TESTS OF EXTRUDED MAGNESIUM CARGO FLOORING FOR AIRCRAFT

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TESTS OF EXTRUDED MAGNESIUM CARGO FLOORING FOR AIRCRAFT[1]

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Summary

In cooperation with and at the request of the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, the Forest Products Laboratory evaluated the properties of four types of cargo flooring for aircraft. These floorings were assembled from five configurations of magnesium alloy extrusions. Tests simulating loads applied in service were made in accordance with established procedures for determination of the properties of cargo flooring materials.[3] The magnesium floorings were compared with each other and with other flooring materials tested previously.[4] [5]

The test results show that three of the floorings are well within the weight limitation of 2 pounds per square foot previously established

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[1]This study was made in cooperation with Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, under Delivery Order No. (33-816) 52-4, Amend. No. A1(54-818).

[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 No. 1550, April 1945.

[4]"Summary of the Results of Tests of Cargo Flooring for Aircraft (A through U)," Forest Products Laboratory Report No. 1550-H, June 1949.

[5]Unpublished memorandum reports on tests of cargo flooring, V, Vv, CA, H-21 B and C, and YC-130.

as the desirable maximum weight for cargo flooring for aircraft. These floorings generally gave equal or better performance in compression and static bending tests than flooring materials, except extruded aluminum, tested previously. They were weaker than other floorings in the same weight class in concentrated load tests, and two were low in resistance to impact loading. Two floorings performed well under rolling-load tests, and a third gave a good performance for its weight. Its performance might well have been improved if the extrusions in this flooring were made to act as a unit instead of as individual planks. The fourth flooring, weighing just over 3 pounds per square foot, gave an outstanding performance in all respects, even when its greater weight was considered. It exhibited the best properties of any flooring that has been completely evaluated under this program. It is equal to or better than the aluminum extruded flooring, on which limited tests were made, particularly when the aluminum flooring weight of nearly 4 pounds per square foot is considered.

Material

Cargo Flooring CB

Cargo flooring CB was fabricated from a magnesium alloy extrusion. The extrusion was in the form of a shallow channel section 5-3/4 inches wide, with a vertical web section at the center of the width as shown in figure 1. The flooring was formed by fastening the lower exterior flanges of adjacent sections together with bolts spaced about 2-1/2 inches on center, thus giving a surface having 4-inch-wide flat sections spaced about 5 inches on center.

Cargo Flooring CC

Cargo flooring CC was fabricated from two types of magnesium alloy extrusions shown in figure 2. The flooring was formed by alternating the two extrusions and riveting them together with rivets spaced about 0.8 inch on center along the edges of the upper flanges. This provided a flooring having a flat wearing surface and stiffened by integral angle sections forming webs and lower flanges spaced about 2-1/8 inches on center.

Cargo Flooring CD

Cargo flooring CD was fabricated from a magnesium alloy extrusion. The extrusion took the form of three integral flat channel sections in

each 5-3/8-inch-wide plank as shown in figure 3. The flooring was formed by fastening the extrusions side by side to the supporting framework without shear connections between adjacent planks.

Cargo Flooring CE

Cargo flooring CE was fabricated from a magnesium alloy extrusion. The extrusion was in the form of seven integral T sections in each 8-3/16-inch-wide plank as shown in figure 4. The flooring was formed by fastening the extrusions side by side to the supporting framework, with the tongue and groove of adjacent planks forming the shear connection.

Method of Test

The magnesium extrusions were weighed and measured in either planks or assembled panel form as received. They were then prepared for use as test specimens, properties of which were determined in accordance with the procedures described in Forest Products Laboratory Report No. 1550, "Methods for Testing and Evaluating Cargo Flooring for Transport Aircraft." The following tests were made:

Compression (perpendicular to face of panel).--Specimens of full extrusion width and 2 inches in length for floorings CB, CD, and CE, and representative 3- by 4-1/4-inch specimens from flooring CC, were tested to failure under a uniform load applied perpendicular to the top surface.

Static bending.--Specimens of full extrusion width for floorings CB, CD, and CE, and a representative 4-1/4-inch width for flooring CC, were tested in static bending over 8- and 16-inch spans.

Concentrated loading.--Flooring panels were tested for their resistance to a concentrated load, applied through a flat-ended, 1-inch-diameter, round steel loading bar to the top surface at midspan at over-web and between-web locations.

Impact loading.--Impact resistance of the flooring was determined by dropping a softwood box corner, loaded to 200 pounds, from specific heights to the top surface of test panels, with the point of impact at the midpoint of the 16-inch test span and centered between webs.

Rolling load.--The resistance of the cargo flooring to repeated applications of rolling load, simulating engine cradle wheel loading, was measured by applying load to the panel through a steel engine cradle wheel. This load, which varied from 600 to 2,800 pounds, was rolled back and forth across the panel until failure occurred or 10,000 trips or repetitions of load were completed. The load was applied parallel to the web direction, both with the wheel path centered above and between webs, and perpendicular to the web direction.

In the concentrated, impact, and rolling-load tests, the cargo flooring materials were secured with cap screws to a rigid steel channel framework. Panels or planks 34 inches in length parallel to the web direction were attached to supports at both ends and midlength, supports spaced with 16 inches on center. The panel or plank assembly width was about 32 inches, except for flooring CD. This flooring had no connection between adjacent planks, and five planks were placed side by side to provide a working and test area.

Discussion and Analysis of Results

Results obtained in tests of the four types of cargo flooring made up of magnesium extrusions are presented in table 1. A minimum of three tests is averaged for each property presented, except in the concentrated load tests, where the average of two tests is given, and the rolling-load test results, each of which is based on tests of a single panel for the given load and path position. Table 2 gives reported strength properties for each type of extrusion.

Weight

The unit weight of each of the four flooring materials is tabulated in pounds per square foot. This figure should be used together with the numerical value of any property when the comparative performance for a given floor is desired, since in most instances heavier floors will provide improved strength properties. Floorings CB, CC, and CD are within the desired weight limitation of 2 pounds per square foot. However, it may be possible to use heavier flooring in some aircraft if superior performance and less maintenance will result. Flooring CE, with its superior strength properties, may be utilized in such instances, even though it is heavier than all floors tested previously except flooring CA,[2] an aluminum extrusion.

Compression

Compressive loading, applied perpendicular to the top surface of cargo flooring specimens, has been indicative of the load which can be carried over a support without damage. In sandwich floors, particularly, crushing over the supports is the first indication of more extensive failure. Data on these floorings of magnesium extrusions provide for comparisons with other floors tested previously, and types of failure indicate probable service behavior. The compressive strength of flooring CB, CC, and CD is of the same magnitude as obtained previously on sandwich floors weighing from 1.6 to 1.9 pounds per square foot. Flooring CE exceeded all of the flooring materials except flooring CA previously tested in this property by nearly 100 percent. It had only 25 percent of the compressive strength of flooring CA, the aluminum extrusion floor. Even on a weight basis, it is evident that flooring CE has the greatest compressive strength of the four magnesium floorings. The other three floorings have strength properties about in line with their unit weights.

The failures of the four magnesium floorings are shown in figures 7 to 10, inclusive. In flooring CB the edge webs bent outward as the load was increased, placing a greater percentage of the load on the center web. This web buckled laterally and eventually failed in 45 degree shear. The L-shaped lower flanges in flooring CC caused the webs to be loaded eccentrically and to buckle laterally in the opposite direction to the toe of this L-shaped flange. If this buckling was carried far enough, tension failures appeared in the buckled web.

It is quite probable that the compressive strength of this flooring would be improved if the lower flange were symmetrical about the web. The exterior webs of flooring CD bowed outward as load was applied and the toes of the inward pointing flanges bent upward. The two center webs tended to be forced into the V in the top surface above each web, with resultant buckling of this surface and failure at its junction with the web. Some of the outer webs failed at midheight when the bending stress in these webs became excessive. As the load was increased on specimens of flooring CE, the webs began to buckle, with resultant failure of one or more webs in each specimen in 45° shear.

Static Bending

The static bending test affords a measure of the flexural strength of the cargo flooring when made over a 16-inch span and a measure of the shear strength when an 8-inch supporting span is used. Ultimate loads per inch of width of specimen provide unit strength

measurements for these two properties. The ultimate work-per-inch-of-width values measure a combination of strength and deflection properties and indicate the amount of energy absorbed to failure, which is a criterion of shock resistance. The results in table 1 compare the performance of the four flooring materials tested and permit comparisons with previous test results. Typical load-deflection curves for the magnesium flooring materials are given in figures 5 and 6. These static bending tests were made on full-width extrusions for floorings CB, CD, and CE. Representative sections with proportionate width of top surface to web spacing were cut from flooring CC for bending-test specimens.

Floorings CB, CC, and CD gave strength values comparable to those obtained in previous tests of sandwich and aluminum flooring materials in tests over a 16-inch span, and superior in tests over an 8-inch span. Insofar as bending properties are concerned, flooring CE was the best flooring material tested in the entire series. Comparisons of the four magnesium flooring materials on a unit weight basis indicate that floorings CB and CD are quite comparable. Flooring CC was somewhat stronger in proportion to its weight, and flooring CE was more than three times stronger than its increased weight would indicate. Values of work per unit width show floorings CB and CC to be deficient in energy absorption. This is also indicated by their relatively low deflection at failure, as shown in figures 5 and 6. Flooring CE was again far superior to the other three floorings.

Figures 7 to 10, inclusive, show the appearance of bending specimens after test. When tested over an 8-inch span, the outer webs of flooring CB spread laterally and showed considerable distortion at low loads until the center web and flange were providing the major support. Lower flanges were stretched to ultimate. The toes of the lower flanges of flooring CC quickly bent upward under load, and the webs bent laterally. Failure occurred at the juncture of the webs and top surface at the end of the span. The early distortion under load of the webs and lower flanges of these two extrusions resulted in failure at low deformations and low values of work to maximum load. Specimens of flooring CD failed in tension of the lower flanges of the center webs. Flooring CE exhibited no positive failure, but, rather, the specimens continued to deflect under load, which reached a maximum and then decreased with continued deflection of the specimens.

In the 16-inch-span bending tests, specimens of flooring CB failed abruptly in tension through the bolt holes at the center of the span in the lower flanges of the edge webs. This abrupt failure occurred at low deflections and caused the low value of work to maximum load for this extrusion. In floorings CC, CD, and CE, bending increased steadily under load until maximum load was reached. This deformation was

accompanied in flooring CC by a bending of the toes of the lower flanges upward and bending of the webs laterally until the toes of the lower flange touched the top surface at midspan.

Concentrated Loading

The concentrated-load tests applied through a flat-ended, 1-inch-diameter, round steel bar simulate the load a flooring would sustain as cargo is pried or levered into position. Each flooring was tested with the load applied in two positions--in one of which the load was applied between webs, wherein the top surface carried the load, and in the other of which the load was centered over a web. Values of load applied over webs were 60 to 200 percent greater than loads between webs, except for flooring CD, in which the increase was only 10 percent. Between webs, where primary failure would occur in service, the loads sustained by flooring CD, CC, and CD were slightly less than those sustained by sandwich and aluminum floors in the same weight class. Flooring CE carried a greater concentrated load than any flooring tested except the extruded aluminum flooring.

Appearance of the four magnesium extrusion floorings after concentrated load tests is shown in figures 11 to 14, inclusive. Loads applied between webs resulted in a punching shear failure in all panels. In flooring CB, when the load was applied over a web, the lower flange and web failed in tension, with concurrent failure of the top surface. When flooring CC was loaded over a web, the top surface failed at the edge of the loading bar, sometimes accompanied by failure of the lower flange and web in tension. Cargo flooring CD, when loaded over a web, continued to deflect under load even after maximum load was reached without complete failure and with only localized evidence of failure at the edge of the loading bar. A punching shear failure resulted in flooring CE when it was loaded over a web, with accompanying failure at the junction between the top surface and the web.

Impact Loading

Impact load tests were made by dropping a softwood box corner carrying a 200-pound load onto the test panels. The point of impact was at the center of the 16-inch span and was applied to the top surface between webs, since this is the most vulnerable point of damage. Cargo floorings CB and CD were less satisfactory under this type of loading than sandwich and aluminum floorings tested previously. Flooring CC was comparable in performance to these other floorings, and flooring

CE surpassed all floors tested and was superior to the other magnesium floorings even when its greater weight was taken into account.

Damage to the magnesium flooring after impact test is shown in figures 15 to 18, inclusive. At drops greater than 4 inches, the top surface of floorings CB and CD was fractured. Flooring CC sustained drops of up to 21 inches without damage other than denting of the top surface, which would not affect serviceability. The outstanding performance of flooring CE is evidenced by the fact that only slight denting of the top surface occurred even at drops of 27 inches.

Rolling Load

A rolling load applied through a steel engine cradle wheel was applied to each flooring construction to determine how such loads would affect the flooring in service. The load on the wheel was varied from 600 to 2,800 pounds in accordance with flooring behavior and direction of load application. A range in magnitudes of load was applied to each flooring, and in each case the load was repeated until failure resulted. When a flooring carried 10,000 repetitions of load without failure, however, the test was concluded arbitrarily.

The values of load and number of trips to failure was plotted semi-logarithmically for each flooring construction in figures 19 to 22, inclusive. The lines giving the general slope defined by the plotted points are indicative of the performance of the flooring materials to loads of this type. Since it was impossible to predict the points at which the rolling load would do most damage, three loading paths were evaluated for each panel. The rolling load was applied parallel to the web direction, with the center of the wheel path placed either between webs or directly over a web. The load was also applied along a path perpendicular to the web direction at the center of the 16-inch span. It is expected that flooring of this type would be placed in aircraft with the webs parallel to the length of the fuselage, and that most loads would be applied in this direction. For this reason the lines drawn through the plotted points are based on application of load in this way. If the flooring is oriented with webs perpendicular to fuselage length, the solid circles on the figures should be used to predict performance.

When the rolling load was applied perpendicular to the web direction, the applied load had an additional impact effect. The top surface deflected between ribs when the loaded wheel passed over, causing it to bounce up and down as it passed over a web. Such impact loading no doubt contributed to the poorer performance of these floorings under rolling load in this direction.

Cargo floorings CB and CC were superior to all sandwich and aluminum flooring materials tested to date, except extruded aluminum, when the load was applied parallel to the webs. Even when the load was applied across the webs, these two floorings were comparable in performance to other floorings tested. Cargo flooring CD is good in its weight class when the perpendicular-to-web loading is applied, and under parallel loading it compares well with heavier floors. On a unit weight basis, floorings CB and CC are much superior to flooring CD. It is probable that flooring CD would give a better performance if the extrusions in the floor were made to act as a unit. Flooring CE is superior on a unit weight basis to the other magnesium flooring and is the best of all the floorings on which complete evaluations were made. It is difficult to compare its performance with that of one test made on extruded aluminum flooring, but it is at least the equal of the aluminum flooring.

The damage done to the magnesium flooring panels under rolling load is shown in figures 23 to 34, inclusive. In flooring CB with the load applied parallel to and between webs, failure was a combination of shear in both the top surface at the edge of the webs and between the webs and the top surface, with the damage decreasing somewhat with decreasing load, until at 1,200 pounds only normal wear was evident after 10,000 trips. Loads parallel to and over a web gave initial failures in the top surface at the edge of the web, with subsequent failure of the web in tension. When the load was applied perpendicular to the webs, failures began at the bolt holes along the wheel path and gradually extended through the lower flanges and into the top surface.

Failures in flooring CC with load applied parallel to and between webs began with failure of the top surface along one web adjacent to the wheel path. This failure also occurred at the other edge of the wheel path, with complete failure of the top surface; or the web and lower flange on the undamaged side of the wheel path failed in tension. When the load was applied parallel to and over a web, a shear failure between the top surface and web occurred and the lower flange and web failed in tension. Loading perpendicular to webs caused failures of the top surface adjacent to the webs in the wheel path area, after which the lower flanges and webs failed in tension.

Cargo flooring CD, because it lacked shear connections between extrusions, deflected greatly under load. Loads applied parallel to and between webs resulted in failure of the top surface adjacent to webs at both edges of the wheel path. When the path was centered over a web, the top surface failed along the web and along one or both edges of the wheel path. Loading in the perpendicular-to-web direction caused primary failures of the top surface adjacent to the webs in the

wheel path area. Subsequently, the lower flanges and webs failed in tension with failures extending into the top surface.

Under a 2,800-pound wheel load applied parallel to and between webs, flooring CE failed in the top surface at the edge of the webs. Similar loading of 2,400 pounds resulted in some incipient failures of the same nature but no complete failure after 10,000 trips. Loaded over a web, the flooring failed in shear between the web and top surface and in the top surface along both edges of the wheel path. The web buckled at the support points. When load was applied perpendicular to the webs, the first failures were cracks in the top surface adjacent to the webs in the wheel path area. The lower flanges and webs then failed in tension, and shear failures occurred between the web and top surface, extending from the wheel path.

Conclusions

1. The unit weight of magnesium extrusion cargo floorings CB, CC, and CD was well within the limitation of 2 pounds per square foot that has been described as the desirable maximum for cargo flooring materials. Flooring CE, about 50 percent heavier than this maximum, may well be utilized wherever possible because of its superior strength properties.

2. The compressive strength, perpendicular to the top surface, of floorings CB, CC, and CD is comparable to that previously obtained on sandwich flooring materials in the same weight range. The strength of flooring CE exceeded that of every flooring previously tested, except the aluminum extrusion, by about 100 percent.

3. The bending strength properties of floorings CB, CC, and CD are comparable to those of sandwich and aluminum floorings previously tested over a 16-inch span and superior over an 8-inch span. Cargo floorings CB and CC were deficient in energy absorption values, failing at relatively low deflections. Flooring CE was more than three times as strong as the other magnesium floorings, even allowing for its increased weight. As far as bending properties are concerned, it was the best of all flooring materials tested.

4. The strength of floorings CB, CC, and CD under concentrated loads applied to the top surface between webs indicated that they were slightly weaker in this respect than sandwich and aluminum floors in the same weight class. Flooring CE was stronger than all floorings

tested previously except the aluminum extrusion flooring, and was comparable to all floorings in strength per unit of flooring weight.

5. Impact strength tests made at between-web locations showed that floorings CB and CD were less satisfactory than sandwich and aluminum floorings tested previously. Flooring CC was closely comparable to other flooring materials, and flooring CE was superior, even on a strength-weight basis, to the other magnesium floorings as well as other flooring materials tested.

6. Cargo floorings CB and CC were superior to all except extruded aluminum floors in tests wherein the rolling load was applied parallel to the web direction. They were comparable in performance to other floorings when the load was applied perpendicular to the webs. Flooring CD is good in its weight class when perpendicular-to-web loading is applied, and under parallel-to-web loading it compares well with heavier floors. The performance of this flooring would no doubt be considerably improved if the extrusions in a flooring panel could be made to act as a unit. Flooring CE is superior on a unit weight basis to the other magnesium flooring and is the best of all floorings tested on which complete evaluations have been made. It is difficult to compare its performance with that of an aluminum extrusion flooring on which a single test was made, but it is at least the equal of this flooring material.

In summary, these conclusions indicate that floorings CB, CC, and CD, all weighing less than 2 pounds per square foot, generally gave equal or better performance than flooring materials tested previously, except the extruded aluminum flooring in compression and static bending tests. They were weaker than other floorings in the same weight class in the concentrated load tests, and CB and CD were poor in resistance to impact loading. Floorings CB and CC performed extremely well under rolling loads. Flooring CE gave an outstanding performance in all respects, even when its properties were considered in relation to its greater weight.

Table 1.--Summary of tests of extruded magnesium cargo flooring

Property	Test results			
	Flooring CB	Flooring CC	Flooring CD	Flooring CE
Weight of panel.....lb. per sq. ft.	1.72	1.81	1.54	3.08
Compressive strength (perpendicular to face of panel)....p.s.i.	1,370	1,260	1,200	2,740
Static bending				
8-inch span -- Ultimate load per inch of width.....lb.	870	1,220	790	5,250
Ultimate work per inch of width.....in.-lb.	230	410	580	3,470
16-inch span -- Ultimate load per inch of width.....lb.	400	580	310	[1] 1,560
Ultimate work per inch of width.....in.-lb.	120	280	240	[1] 2,530
Concentrated load				
Over web -- 1-inch diameter steel cylinder.....lb.	5,560	6,200	3,220	8,540
Deflection at ultimate.....in.	1.32	.67	1.70	.65
Between webs -- 1-inch diameter steel cylinder.....lb.	2,820	2,280	2,910	5,590
Deflection at ultimate.....in.	.68	.28	1.54	.32
Impact loading -- 200-pound box corner				
4-inch drop -- Deflection.....in.	.396		.70	
Set.....in.	.077		.18	
6-inch drop -- Deflection.....in.	[2] .594		[2] .90	
Set.....in.	[2] .163		[2] .24	
8-inch drop -- Deflection.....in.	[2] .703		[2] 1.19	
Set.....in.	[2] .235		[2] .44	
10-inch drop -- Deflection.....in.				
Set.....in.				
12-inch drop -- Deflection.....in.				
Set.....in.				

Table 1.--Summary of tests of extruded magnesium cargo flooring--continued

Property	Test results			
	Flooring CB	Flooring CC	Flooring CD	Flooring CE
Impact loading -- 200-pound box corner (continued)				
15-inch drop -- Deflection....in.				
Set....in.				
18-inch drop -- Deflection....in.		0.52		0.284
Set....in.		.14		.028
21-inch drop -- Deflection....in.		.66		.330
Set....in.		.24		.048
24-inch drop -- Deflection....in.		[2] 1.25		.346
Set....in.		[2] .46		.052
27-inch drop -- Deflection....in.				.357
Set....in.				.056
Rolling load -- Engine cradle wheel				
Load parallel to span length				
800-pound load over web....trips			6,050	
800-pound load between webs....trips			9,100	
1,000-pound load over web....trips			2,690	
1,000-pound load between webs....trips			3,600	
1,200-pound load over web....trips	5,380	7,660	530	
1,200-pound load between webs....trips	[3]10,000	7,830	1,000	
1,450-pound load over web....trips	3,870			
1,450-pound load between webs....trips	3,200	5,730		
1,600-pound load over web....trips	1,310	3,580	25	
1,600-pound load between webs....trips	2,680	3,340	35	
1,800-pound load over web....trips	165	290		
1,800-pound load between webs....trips	300			

Table 1.--Summary of tests of extruded magnesium cargo flooring--continued

Property	Test results			
	Flooring CB	Flooring CC	Flooring CD	Flooring CE
Rolling load -- Engine cradle wheel (continued)				
Load parallel to span length				
2,400-pound load over web.....trips				10,000
2,400-pound load between webs.....trips				[3]10,000
2,800-pound load over web.....trips				5,700
2,800-pound load between webs.....trips				7,430
Load perpendicular to span length				
600-pound load.....trips			2,830	
800-pound load.....trips	4,920		1,620	
1,000-pound load.....trips	2,850	2,930	780	
1,200-pound load.....trips	1,070	2,180	140	
1,450-pound load.....trips	95	1,480		
1,600-pound load.....trips		730		
1,800-pound load.....trips				
2,000-pound load.....trips				6,600
2,400-pound load.....trips				4,220
2,800-pound load.....trips				3,190

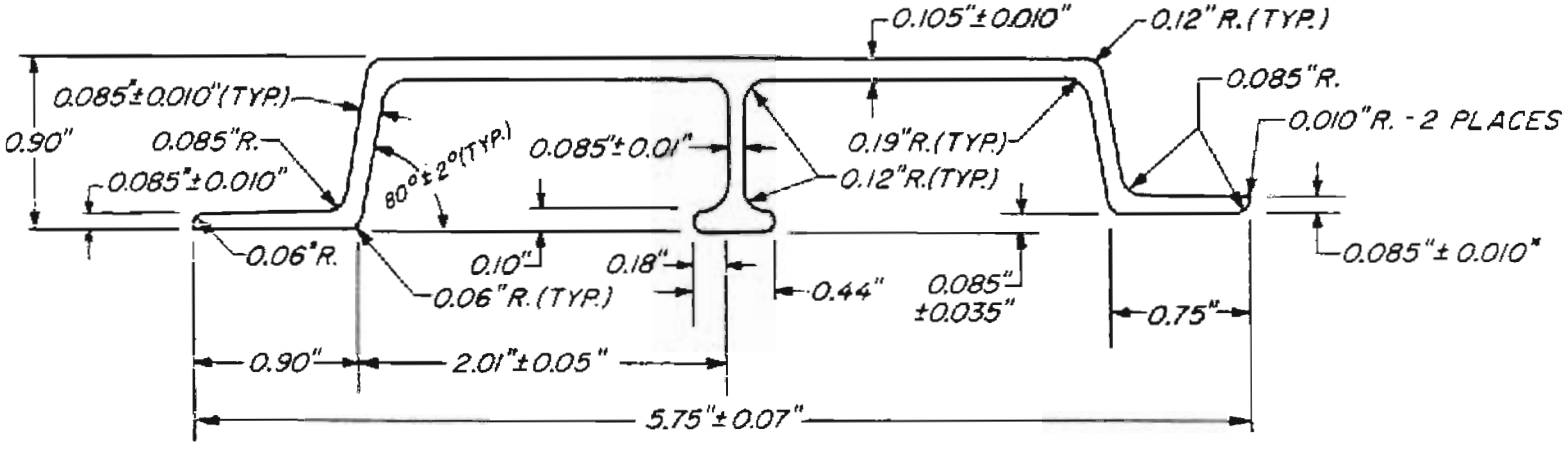
[1]Approximate values, no positive failure since large deflection of specimens at an approximate constant value of load caused them to slip off supports.

[2]Top facing of panels failed under the impact load.

[3]Test stopped, no failure of panels.

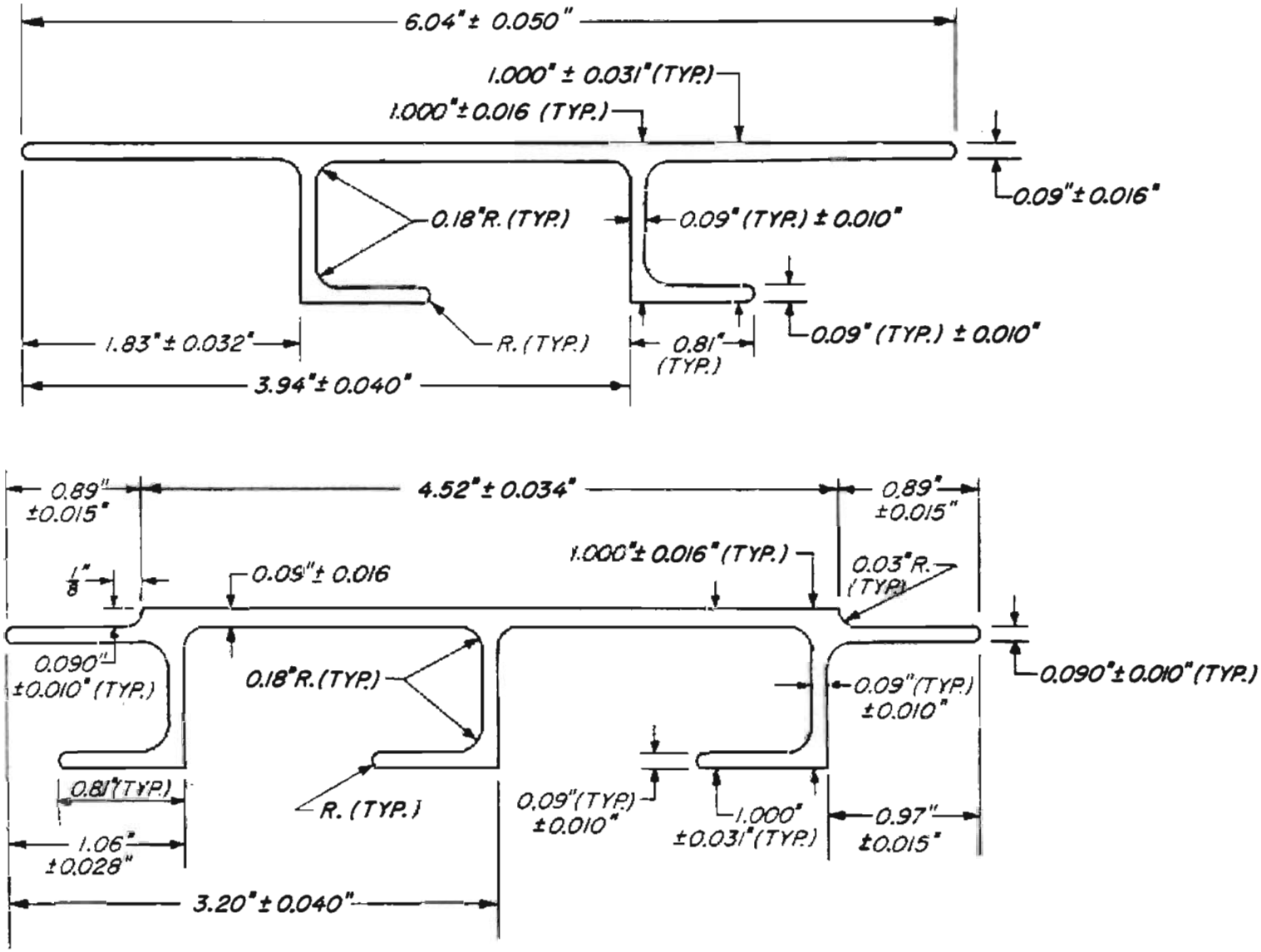
Table 2.--Key to letter designations of cargo flooring

Flooring designation	Reported properties			
	Tensile strength	Tensile yield strength	Elongation	Compressive yield strength
	P.s.i.	P.s.i.	Percent	P.s.i.
CB	53,000	44,000	8.0	35,000
CC	50,900	40,200	11.5	33,500
	53,600	44,800	12.5	38,700
CD	51,300	41,000	11.5	34,000
CE	50,100	40,300	9.5	29,500



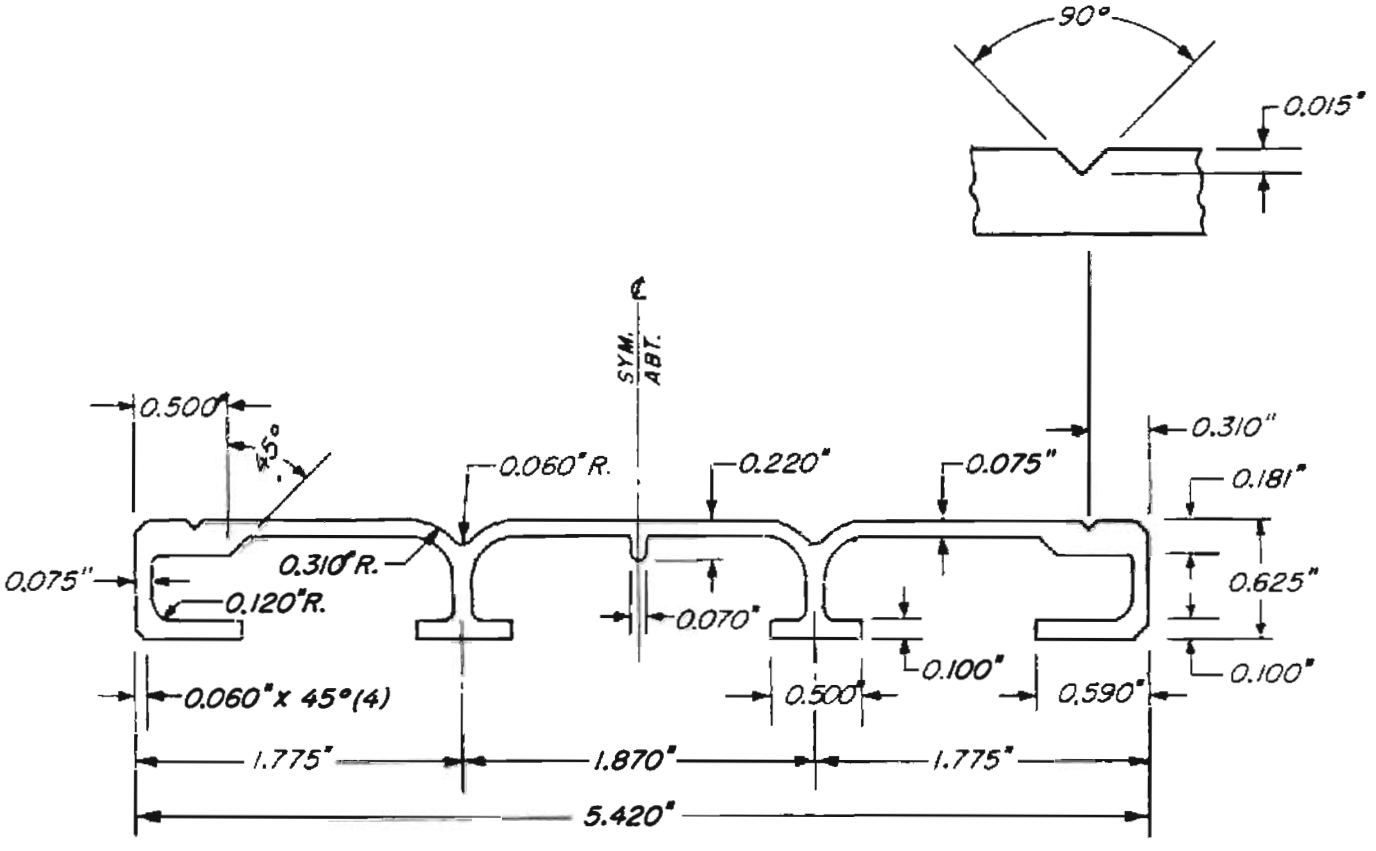
M 96614 F

Figure 1.--Details of magnesium alloy extrusion used in fabrication of cargo flooring CB.



M 96618 F

Figure 2.--Details of two magnesium alloy extrusions used in fabrication of cargo flooring CC.



M 96617 F

Figure 3.--Details of magnesium alloy extrusions used in cargo flooring CD.

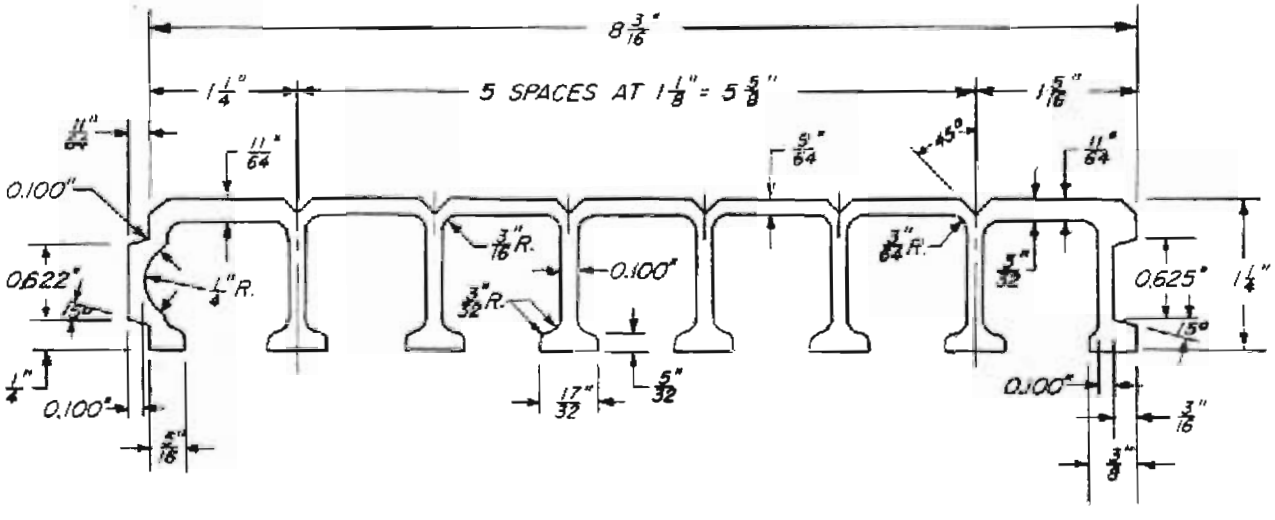
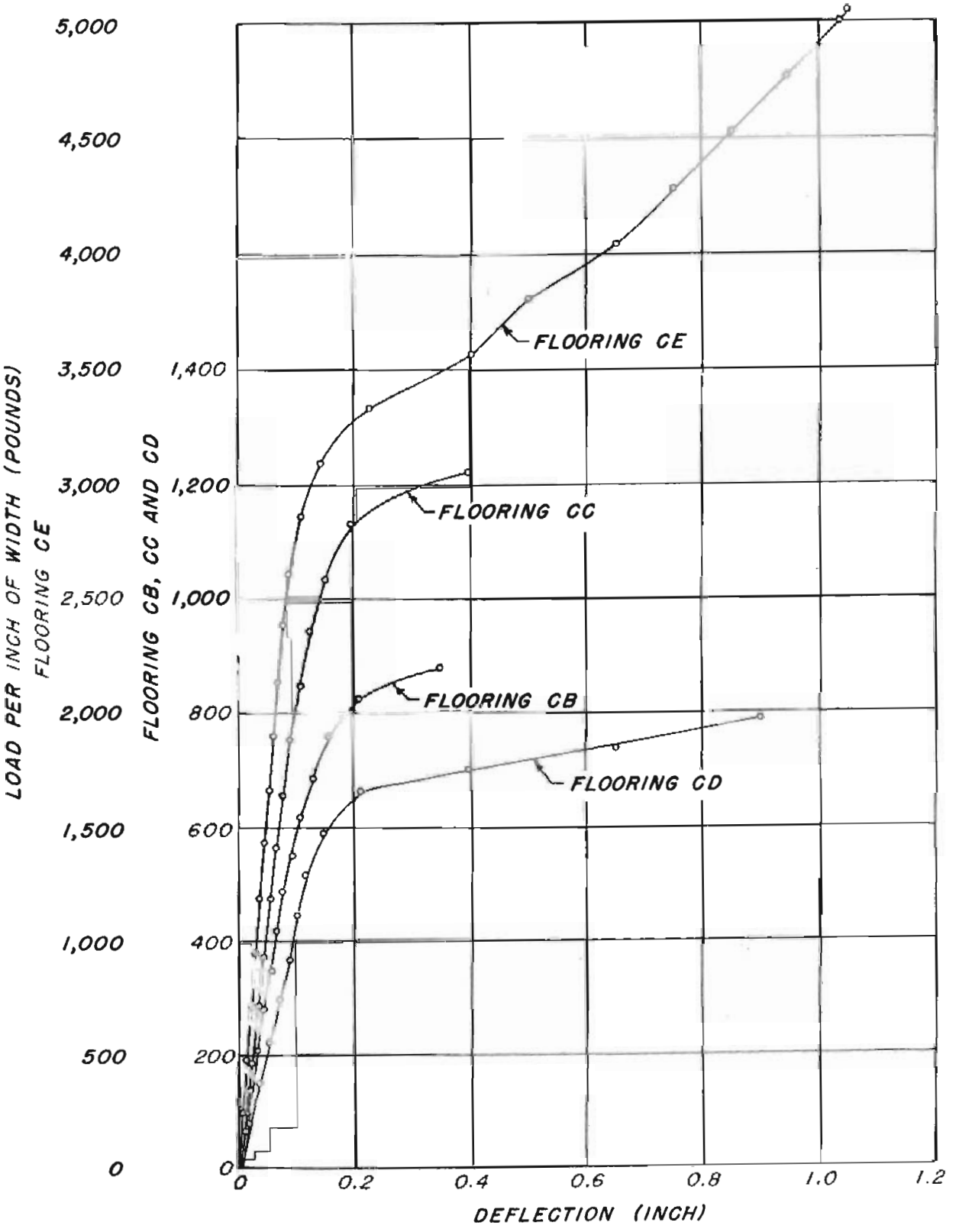
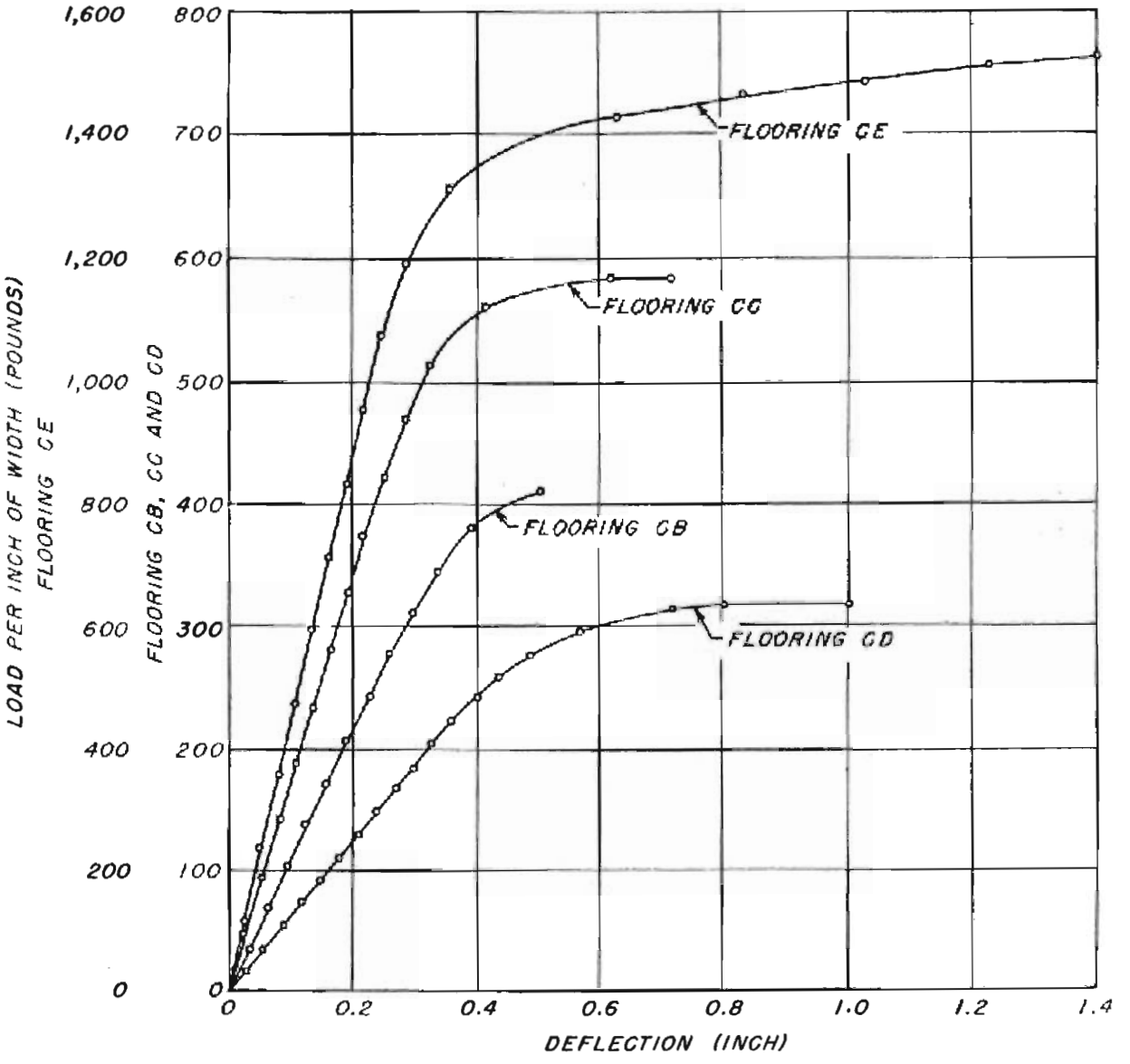


Figure 4.--Details of magnesium alloy extrusion used in cargo flooring CE.



M 96619 F

Figure 5.--Typical load-deflection curves for cargo flooring CB, CC, CD, and CE tested in static bending over an 8-inch span.



M 96620 F

Figure 6.--Typical load-deflection curves for cargo flooring CB, CC, CD, and CE tested in static bending over a 16-inch span.

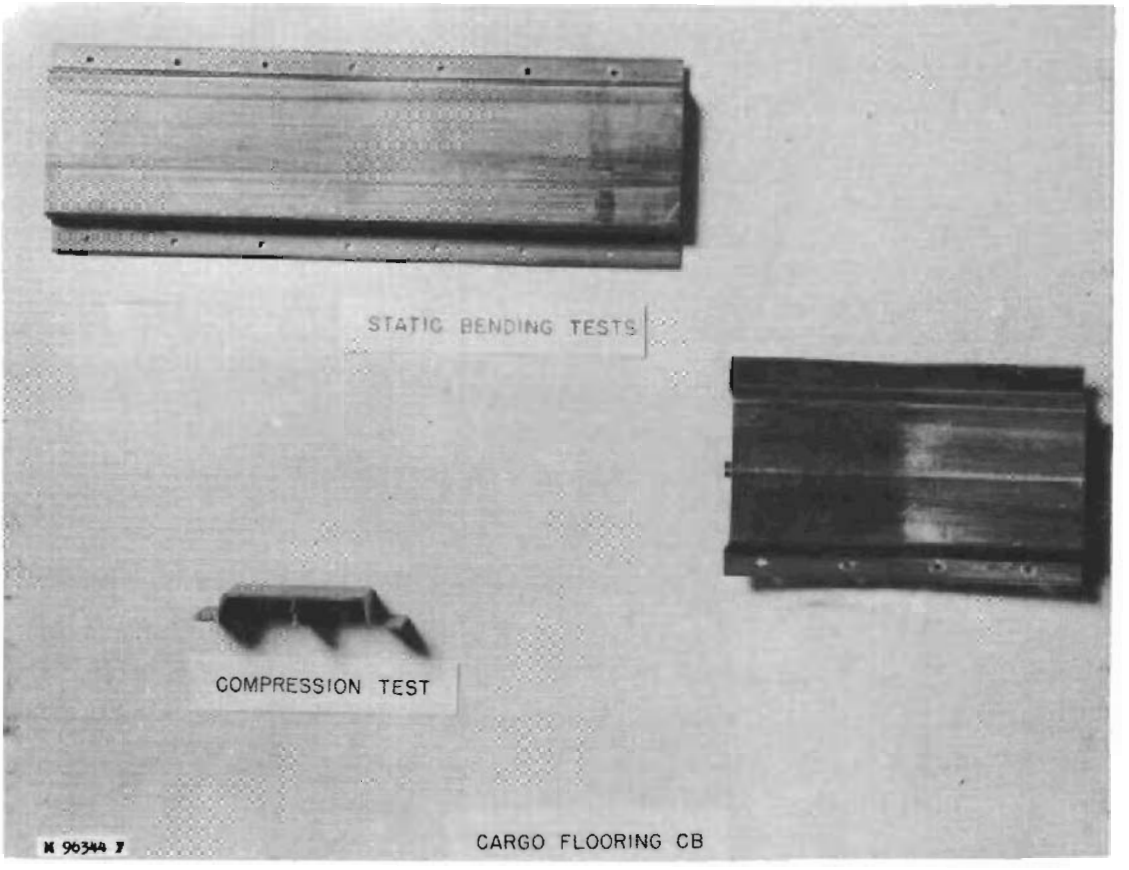


Figure 7.--Appearance of typical specimens of cargo flooring CB after static bending and compression tests. Note fracture through bolt hole at midlength of 16-inch-span bending specimen, and failure of center web in shear in compression specimen.

ZM 96344 F

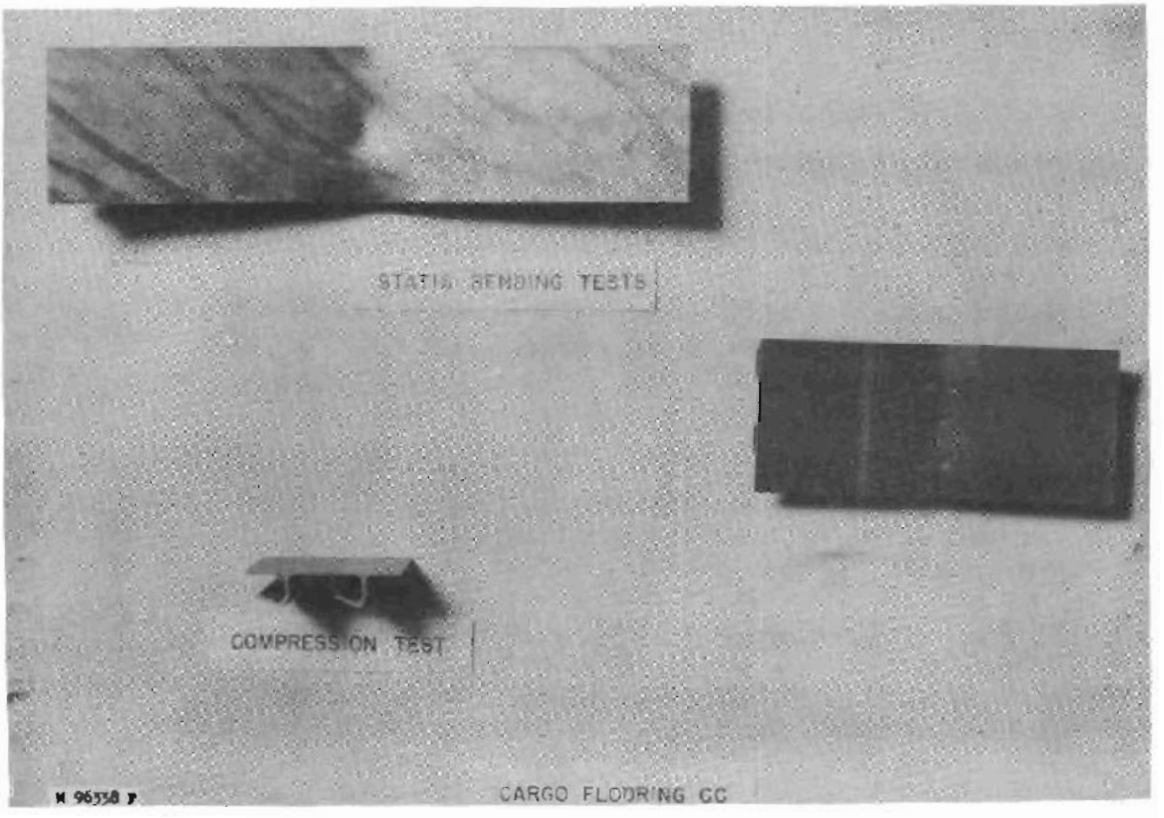


Figure 8.--Appearance of typical specimens of cargo flooring CC after static bending and compression tests. Note bending of webs and lower flanges that occurred during compression test.

ZM 96338 F

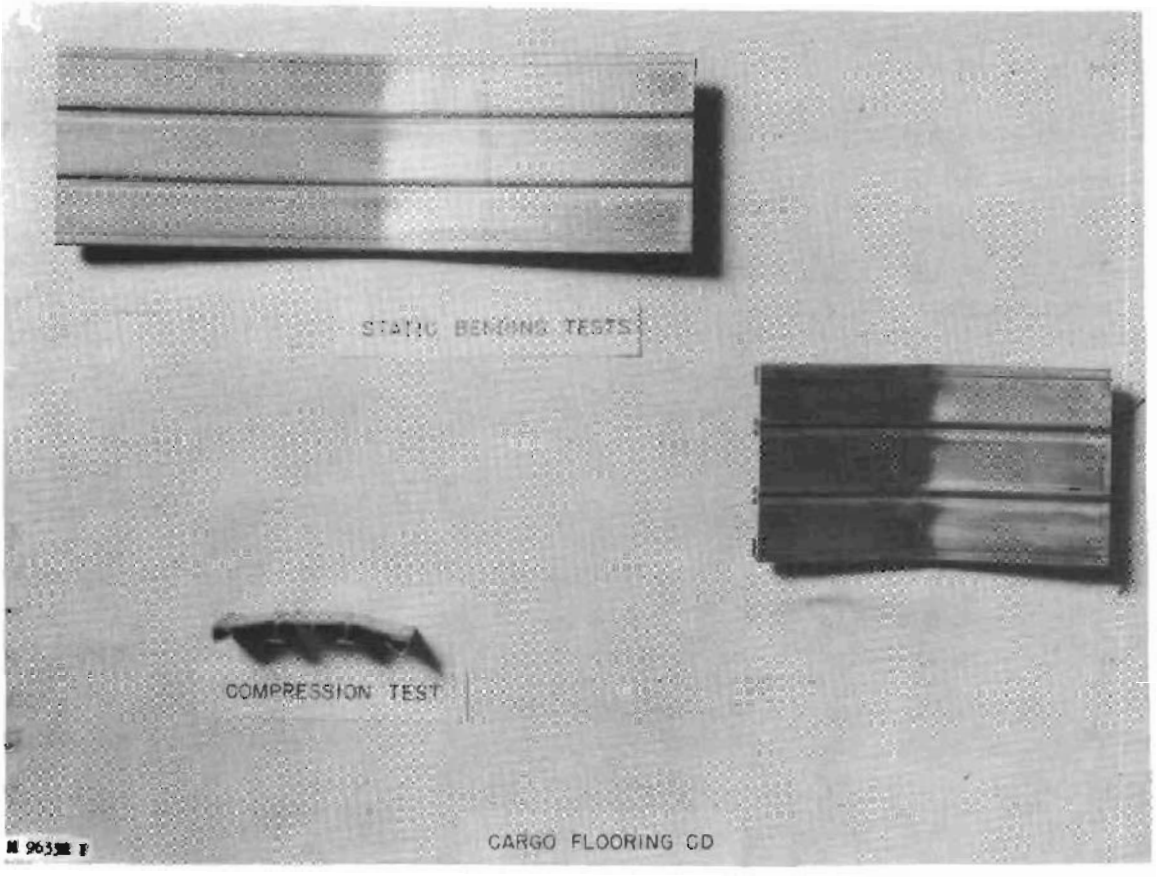


Figure 9.--Appearance of typical specimens of cargo flooring CD after static bending and compression tests. Note distortion of edge webs and lower flanges, and fracture of upper surface at edge of second web from the left in the compression specimen.

ZM 96332 F

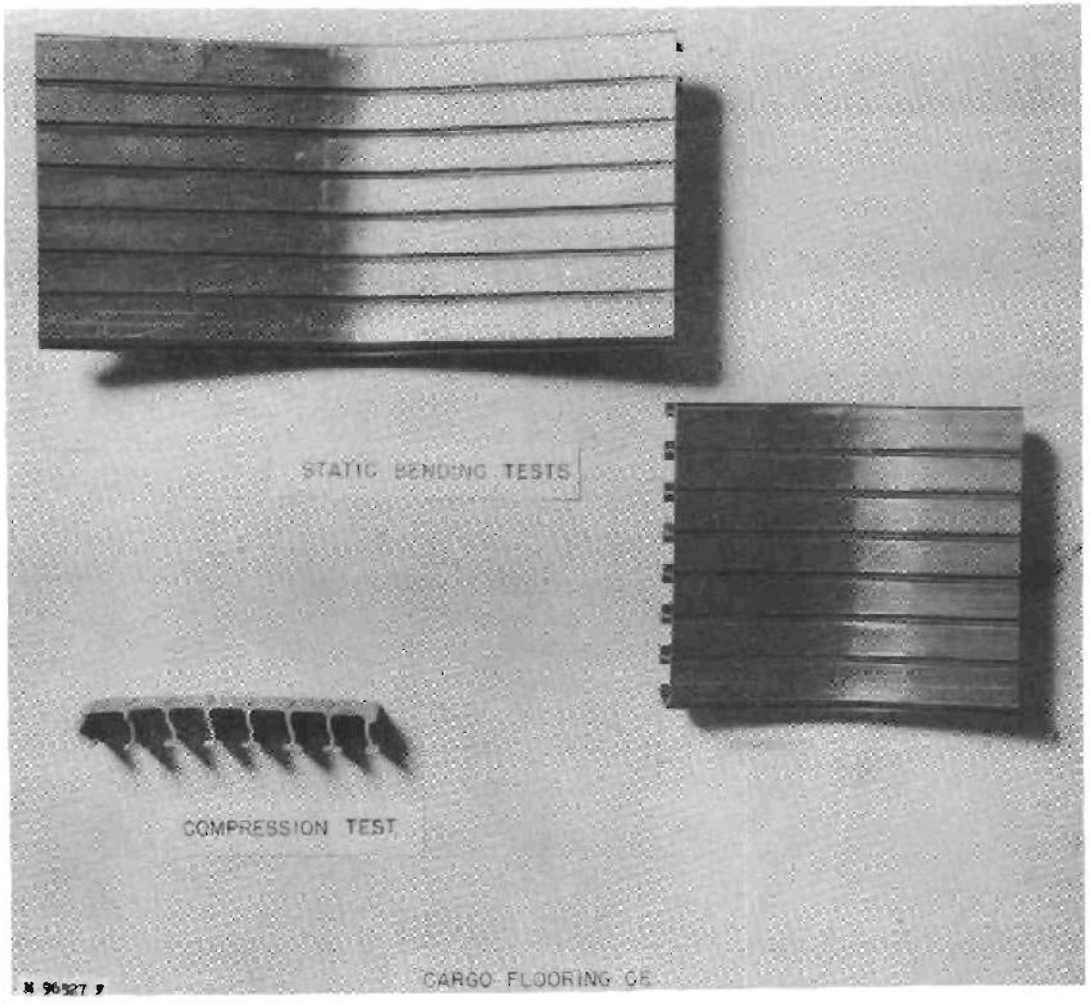


Figure 10.--Appearance of typical specimens of cargo flooring CE after static bending and compression tests. Note buckling of webs that occurred under compressive loading and shear failure of second web from the left in the compression specimen.

ZM 96327 F

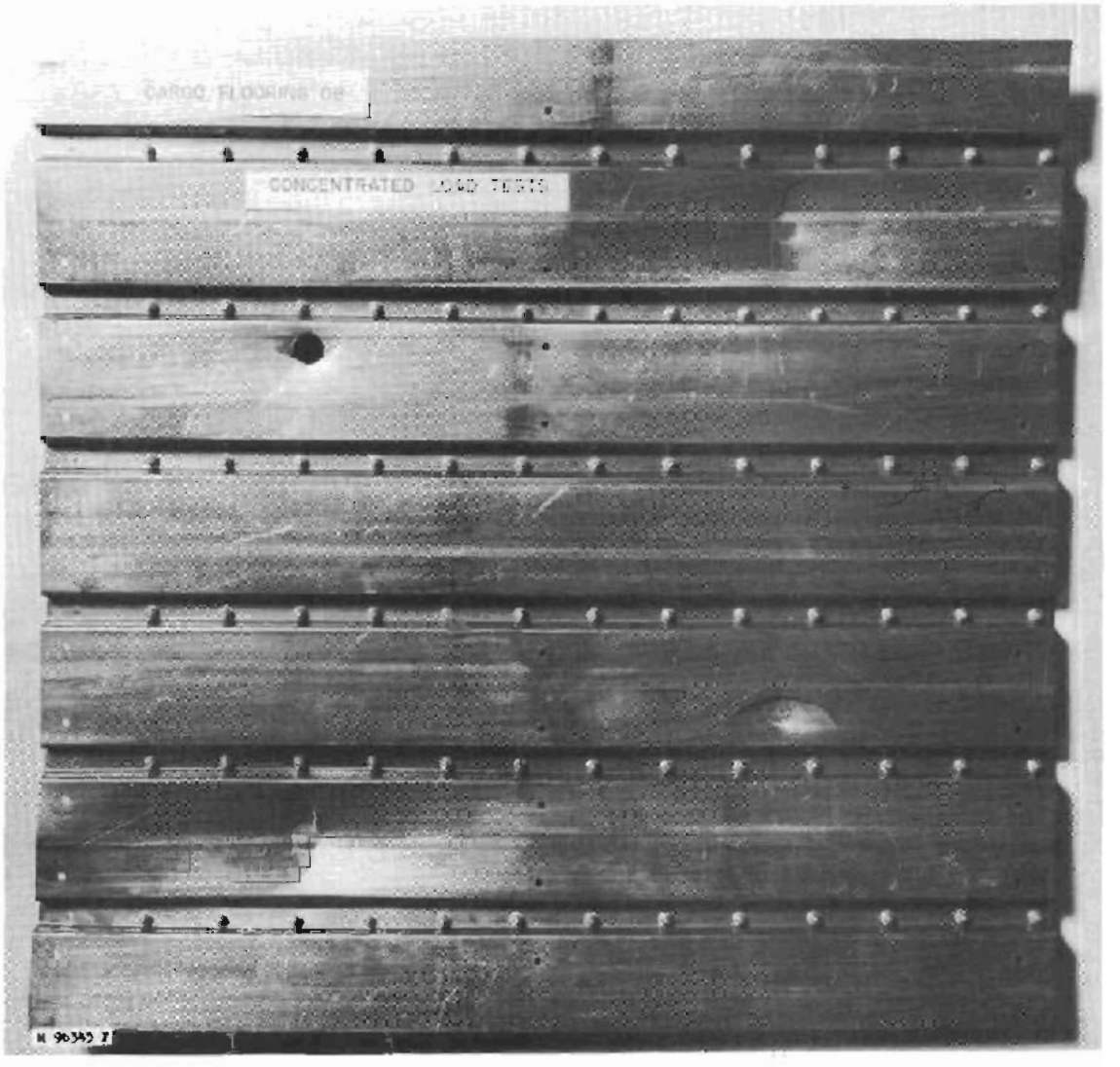


Figure 11.--Damage occurring in cargo flooring CB due to application of a concentrated load through a 1-inch-diameter round steel bar. Application of load to top surface between webs caused a punching shear failure. When the load was applied over a web, the web and lower flange failed in tension with concurrent failure of top surface.

ZM 96345 F

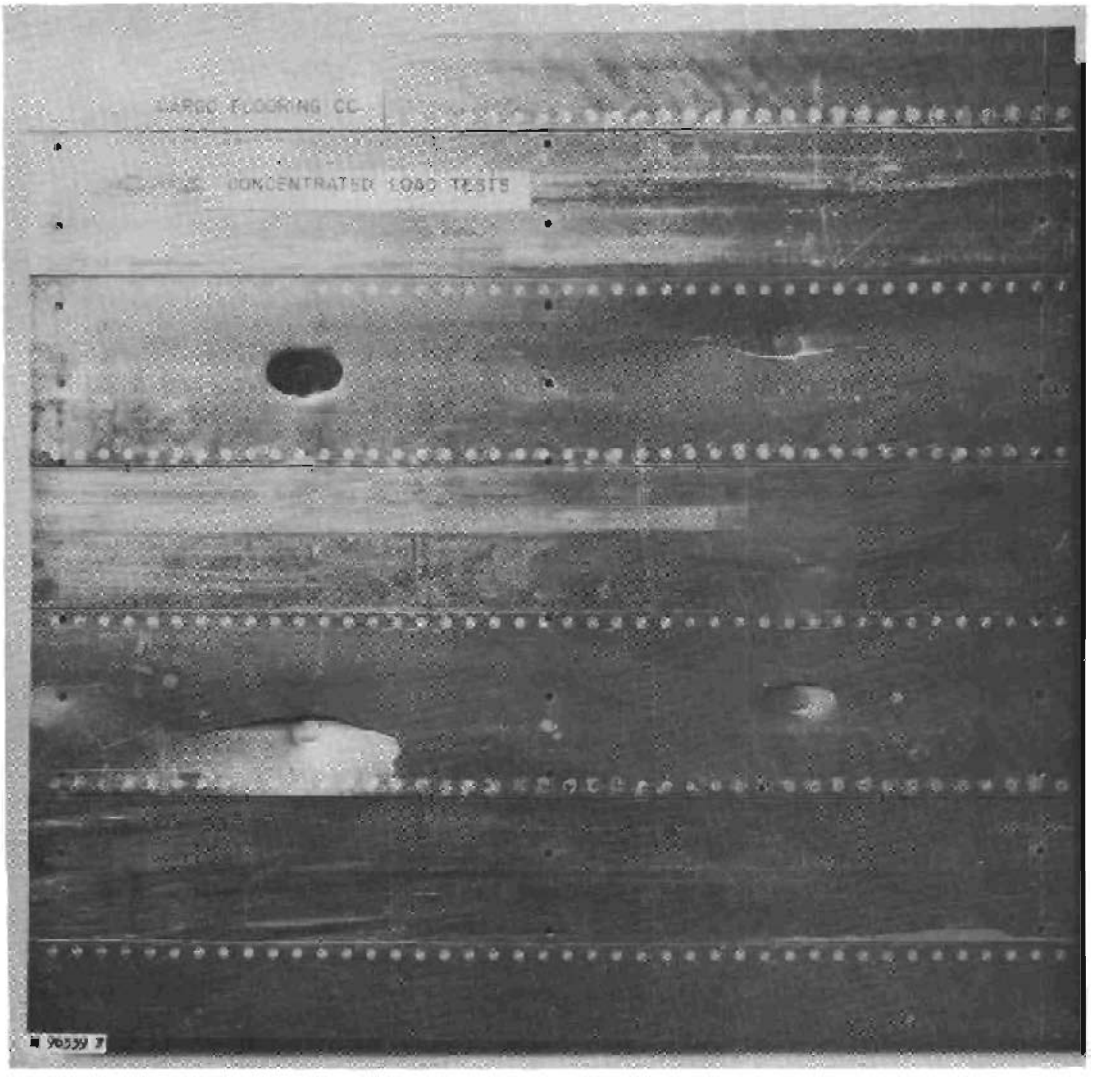


Figure 12.--Damage occurring in cargo flooring CC due to application of a concentrated load through a 1-inch-diameter round steel bar. Load application to top surface between webs caused a punching shear failure. When the load was applied over a web, the top surface failed at the edge of the loading bar, sometimes with accompanying failure of web and lower flange in tension.

ZM 96339 F

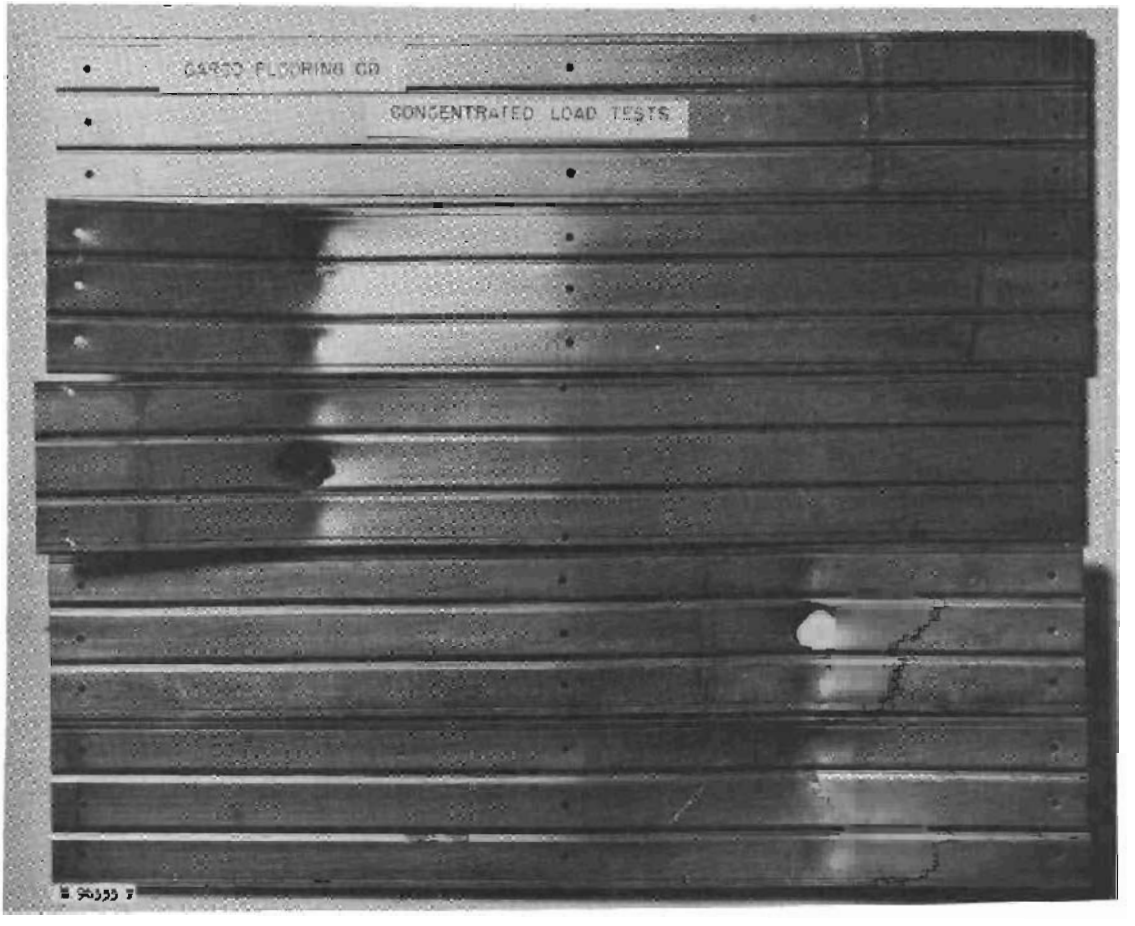


Figure 13.--Damage occurring in cargo flooring CD due to application of a concentrated load through a 1-inch-diameter round steel bar. Load application to top surface between webs caused a punching shear failure. When the load was applied over a web, some evidence of failure in top surface was noted, but panel deflected nearly 2 inches without complete failure.

ZM 96333 F

Figure 14.--Damage occurring in cargo flooring CE due to application of a concentrated load through a 1-inch-diameter round steel bar. Load application to top surface between webs caused a punching shear failure. When the load was applied over a web, the top surface failed in punching shear, and failure also occurred at the juncture between the web and top surface.

ZM 96328 F

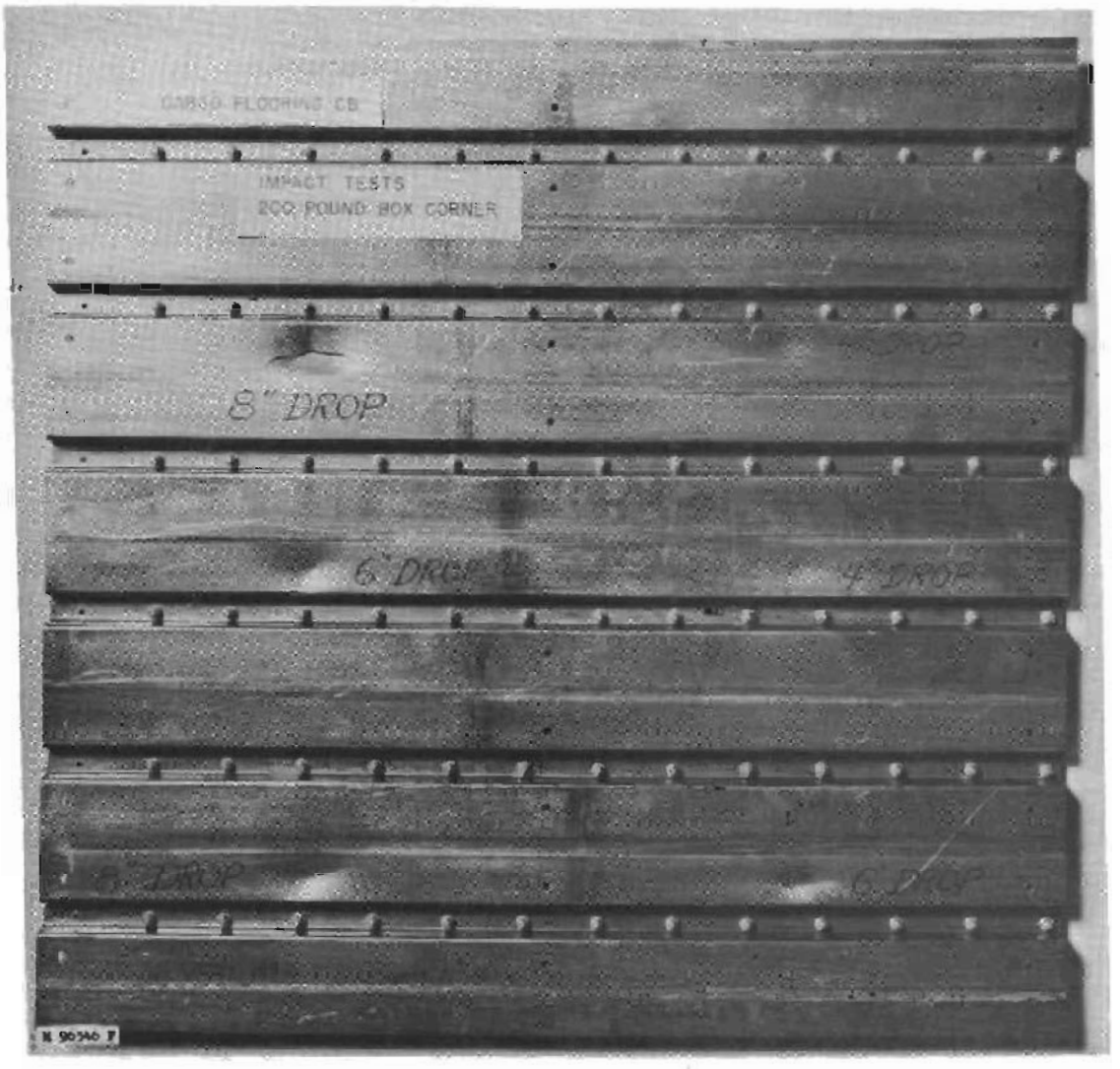


Figure 15.--Damage occurring in cargo flooring CB due to impact load applied with a softwood box corner carrying a 200-pound load dropped from the heights indicated on the panel. Note fractures of the top surface that occurred in the 6- and 8-inch drops.

ZM 96346 F

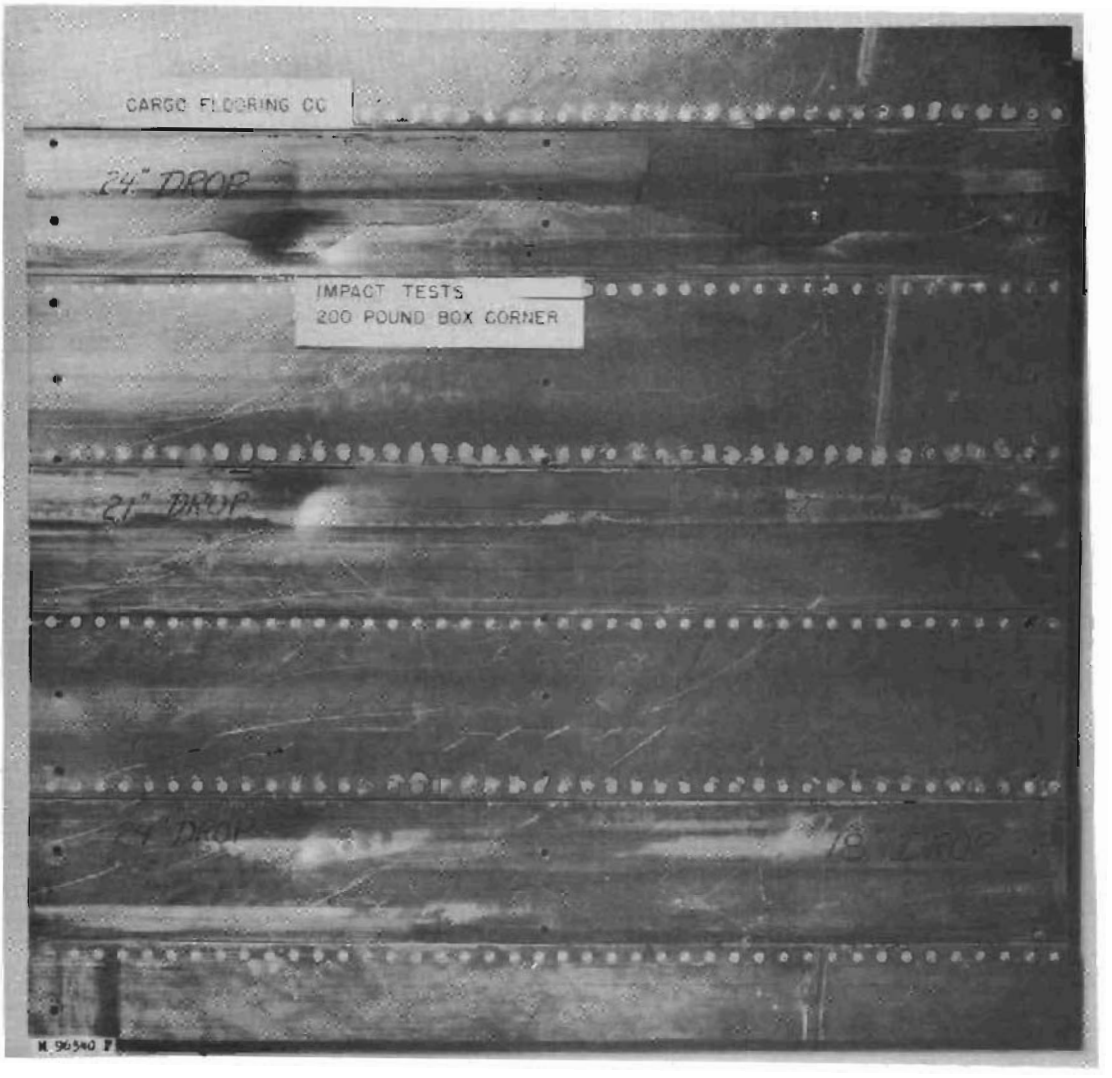


Figure 16.--Damage occurring in cargo flooring CC due to impact load applied with a softwood box corner carrying a 200-pound load dropped from the heights indicated on the panel. Note fracture of the top surface that occurred in the 24-inch drop.

ZM 96340 F

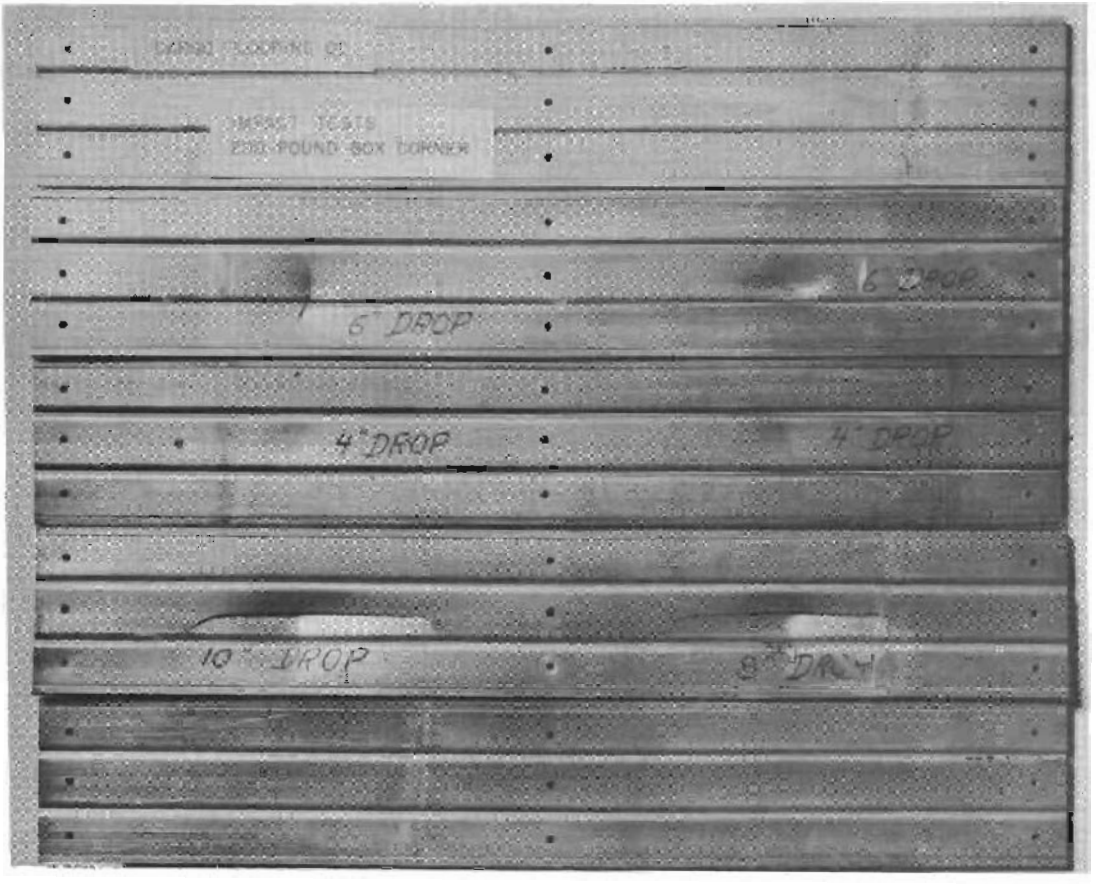


Figure 17.--Damage occurring in cargo flooring CD due to impact load applied with a softwood box corner carrying a 200-pound load dropped from the heights indicated on the panel. Note fractures of the top surface that occurred in the 6-, 8-, and 10-inch drops.

ZM 96334 F

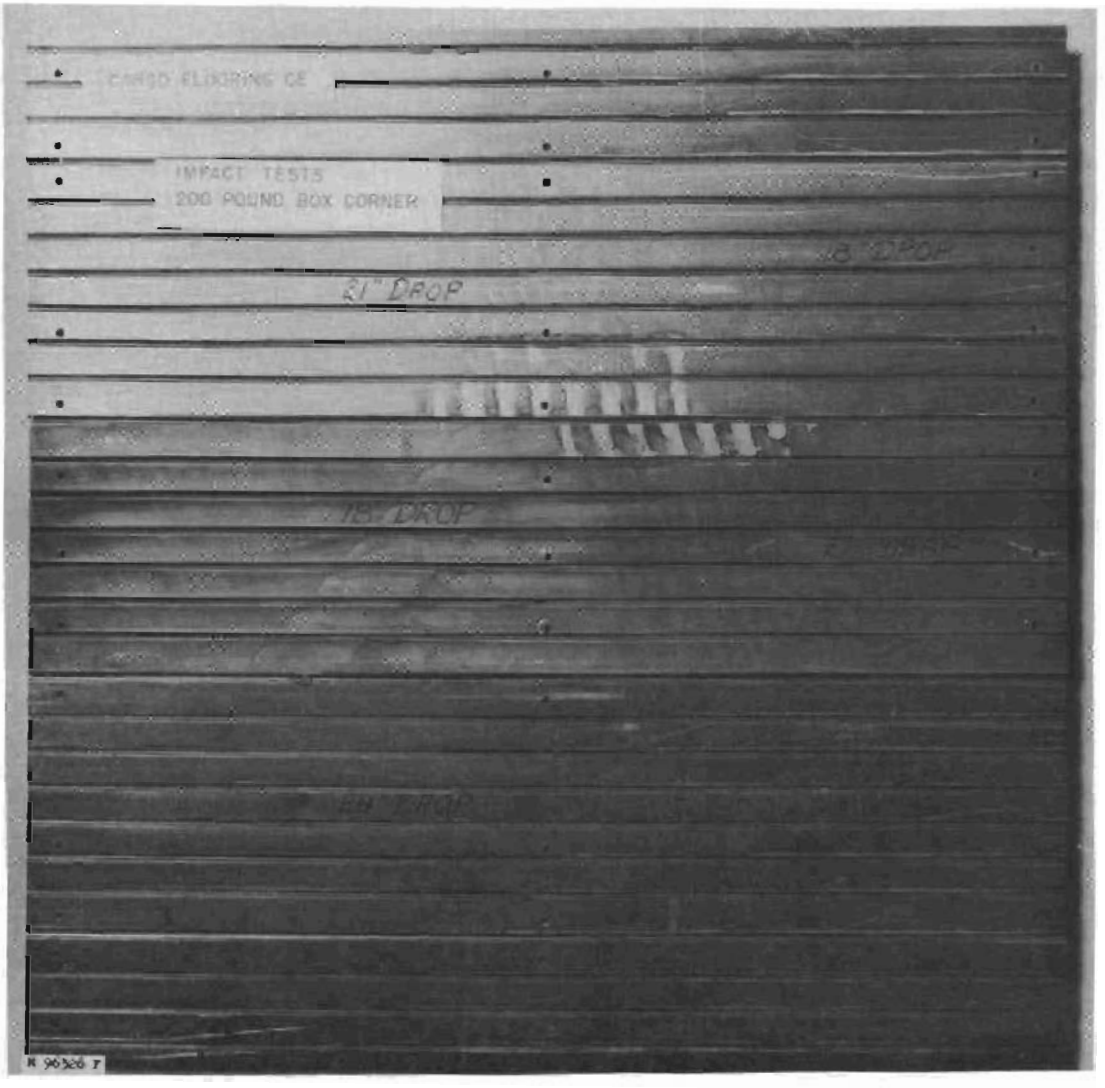
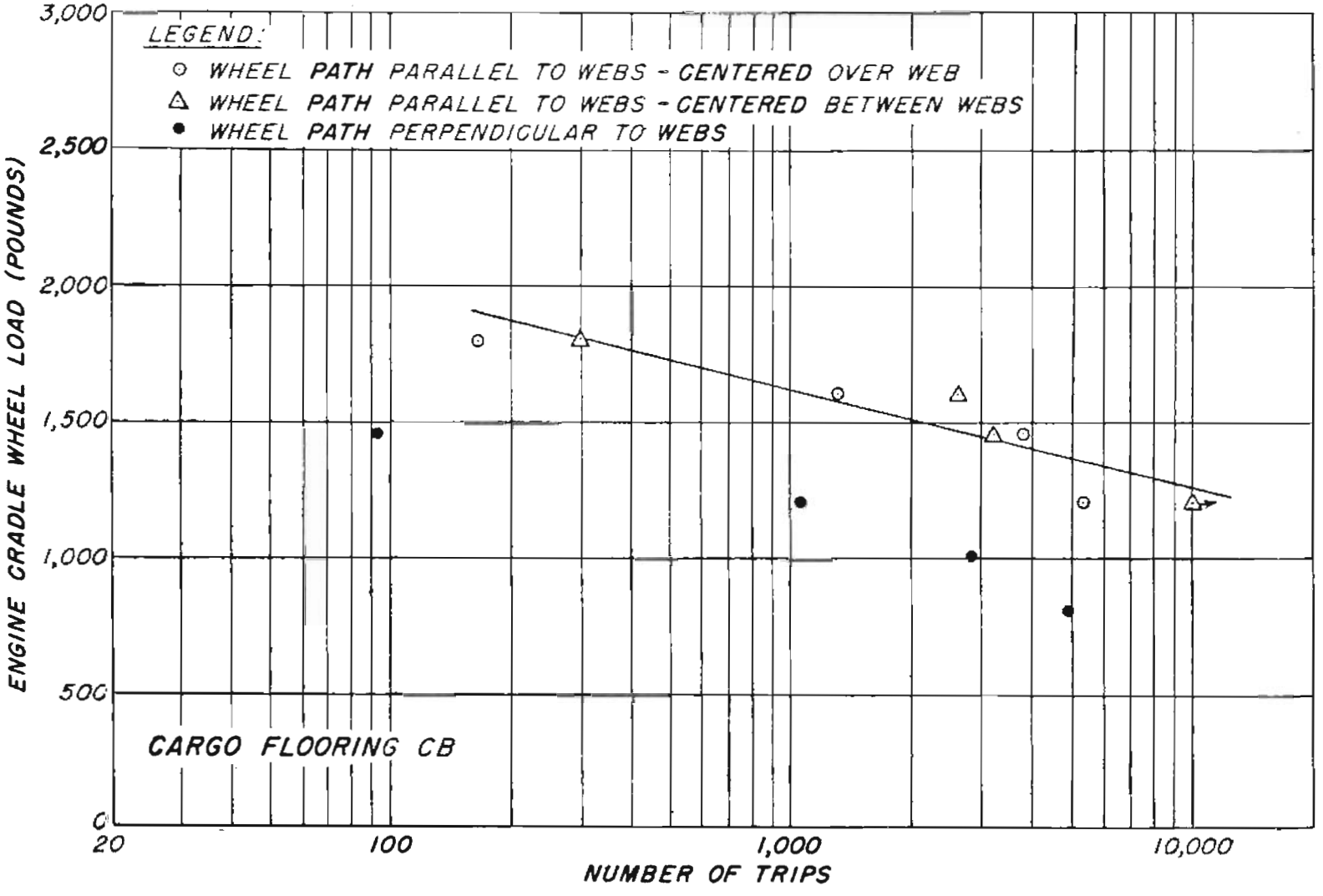


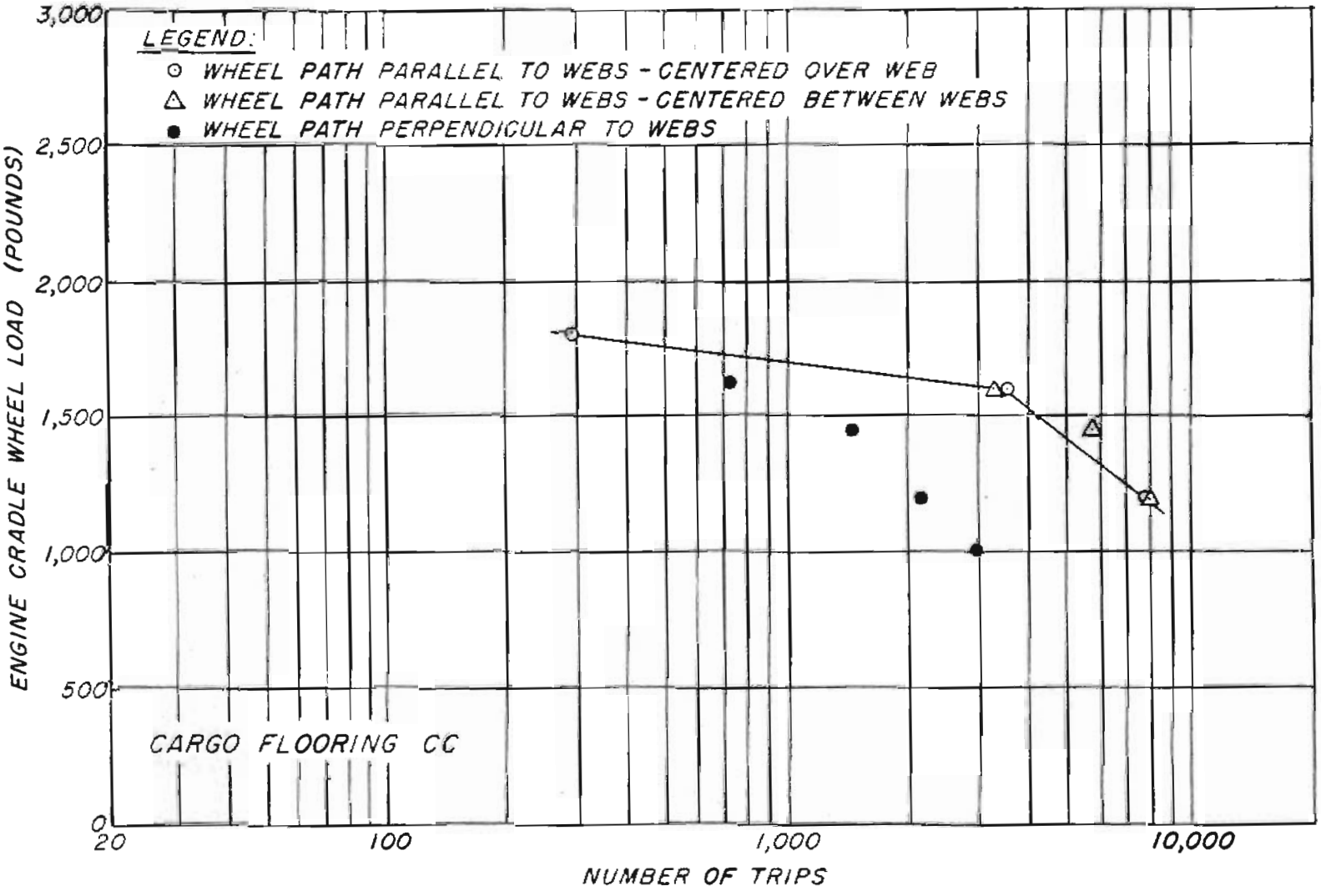
Figure 18.--Damage occurring in cargo flooring CE due to impact load applied with a softwood box corner carrying a 200-pound load dropped from the heights indicated on the panel. No damage to the panel other than surface denting was apparent.

ZM 96326 F



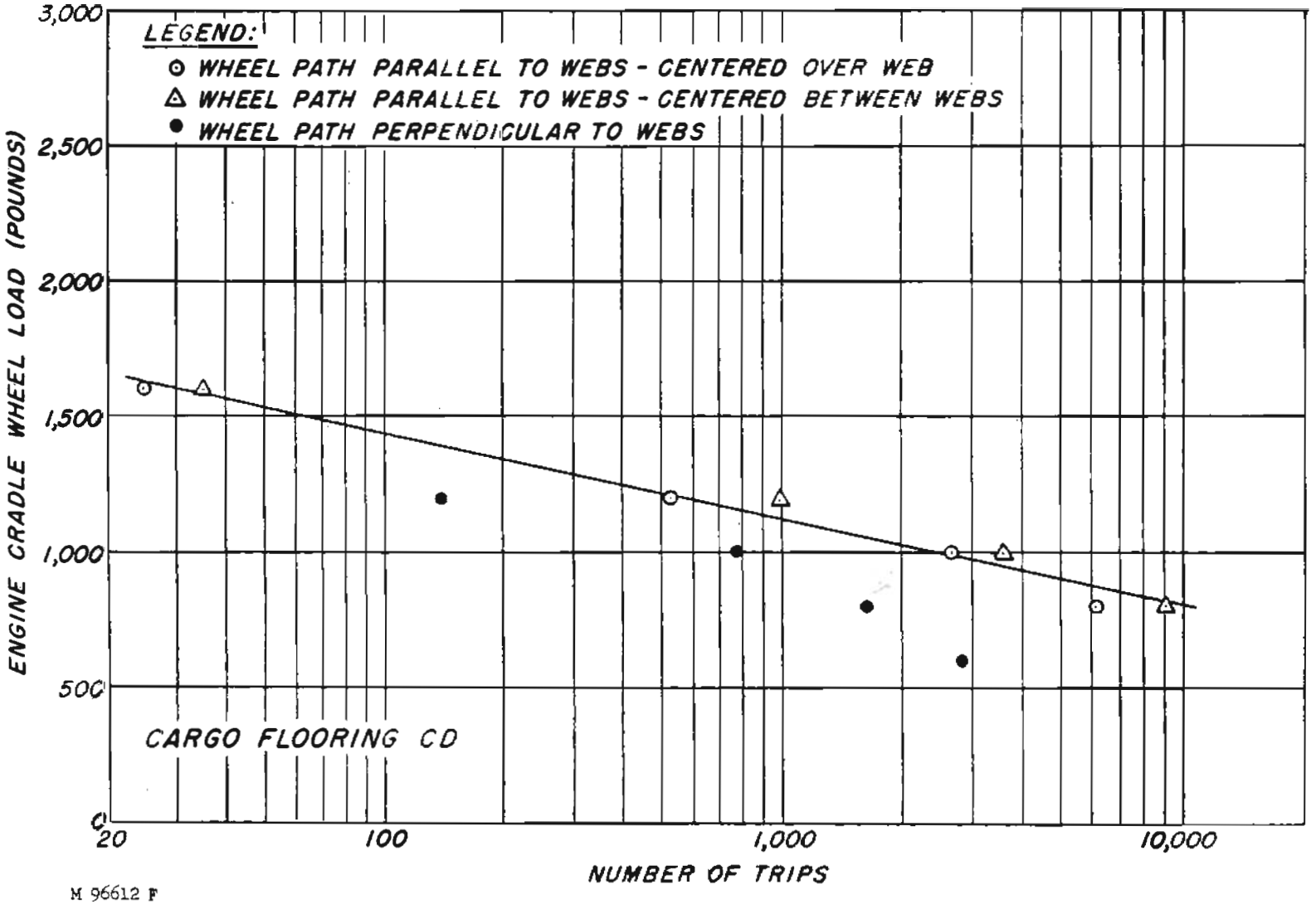
M 96611 F

Figure 19.--Relationship between engine cradle wheel load and number of repetitions of this load sustained by cargo flooring CB.



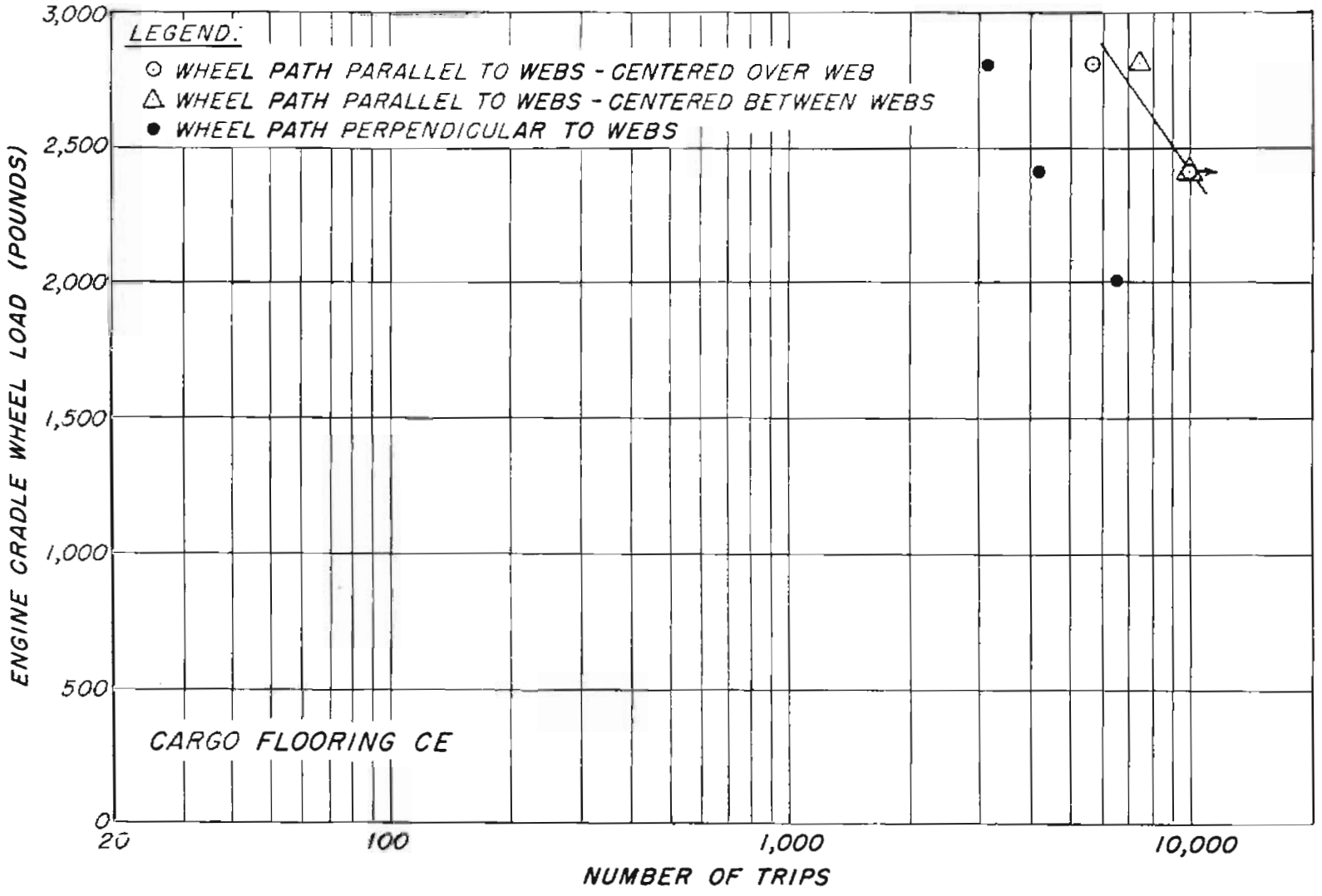
M 96615 F

Figure 20.--Relationship between engine cradle wheel load and number of repetitions of this load sustained by cargo flooring CC.



M 96612 F

Figure 21.--Relationship between engine cradle wheel load and number of repetitions of this load sustained by cargo flooring CD.



M 96613 F

Figure 22.--Relationship between engine cradle wheel load and number of repetitions of this load sustained by cargo flooring CE.

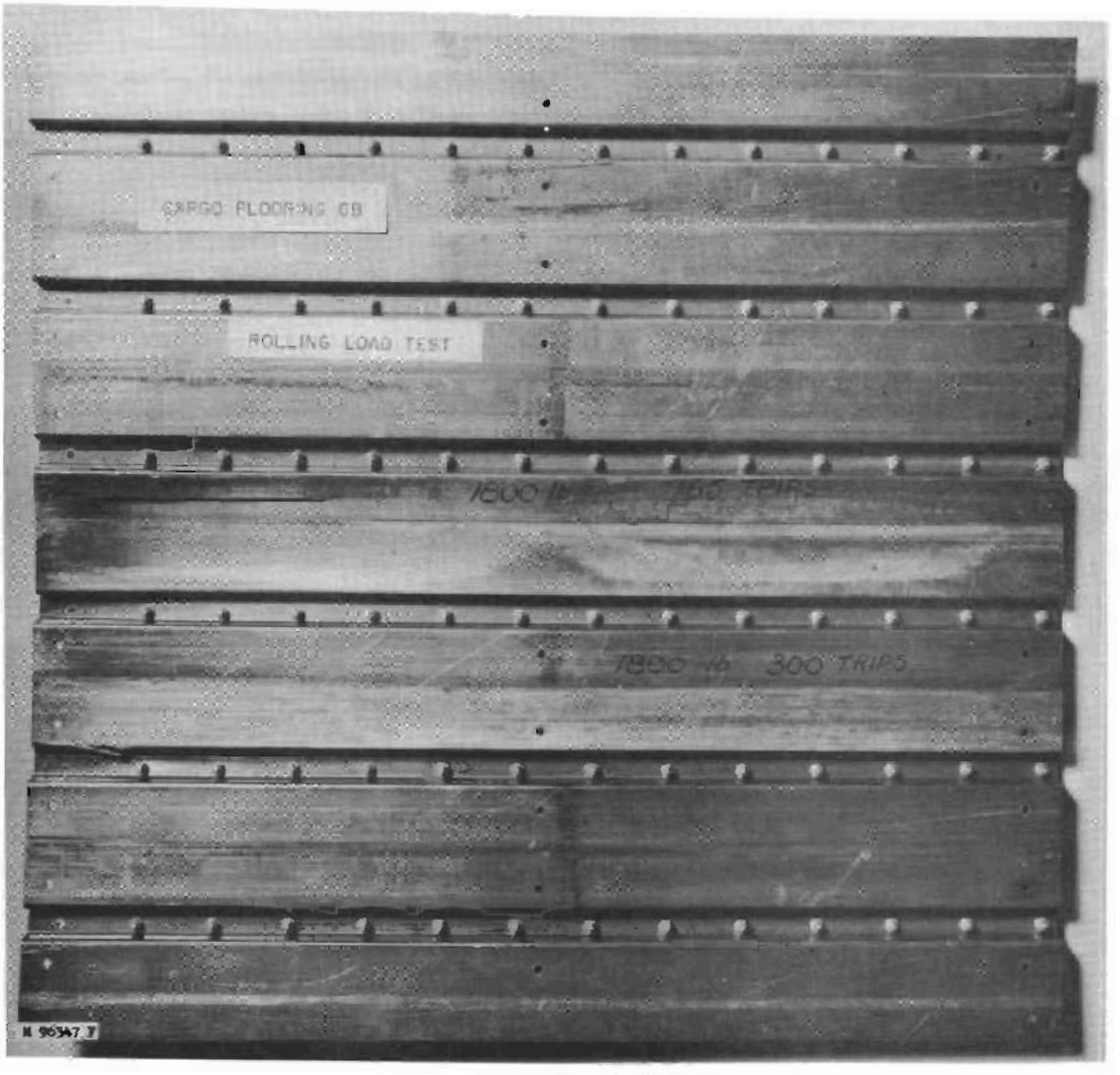


Figure 23.--Cargo flooring CB after rolling load tests. The upper wheel path was centered over a web and the lower between webs. Note fractures occurring at edge of wheel path and at end of panel.

ZM 96347 F

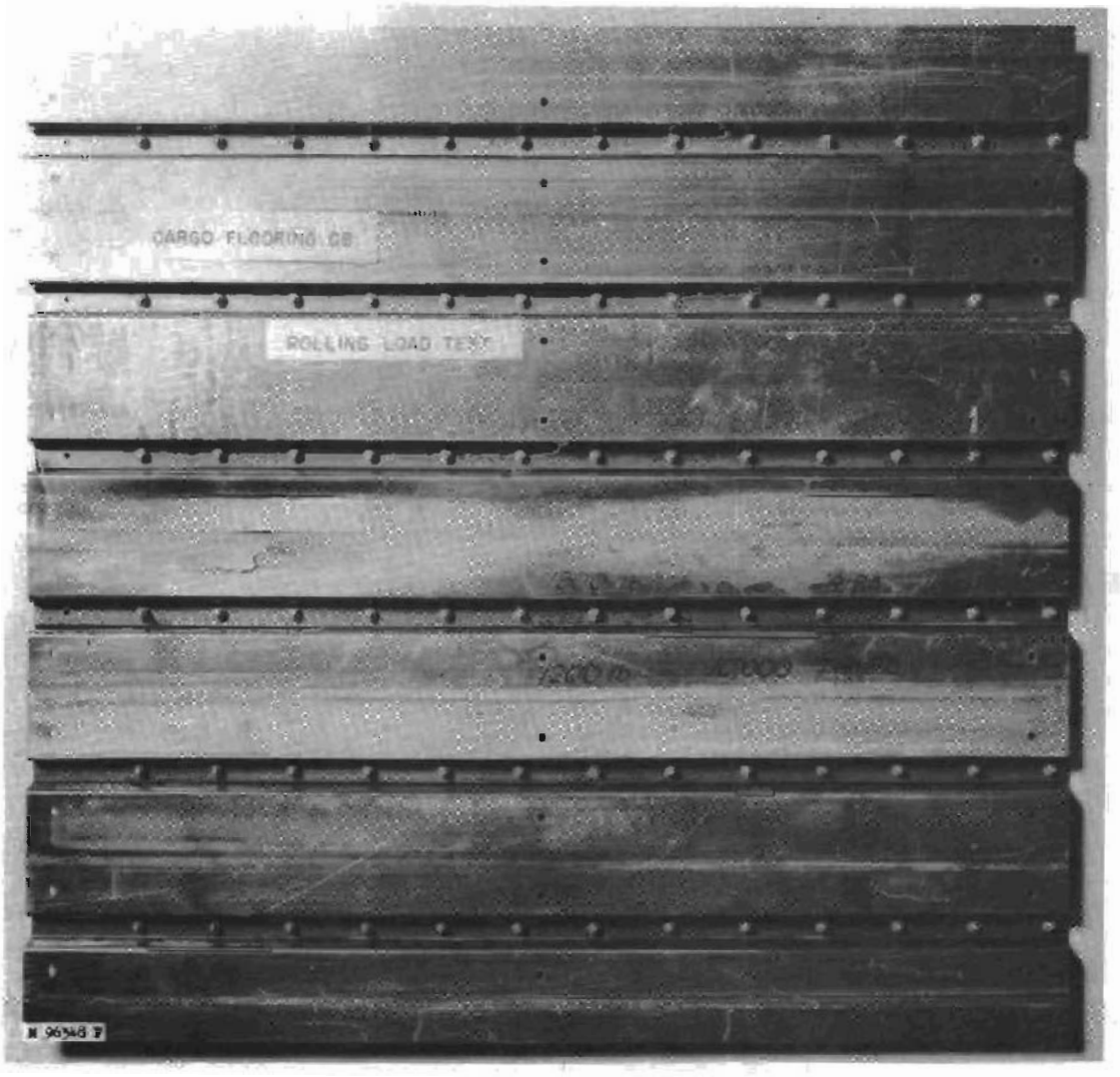


Figure 24.--Cargo flooring CB after rolling load test. The upper wheel path was centered over a web and the lower between webs. Note extent of damage in upper load path and negligible damage except wear when the load was applied between webs.

ZM 96348 F

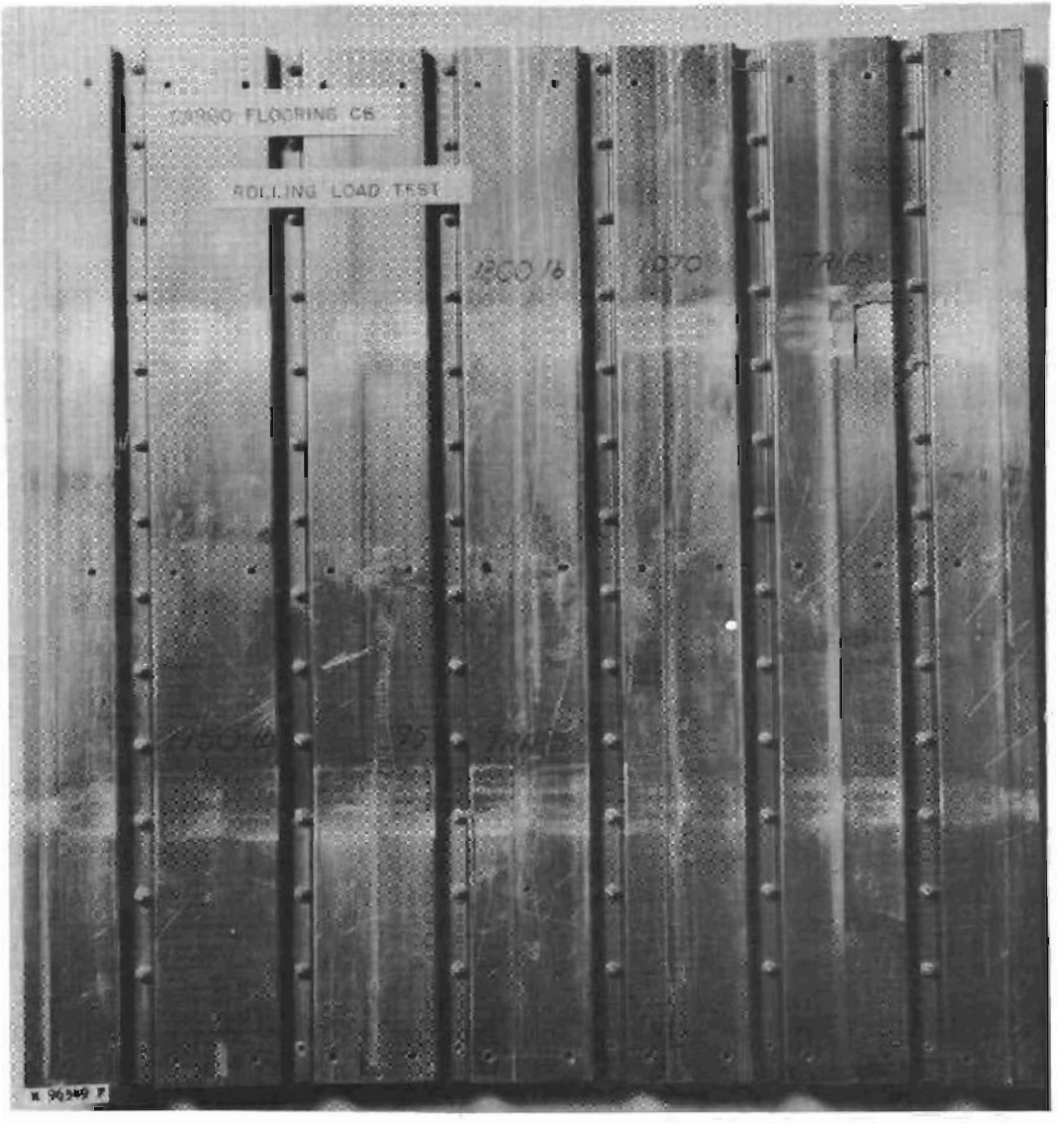


Figure 25.--Cargo flooring CB after rolling load test with wheel path perpendicular to the webs. Note failures along both wheel paths that extend from the bolt holes.

ZM 96349 F

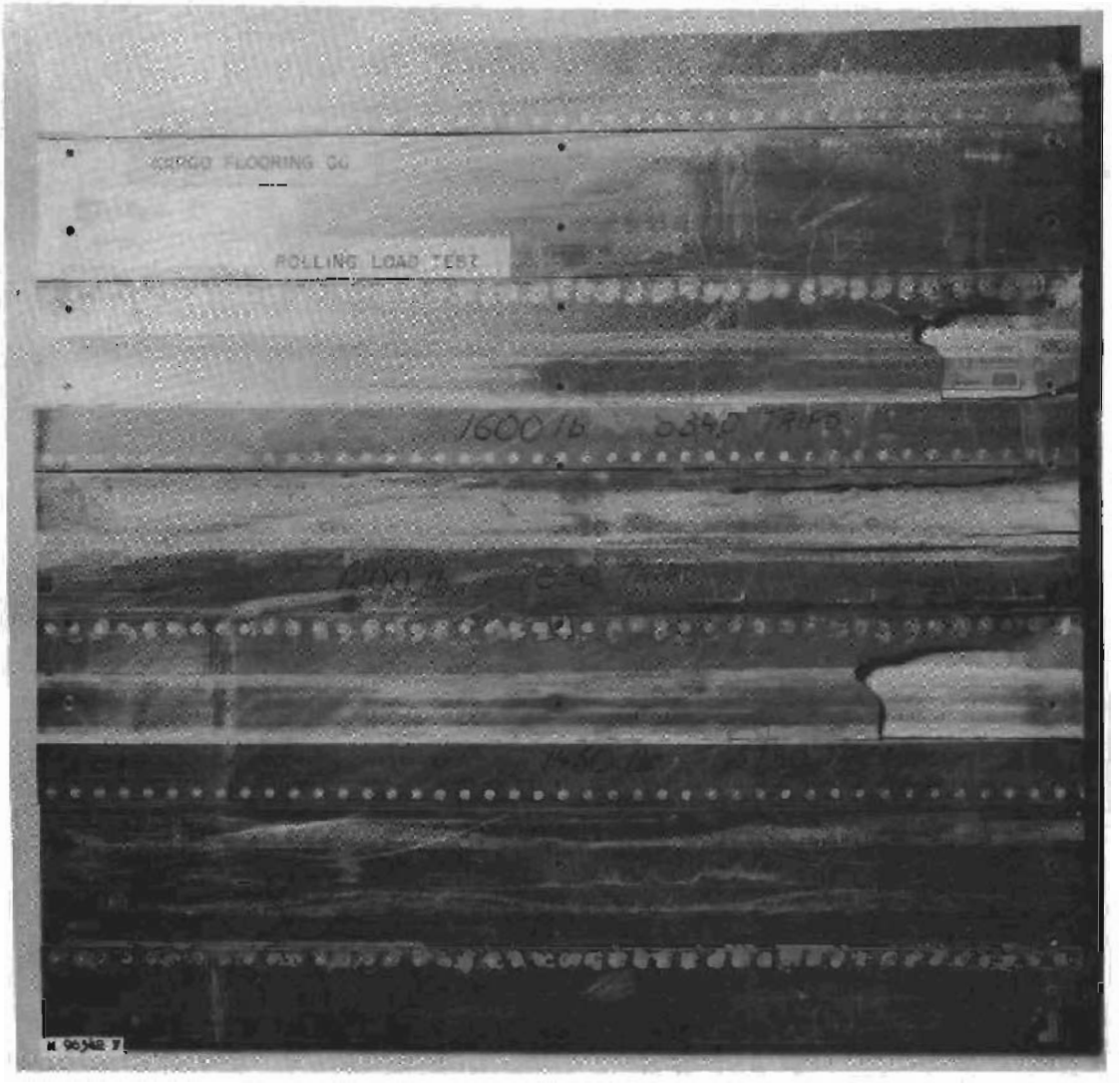


Figure 26.--Cargo flooring CC after rolling load tests, all wheel paths parallel to and between webs. Note fractures along edges of wheel path and final complete failures.

ZM 96342 F

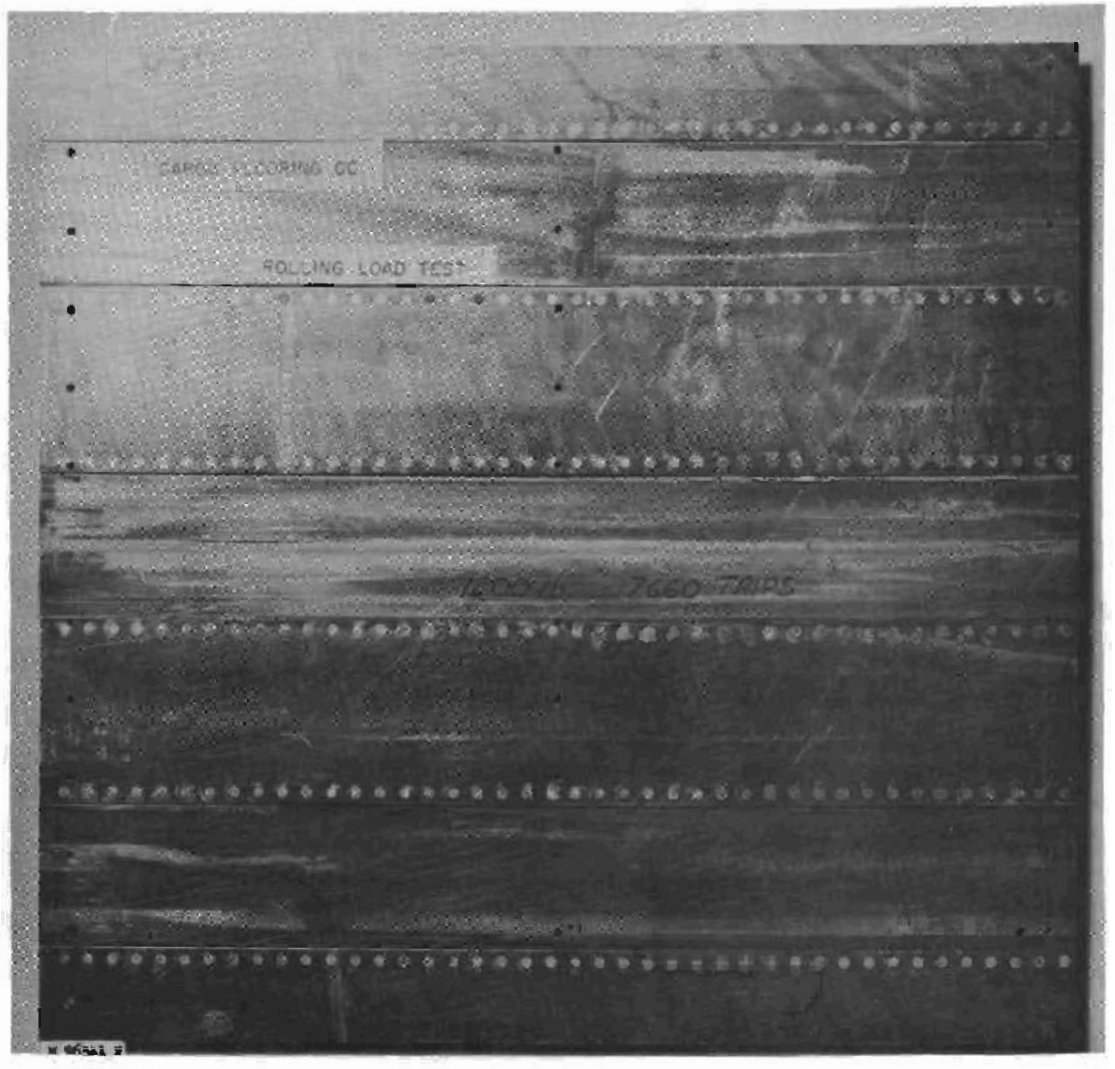


Figure 27.--Cargo flooring CC after rolling load test with wheel path parallel to and over web. Extensive fracture along wheel path at edge of web. Web and lower flange at center of right-hand span failed in tension.

ZM 96341 F

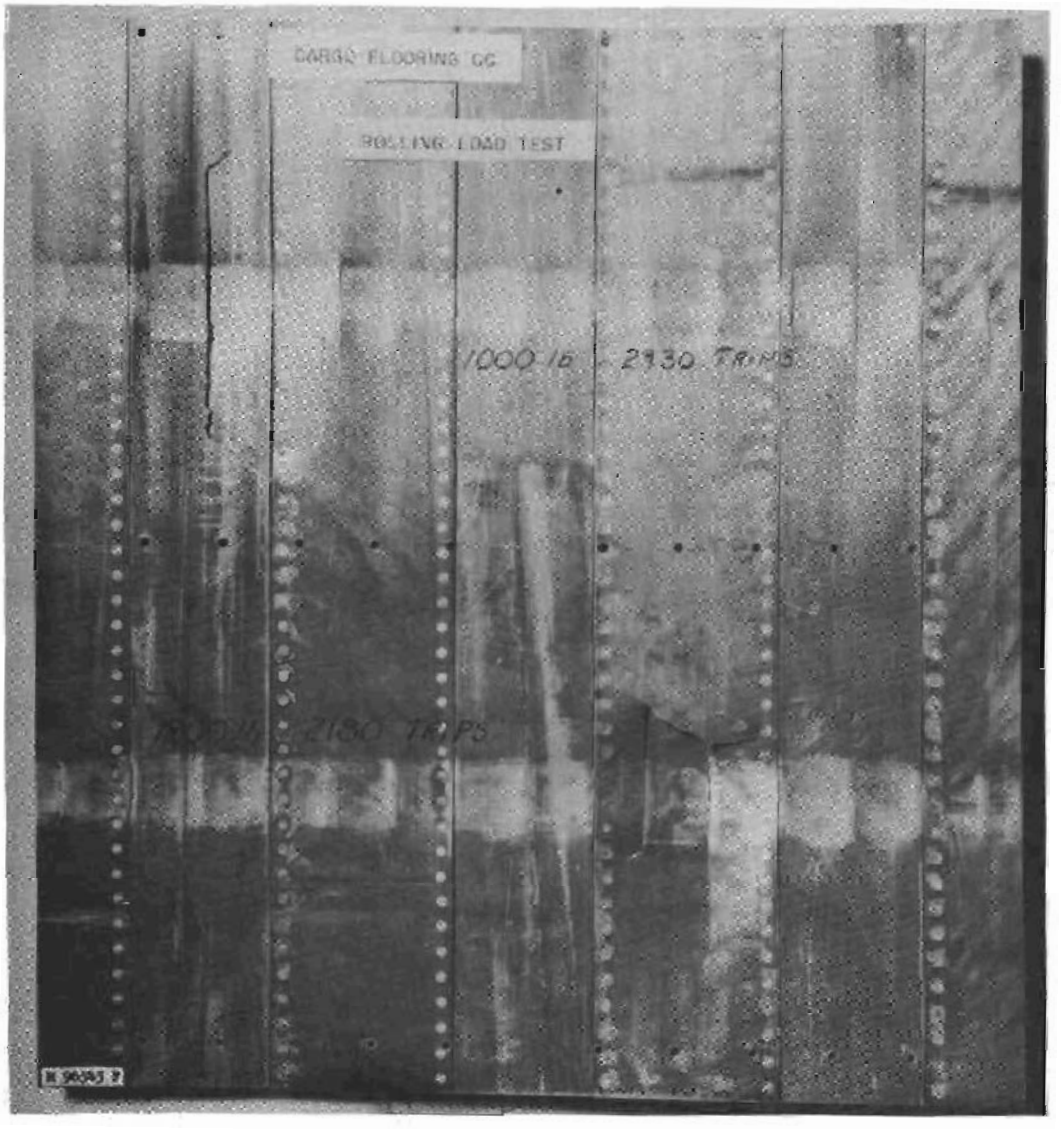


Figure 28.--Cargo flooring CC after rolling load test with wheel paths perpendicular to the webs. Note failures in top flange adjacent to webs. Webs and lower flanges then failed in tension and failures extended to top flange.

ZM 96343 F

Figure 29.--Cargo flooring CD after rolling load test. The upper wheel path was centered between webs and the lower path over a web. Note failures along edges of wheel path and edge of web.

ZM 96336 F

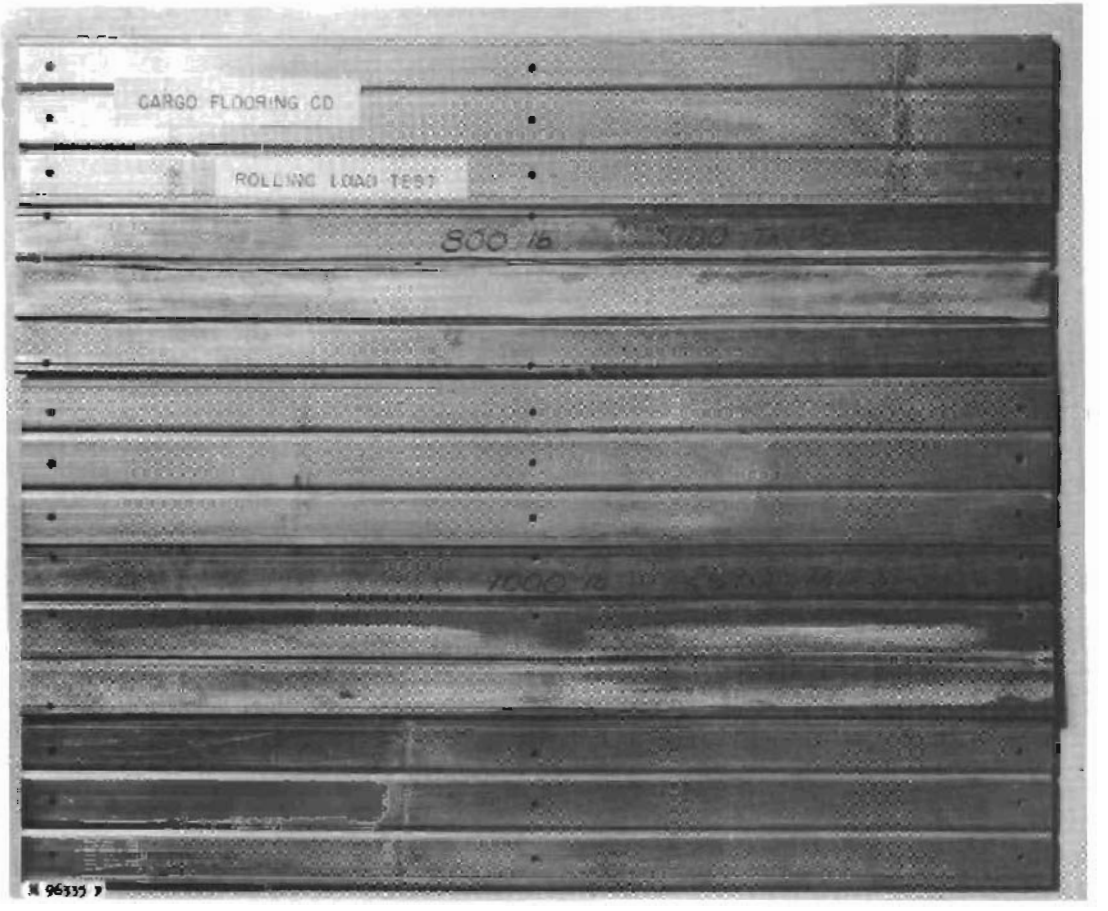


Figure 30.--Cargo flooring CD after rolling load test. The upper wheel path was centered between webs and the lower path over a web. Failures in top surface at edges of wheel path and adjacent to webs.

ZM 96335 F

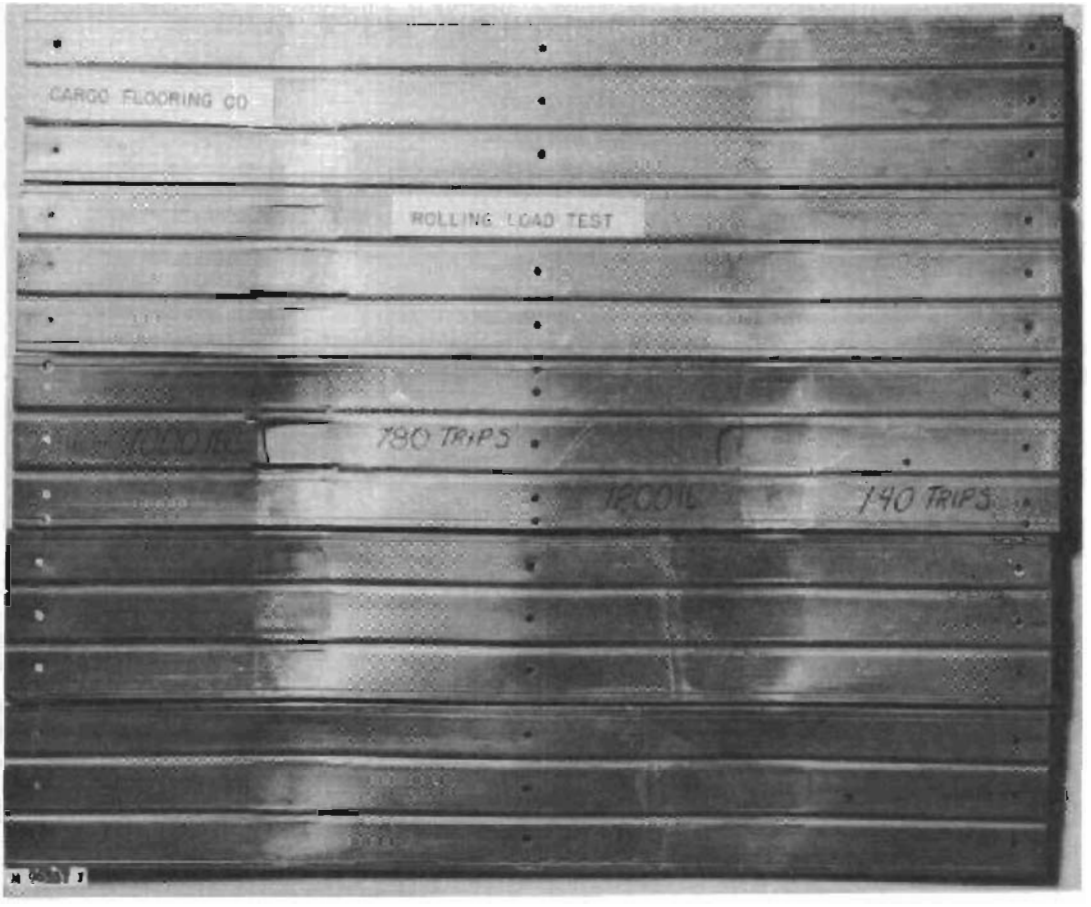


Figure 31.--Cargo flooring CD after rolling load test with wheel path perpendicular to the webs. Failures in top surface adjacent to webs, subsequent failure of webs and lower flanges in tension, with failures extending into top surface.

ZM 96337 F

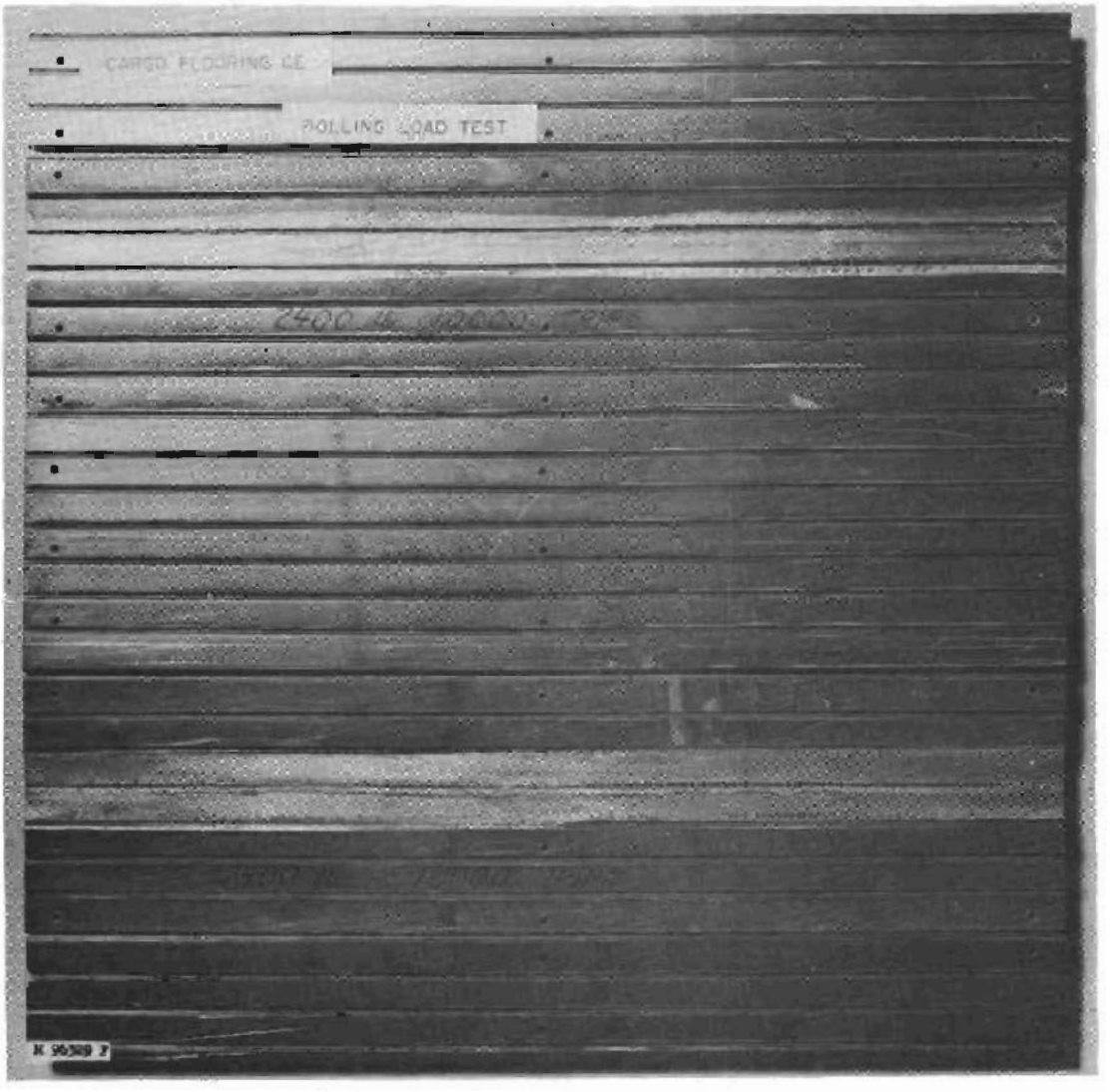


Figure 32.--Cargo flooring CE after rolling load test. The upper wheel path was centered between webs and the lower wheel path over a web. Failure of upper surface along both edges of wheel path and cracks along edge of wheel path, in path centered over a web. Portion of panel carrying wheel path between webs shows wear and some cracks but no complete failure.

ZM 96329 F

Figure 33.--Cargo flooring CE after rolling load test. The upper wheel path was centered between webs and the lower path was centered over a web. Failures in top surface along edges of wheel path and adjacent to webs.

ZM 96330 F

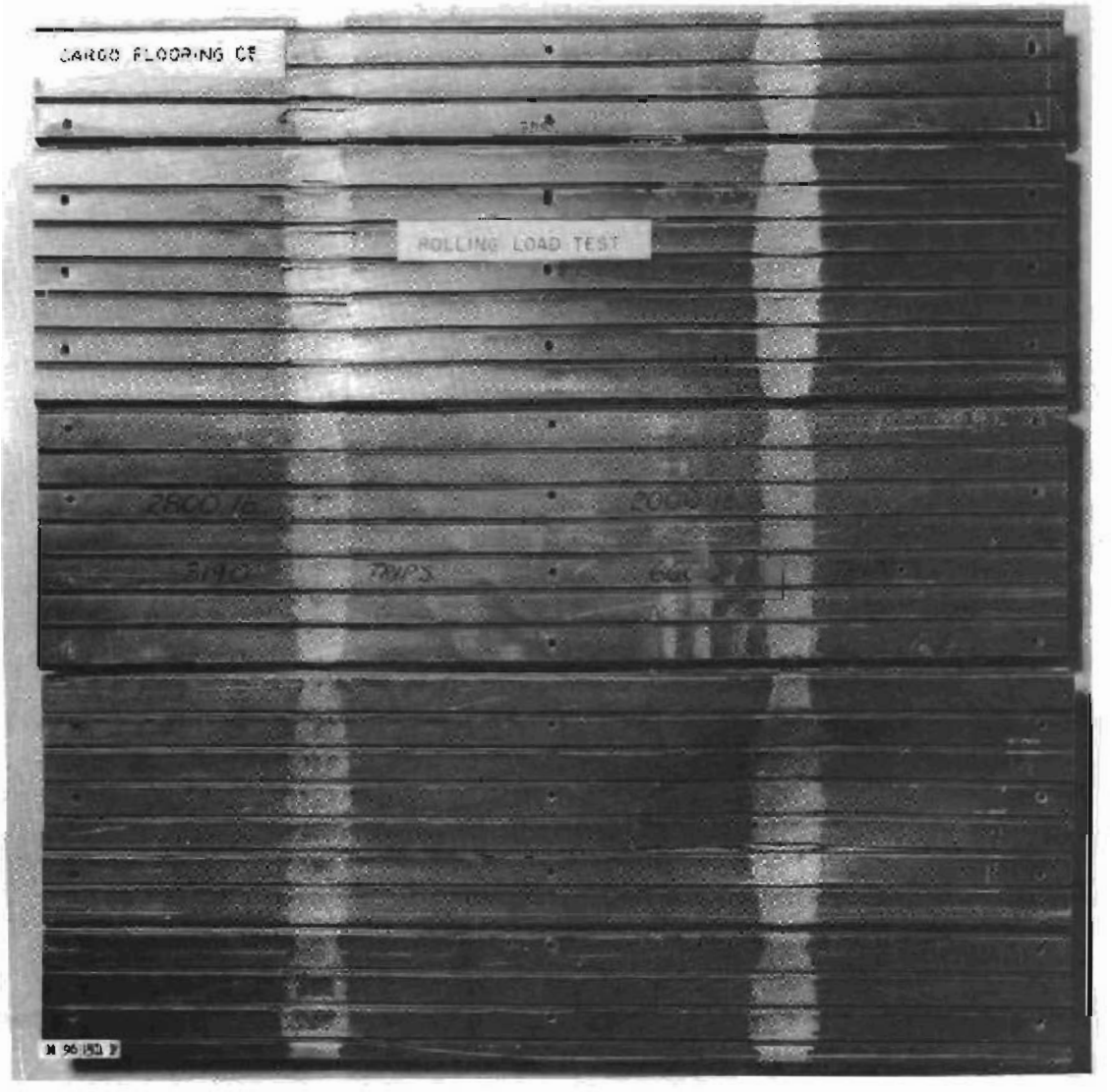


Figure 34.--Cargo flooring CE after rolling load test with wheel path perpendicular to webs. Failures in top surface adjacent to the webs were followed by failure of webs and lower flanges in tension and shear between webs and top surface.

ZM 96331 F