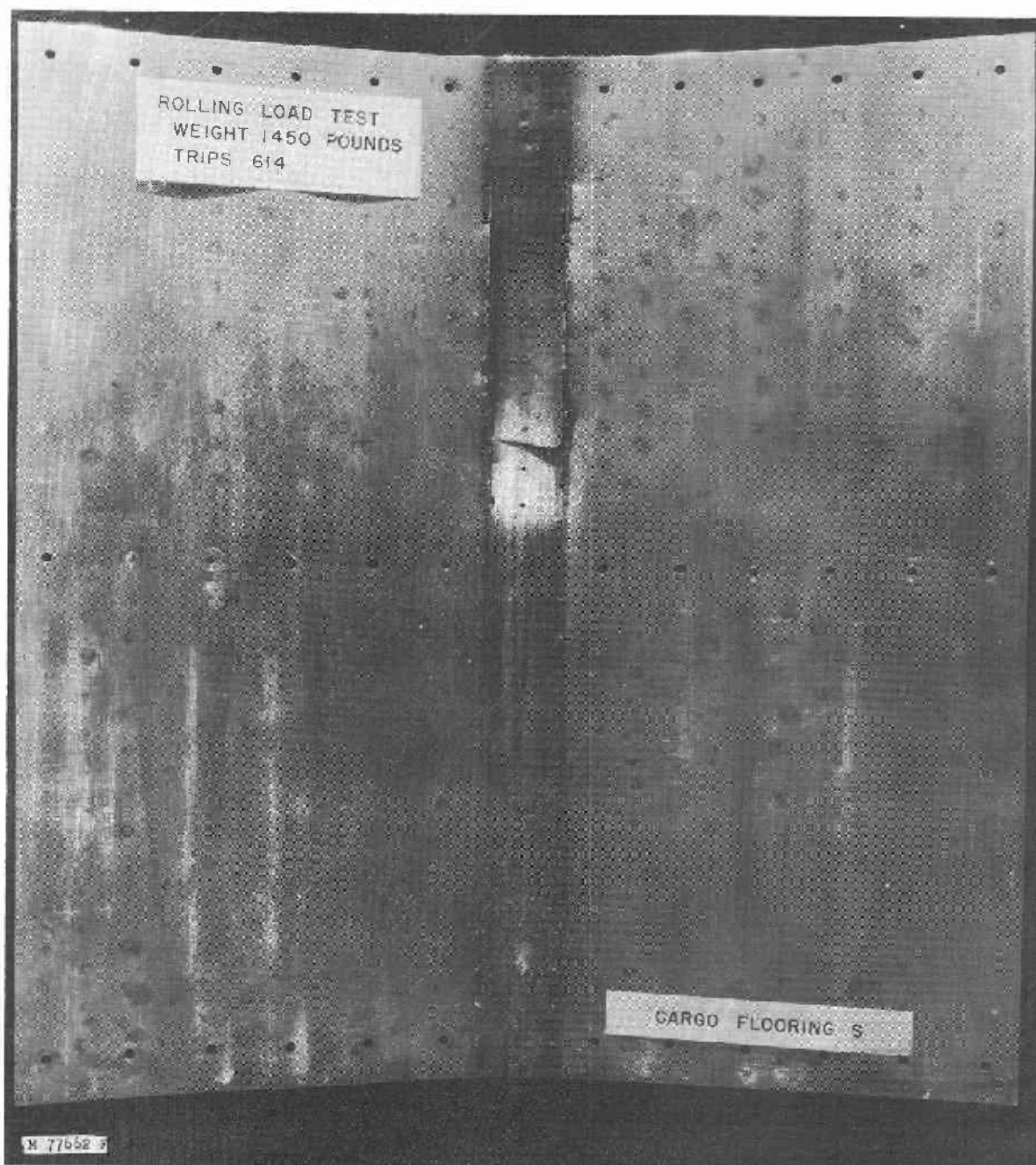


Figure 16.--Loaded surface of cargo-flooring S rolling-load test panel showing damage caused by 614 repetitions of a 1,450-pound engine-cradle-wheel load. The wearing surface has been fractured through the line of rivet holes at the edge of the wheel path. Corrugations under the wheel path have been crushed over all supports and failed in tension adjacent to center support.

ZM 78630 F

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