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USATEA Report 66-11

Engineering Report

**PERSHING TRANSPORTABILITY
STUDY**

CONUS Railways, Vol. II of IV

July 1966

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ENGINEERING REPORT

PERSHING TRANSPORTABILITY STUDY,

CONUS Railways

Volume II of IV

July 1966

Prepared by

John H. Grier

U.S. ARMY TRANSPORTATION ENGINEERING AGENCY
Fort Eustis, Virginia

CONTENTS

	<u>Page</u>
LIST OF ILLUSTRATIONS	iii
ABSTRACT	1
I. INTRODUCTION	2
II. OBJECTIVES	3
III. CONCLUSIONS	3
IV. RECOMMENDATIONS	4
V. FIELD EVALUATION	8
VI. TRANSPORTATION ENGINEERING ANALYSES	13
VII. REFERENCES	34
ANNEX--Documentation Tables	35
DISTRIBUTION	

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Distributed Uniform Loading Arrangement for the XM 474, XM 475, and XM 476 Containers	5
2	Vertical Restraint for XM 474, XM 475, and XM 476 Containers	6
3	Savanna Army Depot Drawing No. 5425, Page 9	7
4	Loaded Test Car	9
5	Loaded Test Car	10
6	Schematic of Electronic Instrumentation	12
7	Relative Positioning of Rail Test Equipment	14
8	Test Conditions	15
9	Damaged Blocking	17
10	Complete Failure of Transverse Blocking Member	18
11	Coupler Force Versus Buffer Force on CONUS and Foreign Service Railcars	19
12	Longitudinal Accelerations on Car Floor: CONUS Versus Foreign Service Railcars	20
13	Longitudinal Accelerations on Exterior of XM 475: CONUS Versus Foreign Service Railcars	21
14	Longitudinal Accelerations on Interior Carriage of XM 475: CONUS Versus Foreign Service Railcars.	22
15	Coupler Force Versus Longitudinal Acceleration - Car Floor (Condition A, Figure 8)	25
16	Coupler Force Versus Longitudinal Acceleration - Car Floor (Conditions B and C for Coupler, Condition B for Accelerometer, Figure 8)	26
17	Longitudinal Accelerations - Car Floor and Exterior of XM 475 (Condition A, Figure 8)	27
18	Longitudinal Accelerations - Car Floor and Exterior and Interior Carriage of XM 475 (Condition B, Figure 8)	28

ILLUSTRATIONS (contd)

<u>Figure</u>		<u>Page</u>
19	Vertical Accelerations - Car Floor and Exterior and Interior Carriage of XM 475 (Condition A, Figure 8) .	29
20	Vertical Accelerations - Car Floor and Exterior and Interior Carriage of XM 475 (Condition B, Figure 8) .	30
21	Transverse Accelerations - Car Floor and Exterior and Interior Carriage of XM 475 (Condition A, Figure 8) .	31
22	Transverse Accelerations - Car Floor and Exterior and Interior Carriage of XM 475 (Condition G, Figure 8) .	32
23	Longitudinal and Vertical Accelerations - Exterior of XM 476 (Condition A, Figure 8)	33

ABSTRACT

CONUS railcars were used in conducting railcar impact tests on three research and development containers: the Pershing missile guidance and control section container (XM 474) and the first and second stage motor containers (XM 475 and XM 476). Data from the tests were used to determine scientifically the imposed shocks on the containers and to evaluate the structural adequacy of the tiedown and restraint arrangements when subjected to CONUS railway environments contained in Department of the Army TB 55-100.

The second stage motor container, XM 476, was restrained to the railcar in conformance with Savanna Army Depot Drawing No. 5425, page 9. The guidance and control section and the first stage motor containers, XM 474 and XM 475, were restrained in accordance with the arrangement recommended in USATEA Report 66-11, PERSHING TRANSPORTABILITY STUDY, Foreign Railways, Volume III, dated July 1966.

This study evaluates the two restraint systems to determine which system provided sufficient structural integrity to withstand the CONUS test loadings. It also presents a proposed common restraint system for CONUS and foreign rail environments.

The results of this study demonstrate that the arrangement recommended in USATEA Report 66-11, Volume III, and shown in this report as Figures 1 and 2, satisfactorily withstood the test environments and provided greater structural integrity than the arrangement prescribed in the referenced Savanna Army Depot drawing. It is recommended that this system be adopted for CONUS and foreign railcar movements.

I. INTRODUCTION

During a meeting at Savanna Army Depot, 24-25 June 1965, on "Transportability Criteria", engineers of various Army commands and agencies reviewed problems encountered in the movement worldwide of the Pershing missile system. As a result of this meeting and subsequent meetings, a program to conduct a scientific "Transportability Study on Movement Worldwide of the Pershing Missile System" was prepared (Reference 2). The purpose of this program is to establish transportability criteria that will serve as a basis for the development of movement standards and procedures.

A meeting was held in the Office of the Deputy Chief of Staff for Logistics, Transportation Engineering Office (DCSLOG/TENO), 21-22 September 1965, to review, coordinate, and approve the study. Participating agencies included representatives of DCSLOG/TENO; U.S. Army Materiel Command (USAMC); U.S. Army Supply and Maintenance Command (USASMC); Military Traffic Management and Terminal Service (MTMTS); Headquarters, Eastern Area, Military Traffic Management and Terminal Service (HQ, EAMTMTS); U.S. Army Missile Command (USAMICOM); and the U.S. Army Transportation Engineering Agency (USATEA). Approval was obtained and USATEA was instructed to conduct the transportability study.

This report presents the results of the CONUS railways study, which is Volume II of the PERSHING TRANSPORTABILITY STUDY. Other reports on the PERSHING TRANSPORTABILITY STUDY include Volume I, Calculations and Analysis of Railway Tests; Volume III, Foreign Railways; and Volume IV, Vessel Stowage.

II. OBJECTIVES

1. To develop transportability criteria factors pertinent to CONUS rail movement of Pershing missile motors and guidance units.
2. To evaluate restraining and tiedown arrangements for Pershing missile motors and guidance units subjected to railcar impacts.
3. To establish a standard tiedown arrangement for Pershing missile system containers XM 474, XM 475, and XM 476 that will provide an effective means of restraint for both CONUS and foreign railcar movements.

III. CONCLUSIONS

1. Mechanical differences between the impact of foreign service railcars and CONUS railcars are great enough to warrant special design considerations, as evidenced by the following test data:

LONGITUDINAL ACCELERATION

Location	Speed (mph)	CONUS Rail		Foreign Rail	
		Ampl.	Dura.	Ampli.	Dura.
Car Floor	8	21.7g	20-70 ms	49.8g	8-25 ms
Exterior Container XM 475	8	16.3g	25-65 ms	19.5g	18-45 ms
Interior Carriage XM 475	8	15.3g	24-170 ms	16.8g	20-60 ms
Coupler Impact Force	8	739 kips	116 ms	588 kips	8-40 ms

2. The restraining arrangement used on the XM 476 container (Figure 3) failed at an impact velocity of 8.9 miles per hour; consequently, the arrangement does not meet the requirements of paragraph 4, TB 55-100.
3. The restraining arrangement illustrated in Figures 1 and 2 provides a better distribution of loads consequent to railcar impacts. This improvement makes the Figures 1 and 2 arrangement substantially safer than the Figure 3 arrangement.
4. The restraining arrangement used on the XM 475 container (Figures 1 and 2) has adequate structural integrity to resist longitudinal shock forces of up to 26.2g at 40 milliseconds at an impact velocity of 10.7 miles per hour.

5. The restraining arrangement used on the XM 474 and XM 475 containers (Figures 1 and 2) is in conformance with the requirements of TB 55-100.
6. The cushioning between the cargo and the container produces substantial shock attenuation in the vertical and transverse directions and minor shock attenuation in the longitudinal direction.

IV. RECOMMENDATIONS

1. That in the design of Army materiel which will be shipped on foreign service railcars, consideration be given to the imposed shock and vibration environment.
2. That the distributed uniform loading arrangement illustrated in Figures 1 and 2 be the preferred means of restraint of Pershing missile containers XM 474, XM 475, and XM 476 for CONUS rail shipment.
3. That the distributed uniform loading arrangement illustrated in Figures 1 and 2 be standardized and used for both CONUS and foreign rail shipment of Pershing missile containers XM 474, XM 475, and XM 476.

NOTES

1. Blocking material will consist of hardwood, spruce, fir, larch, hemlock or dense southern yellow pine of the following species: long-leaf, slash and/or loblolly, straight grained, free from decay and strength impairing knots.
2. Blocking is X-hatched. All doubled 2x6s except 2x4 filler, 30d nails bottom piece, 60d top piece, 6" C.C.

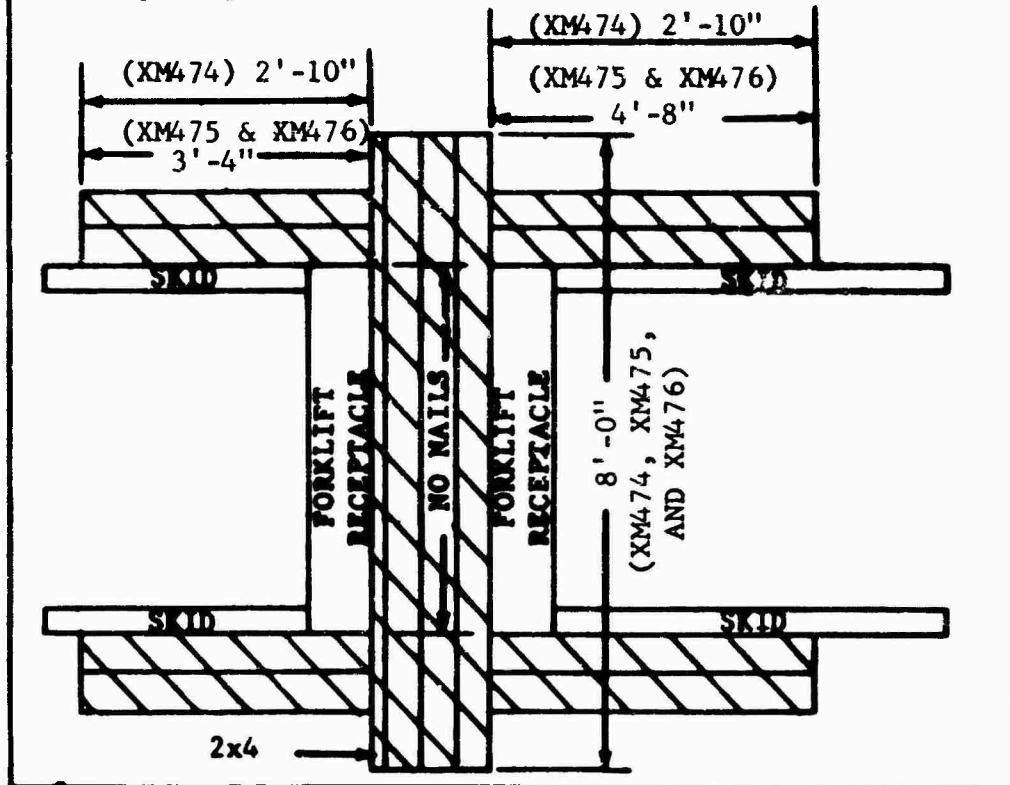


Figure 1. Distributed Uniform Loading Arrangement for the XM 474, XM 475, and XM 476 Containers.

NOTES

1. Only two steel straps are required for the XM 474.
2. 2"x.05" steel strapping, doubled. Seal lap joint with two seals, two crimps per seal; provide anti-chafing material (canvas) at all points of contact with container; protect all straps at bottom of stake pockets with 12- to 16-gage sheet metal, or equivalent.

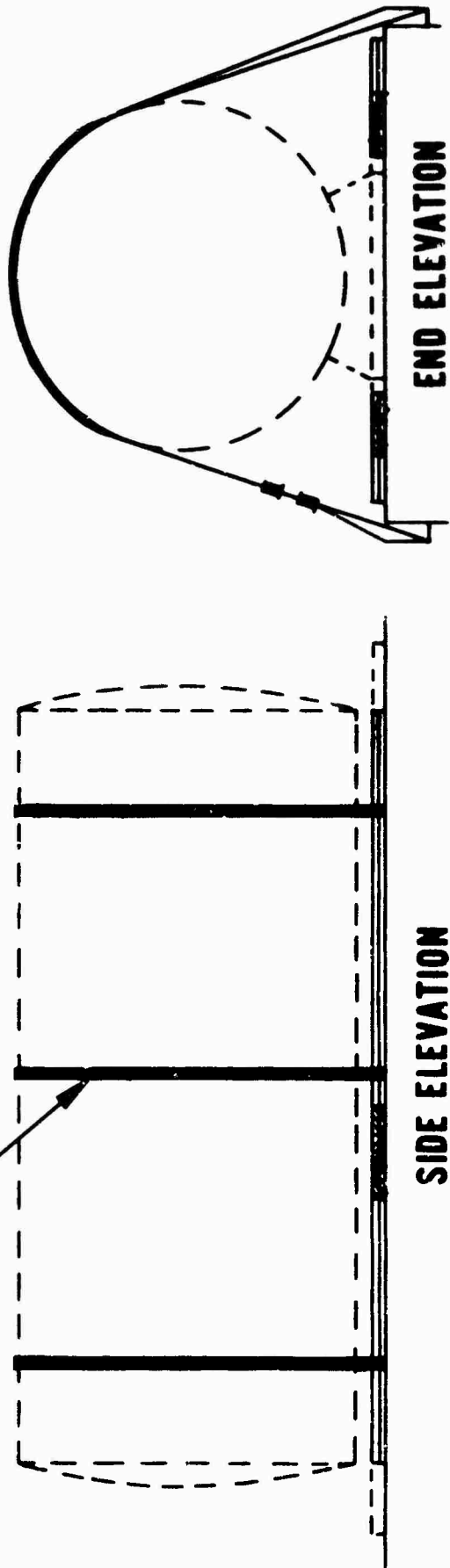


Figure 2. Vertical Restraint for XM 474, XM 475, and XM 476 Containers.

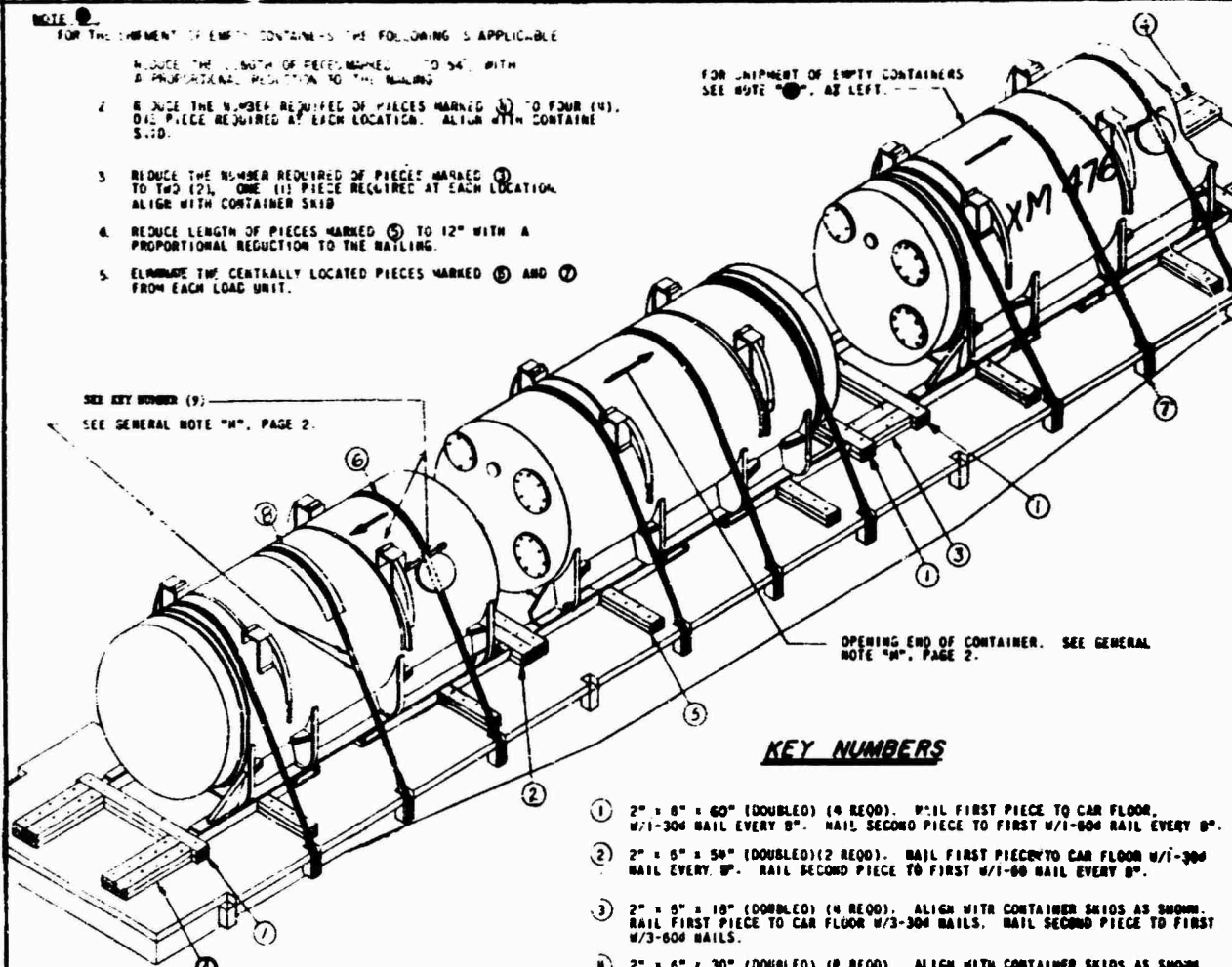
NOTE

FOR THE SHIPMENT OF EMPTY CONTAINERS THE FOLLOWING IS APPLICABLE

1. REDUCE THE LENGTH OF PIECES MARKED (1) TO 54" WITH A PROPORTIONAL REDUCTION TO THE NAILING.
2. REDUCE THE NUMBER REQUIRED OF PIECES MARKED (2) TO FOUR (4). ONE (1) PIECE REQUIRED AT EACH LOCATION. ALIGN WITH CONTAINER SKID.
3. REDUCE THE NUMBER REQUIRED OF PIECES MARKED (3) TO TWO (2). ONE (1) PIECE REQUIRED AT EACH LOCATION. ALIGN WITH CONTAINER SKID.
4. REDUCE LENGTH OF PIECES MARKED (5) TO 12" WITH A PROPORTIONAL REDUCTION TO THE NAILING.
5. ELIMINATE THE CENTRALLY LOCATED PIECES MARKED (6) AND (7) FROM EACH LOAD UNIT.

FOR SHIPMENT OF EMPTY CONTAINERS
SEE NOTE "M", AS LEFT.

SEE KEY NUMBER (9)
SEE GENERAL NOTE "M", PAGE 2.



ISOMETRIC VIEW

KEY NUMBERS

- (1) 2" x 6" x 60" (DOUBLED) (4 REQD). NAIL FIRST PIECE TO CAR FLOOR W/1-304 NAIL EVERY 8". NAIL SECOND PIECE TO FIRST W/1-604 NAIL EVERY 8".
- (2) 2" x 6" x 54" (DOUBLED) (2 REQD). NAIL FIRST PIECE TO CAR FLOOR W/1-304 NAIL EVERY 8". NAIL SECOND PIECE TO FIRST W/1-604 NAIL EVERY 8".
- (3) 2" x 6" x 18" (DOUBLED) (4 REQD). ALIGN WITH CONTAINER SKIDS AS SHOWN. NAIL FIRST PIECE TO CAR FLOOR W/3-304 NAILS. NAIL SECOND PIECE TO FIRST W/3-604 NAILS.
- (4) 2" x 6" x 30" (DOUBLED) (8 REQD). ALIGN WITH CONTAINER SKIDS AS SHOWN. NAIL FIRST PIECE TO CAR FLOOR W/5-304 NAILS. NAIL SECOND PIECE TO FIRST W/5-604 NAILS.
- (5) 2" x 6" x 24" (DOUBLED) (12 REQD). NAIL FIRST PIECE TO CAR FLOOR W/4-304 NAILS. NAIL SECOND PIECE TO FIRST IN LIKE MANNER.
- (6) STRAPPING, STEEL, 2" x .050" x 24'-0" (9 REQD). SEE GENERAL NOTE "J", PAGE 2.
- (7) PAD, 2" x .050" STRAP 24" LONG (18 REQD). POSITION UNDER AND SEAL TO (6). SEE DETAIL "A", PAGE 2.
ALT: STAKE POCKET PROTECTORS (36 REQD). TWO (2) USED UNDER EACH STAKE POCKET WITH (6). SEE DETAIL "B", PAGE 2.
- (8) ANTI-CHAFING, NEUTRAL BARRIER MATERIAL. PLACE UNDER STRAPPING AT ALL POINTS OF CONTACT WITH CONTAINERS.
- (9) STRAPPING, "KEY NUMBER (6)," WILL BE PLACED UNDER THE SAND SHOE BRACKET OR BETWEEN SAND SHOE BRACKET AND THE STACKING PADS TO ALIGN CORRECTLY WITH STAKE POCKETS OF THE CAR.

BILL OF MATERIAL

LUMBER	LINEAL FEET	BOARD FEET
2" x 6"	158	158
NAILS	NO. REQD	POUNDS
30s (4-1/2")	190	9-3/4
50s (6")	94	9-1/2
STRAPPING, STEEL, 2" x .050" - - - -252' REQD - - - 84 LBS		
ANTI-CHAFING MATERIAL - - - - -45 REQD		

LOAD AS SHOWN

ITEM	QUANTITY	WEIGHT (APPROX)
MOTOR, FIRST STAGE	3	27,579 LBS
DUNNAGE		499 LBS
TOTAL WEIGHT		28,078 LBS (APPROX)

46'-6" LONG X 8'-6" WIDE FLAT CAR

Figure 3. Savanna Army Depot Drawing No. 5425, Page 9.

V. FIELD EVALUATION

GENERAL

Loading and restraining arrangements developed for the shipment of Pershing missile system containers XM 474, XM 475, and XM 476 on CONUS railcars are incorporated in a series of Savanna Army Depot drawings. As part of a joint DCSLOG/TENO, USAMC, and USAMICOM program to conduct a "Transportability Study on Movement Worldwide of the Pershing Missile System" (Reference 2), these arrangements for restraining the containers were evaluated under the foreign railway study, the results of which are reported in Volume III of the PERSHING TRANSPORTABILITY STUDY (Reference 4). The report concluded that one of the tiedown arrangements, combined with container construction differences, results in overloading the skid bolts (when the skid is not abutted against the forklift receptacles), with consequent failure during railcar impacts of 6- to 7-mile-per-hour velocity. To overcome this deficiency, a modified restraining arrangement was developed during the study. The report recommended that the modified arrangement, referred to as the "Distributed Uniform Loading Arrangement", be adopted for foreign railway movement and that the arrangement be further evaluated for CONUS railway movement.

Consequently, the CONUS railway study was expanded to evaluate scientifically one of the restraining procedures shown in Savanna Army Depot Drawing No. 5425 and the modified arrangement under CONUS railway environments. Also, the study would evaluate the possibility of establishing a common restraint arrangement for CONUS and foreign rail movement.

DESCRIPTION OF EQUIPMENT

Three research and development containers, an XM 474, XM 475, and XM 476, were used in the study. Figure 4 shows the containers loaded on one of the test cars. Other Pershing missile containers have a similar geometry and construction; therefore, the results of the study are equally applicable to them, except for correlating the spring constants between the R&D container and the production model.

The test car (struck car) used for the impacts under Conditions A, B, and C were U.S. Army flatcars, 80-ton, 12-wheel (Figure 4). For impacts under Conditions D and E, a U.S. Army flatcar, 50-ton, 8-wheel, was used (Figure 5).

A U.S. Army hopper car, 70-ton, 8-wheel, loaded to a gross weight of 169,000 pounds was used as the hammer car in all the impact tests.

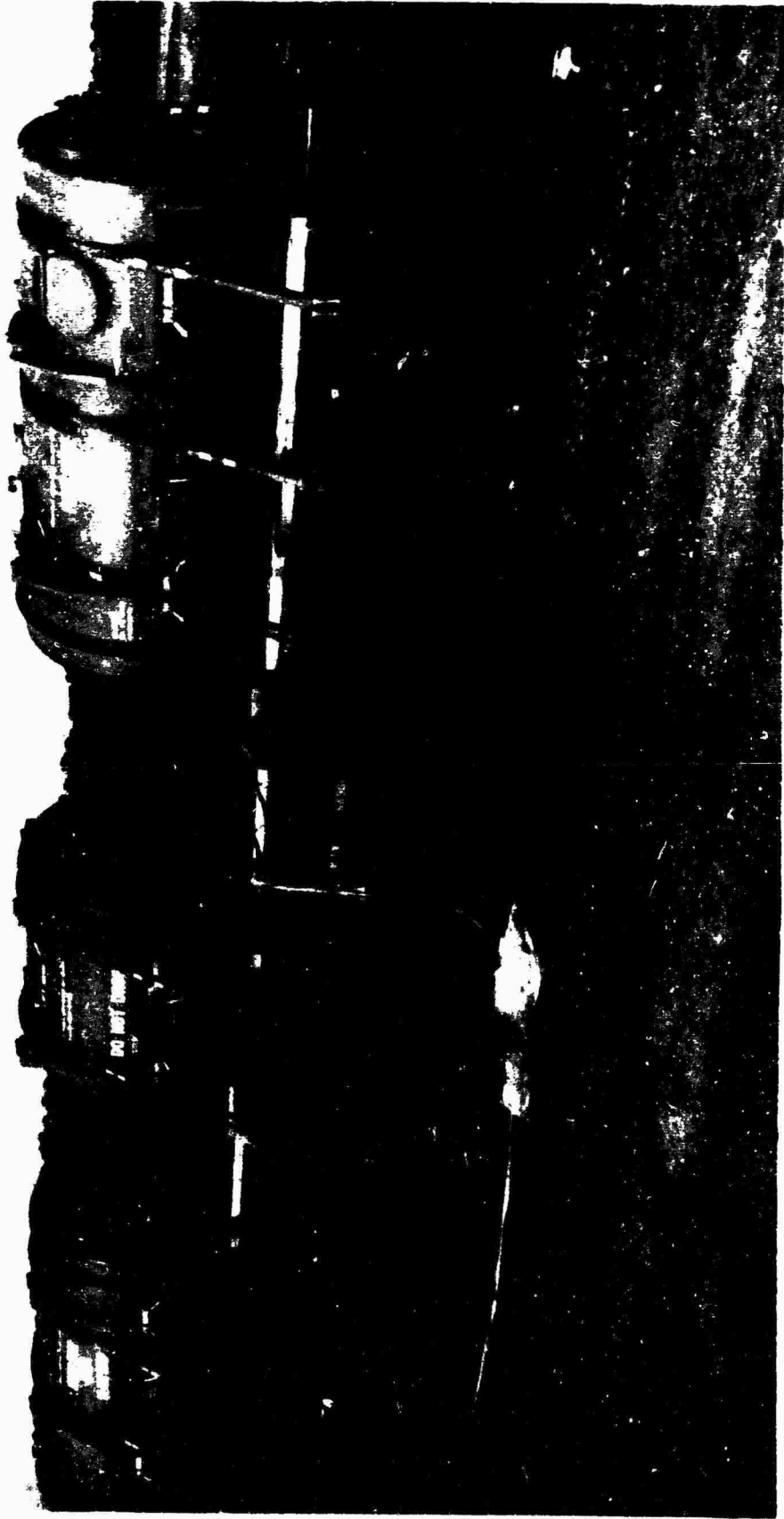


Figure 4. Loaded Test Car.



Figure 5. Loaded Test Car.

INSTRUMENTATION

The electronic instrumentation for the XM 475 and XM 476 containers is illustrated in Figure 6. The XM 474 was not instrumented. A dynamometer coupler was used for measuring impact forces into the transport system.

Electronic instrumentation consisted of strain gage accelerometers having a frequency response of from 0 to 280 cycles per second, and an automatic electrical recording system.

Accelerometers oriented to measure accelerations in the longitudinal, vertical, and transverse planes were located on the exterior and interior carriage structures of the XM 475 container and also on the car floor adjacent to the container. Accelerometers oriented in the longitudinal and vertical planes were located on the exterior of the XM 476. An electrically operated program time switch was used to measure the exact velocity of the hammer car at impact.

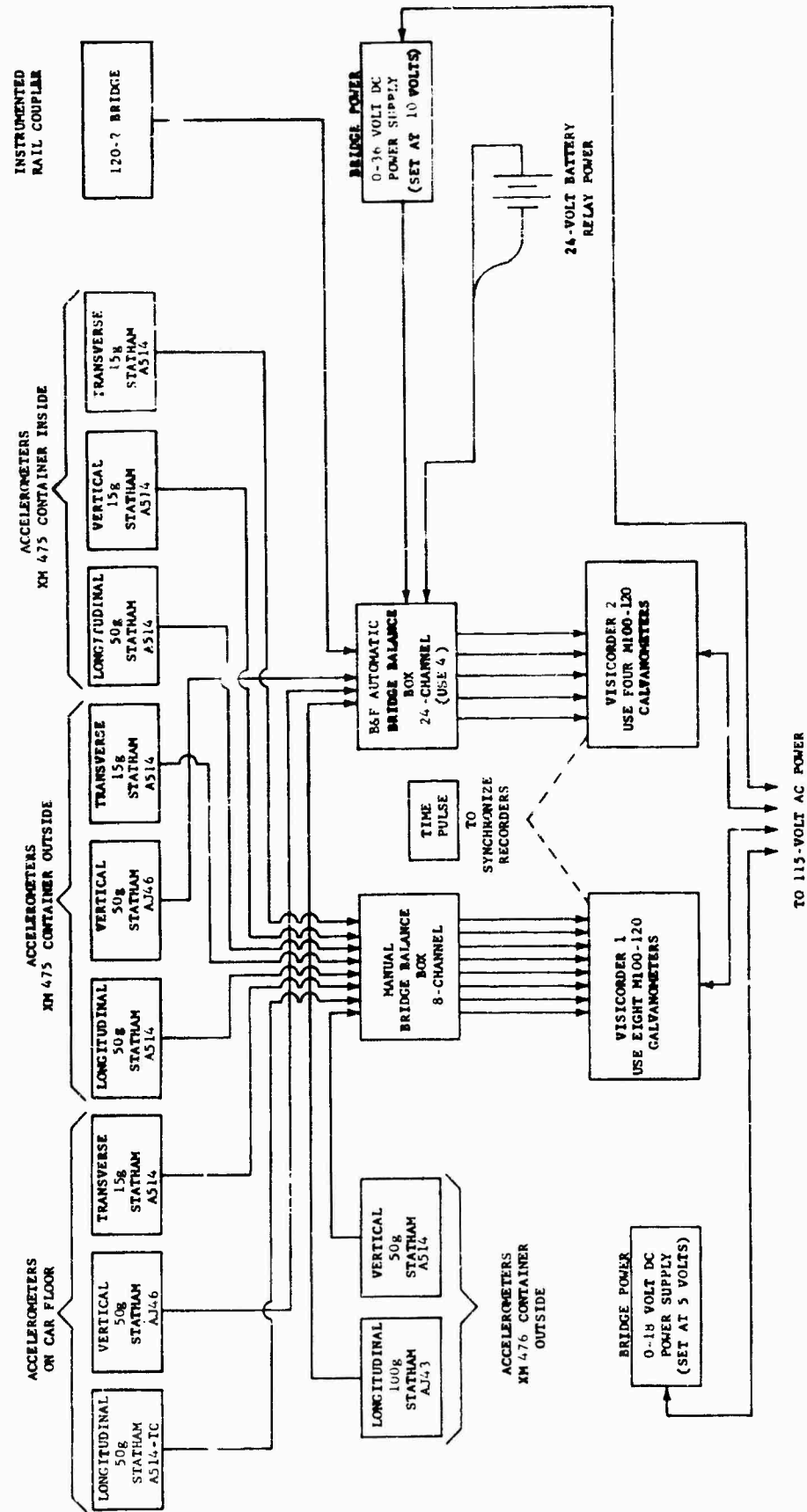


Figure 6. Schematic of Electronic Instrumentation.

VI. TRANSPORTATION ENGINEERING ANALYSES

RAIL IMPACT PROCEDURES

Prior to the test, the containers were examined to determine the extent of damage to forklift receptacles, skids, and skid bolts.

Damage to the forklift receptacles that occurred on the XM 476 container during the vessel stowage static study was repaired, damaged skid bolts were replaced, and all skids were abutted against the forklift receptacles.

The XM 474 and XM 475 containers were restrained in accordance with the distributed uniform loading arrangement (Figures 1 and 2). The XM 474 and XM 476 containers were restrained in accordance with Savanna Army Depot Drawing No. 5425 (Figure 3).

Figure 7 shows the relative positioning of the test equipment (hammer car, test car, and backup cars) for the railcar impacts. The following test conditions were set up (1) to obtain environmental data over a wide range of impact velocities (Conditions A, B, and C), and (2) to evaluate the uniform distributed loading arrangement in accordance with the environment specified in paragraph 4, TB 55-100 (Conditions D and E). The test conditions, illustrated in Figure 8, are described as follows:

Condition A -- All three containers loaded on the test car, with the XM 475 container on the impacted end.

Condition B -- The XM 475 container on the test car, on the impacted end.

Condition C -- The XM 475 container on the test car, on the end opposite the impacted end.

Condition D -- The XM 474 and XM 475 containers, one on each end of the car, with the XM 475 on the impacted end.

Condition F -- The XM 474 and XM 475 containers, one on each end of the car, with the XM 474 on the impacted end.

During the study, 31 railcar impacts were performed at impact velocities varying from 3.4 to 11.3 miles per hour.

RAIL IMPACT RESULTS

Container Restraint Arrangements

Condition A. The restraining system used on the XM 476 container (illustrated in Savanna Army Depot Drawing, Figure 3) did not sustain the applied dynamic loadings. At an impact velocity of 8.9 miles per hour, the transverse blocking member was severely crushed by the ends



Figure 7. Relative Positioning of Rail Test Equipment.



CONDITION A



CONDITION B



CONDITION C



CONDITION D



CONDITION E

Figure 8. Test Conditions.

of the container skids. The damage is illustrated in Figure 9. During the following impact, at 10.4 miles per hour, the member failed completely (Figure 10). There was no apparent damage to the container skids.

Prior to the failure, the restraining arrangement used on the XM 476 container sustained eight impacts varying in impact velocity from 3.5 to 8 miles per hour.

The restraining arrangement used on the XM 474 container (illustrated in Savanna Army Depot Drawing, Figure 3) and on the XM 475 container (exhibited in Figures 1 and 2) sustained the applied dynamic loadings resulting from the impacts without any apparent damage.

Conditions B and C. The restraining arrangement used on the XM 475 container (exhibited in Figures 1 and 2) sustained the applied dynamic loadings resulting from the impacts without any apparent damage.

Conditions D and E. The restraining arrangement used on the XM 474 and XM 475 containers (exhibited in Figures 1 and 2) sustained the applied dynamic loadings resulting from the impacts without any apparent damage.

The XM 476 container is similar in geometry and construction to the XM 475 container; consequently, the restraining arrangement used on the XM 475 (Figures 1 and 2) is applicable to the XM 476.

Transport System

Figure 11 is a comparison of the input forces (coupler force in the CONUS railcar test versus buffer forces in the foreign railcar test). At impact velocities up to 5.5 miles per hour, the curves are similar; above 5.5 miles per hour, the coupler force curve (CONUS test) rises at a much more rapid rate. This rise is due to the greater gross weight of the CONUS test car.

A comparison of the longitudinal peak accelerations on the car floor and on the exterior and interior of the containers (CONUS test versus foreign test) (Figures 12 through 14) shows that accelerations were greater on the foreign railcar. The car floor accelerations were more than twice as great. The accelerations on the exterior and interior of the XM 475 container were significantly higher. The higher accelerations on the foreign railcar are due to its relatively light weight. (There is not as much mass to absorb the energy developed as a result of the impact.) A comparison of the vertical and transverse accelerations revealed similar results.

The transportability criteria resulting from the railcar impacts are the maximum recorded peak values. All recorded peak values are contained in Tables 1 through 9. As indicated in these tables, the maximum recorded values usually occur at the impacted end of the test car; therefore, correlation of the results will be made from the values recorded at the impacted end.



Figure 9. Damaged Blocking.

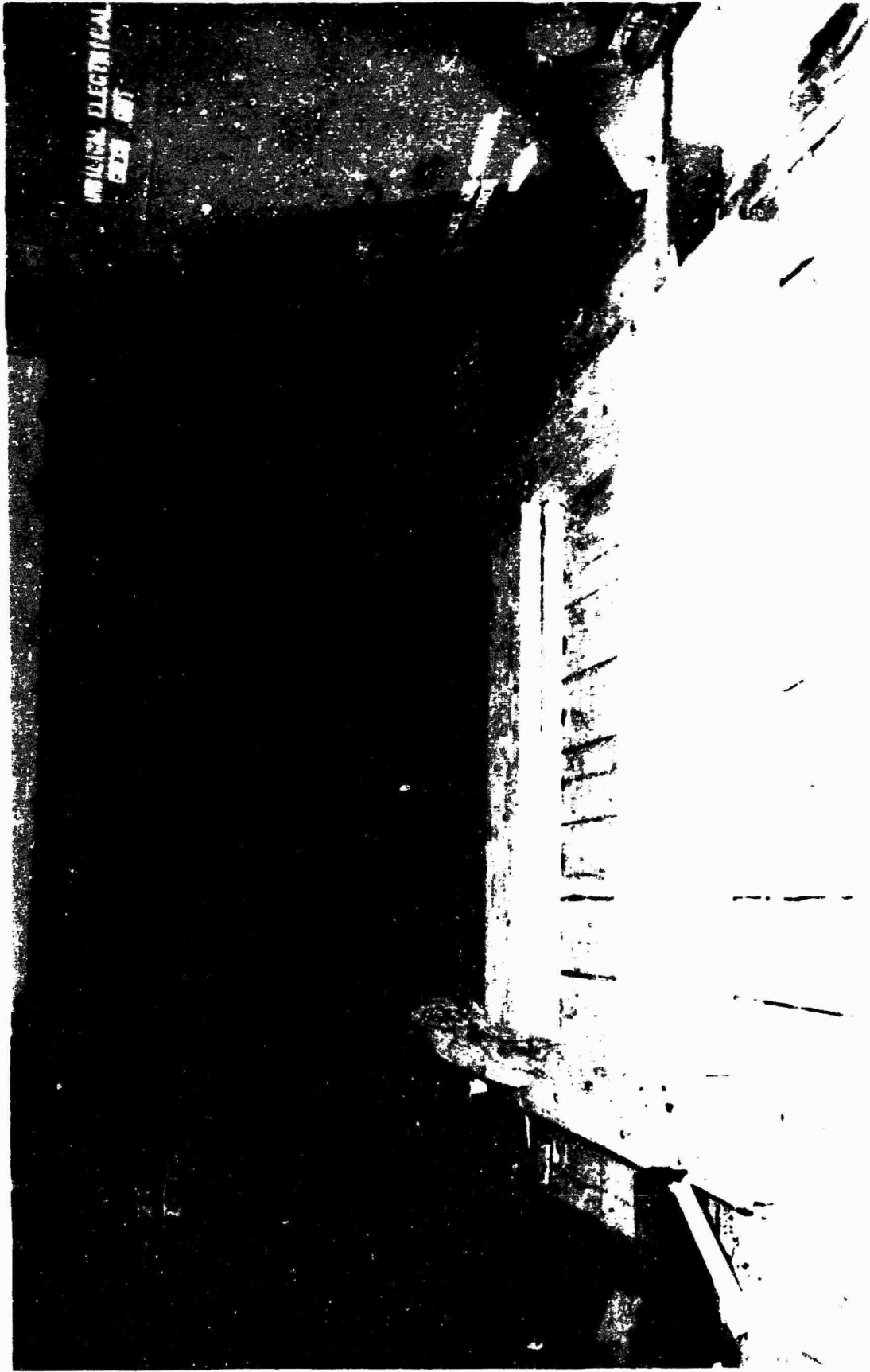


Figure 10. Complete Failure of Transverse Blocking Member.

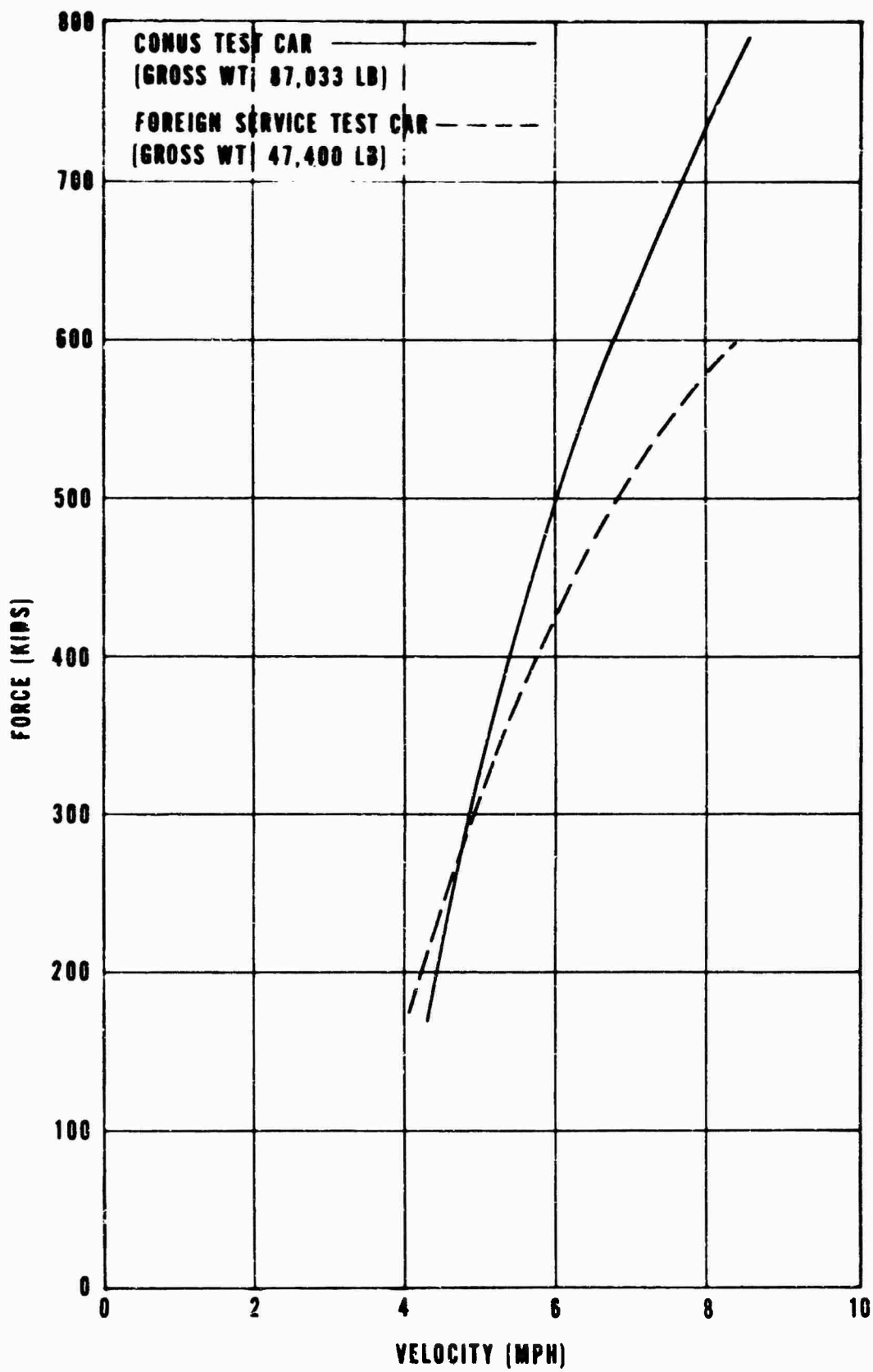


Figure 11. Coupler Force Versus Buffer Force on CONUS and Foreign Service Railcars.

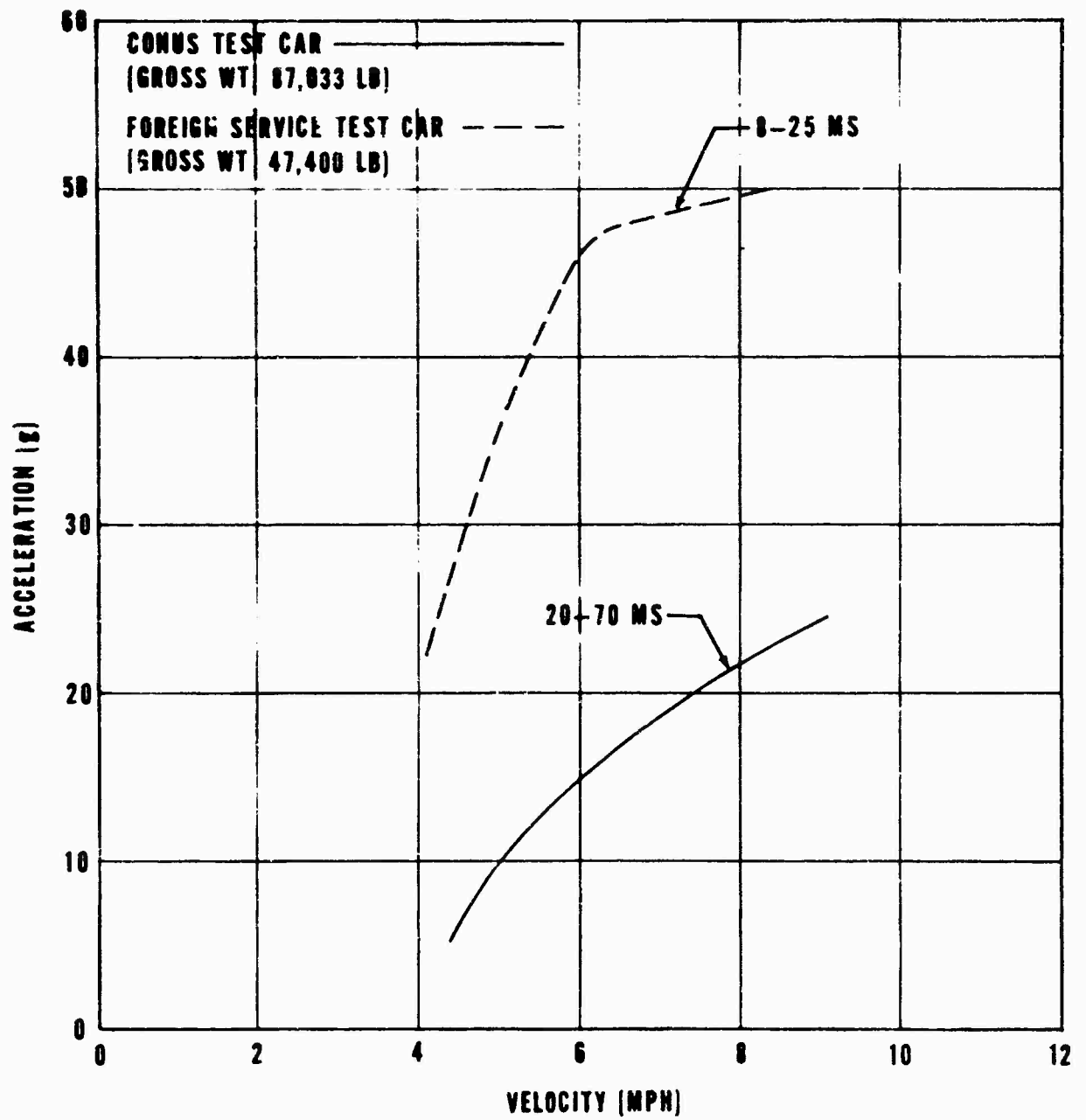


Figure 12. Longitudinal Accelerations on Car Floor:
CONUS Versus Foreign Service Railcars.

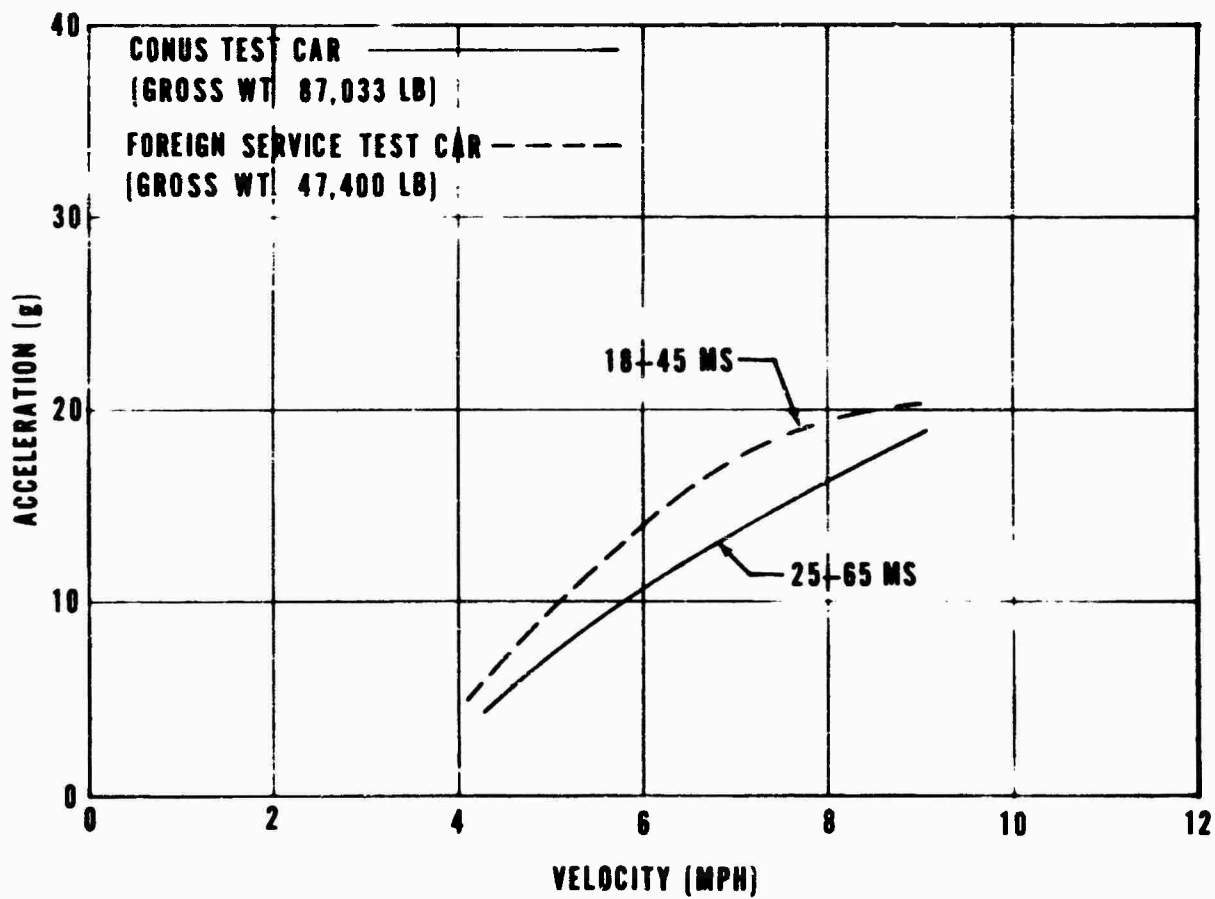


Figure 13. Longitudinal Accelerations on Exterior of XM 475: CONUS Versus Foreign Service Railcars.

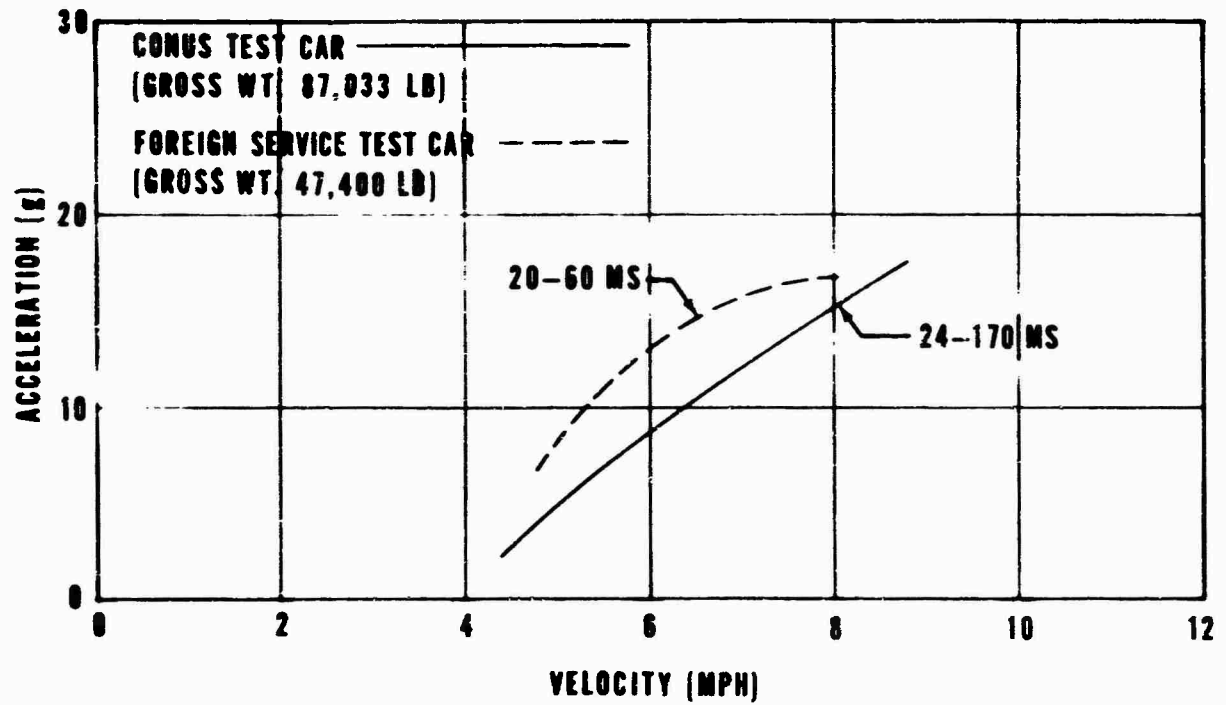


Figure 14. Longitudinal Accelerations on Interior of XM 475: CONUS Versus Foreign Service Railcars.

The coupler force for the various impacts is presented graphically in Figures 15 and 16. Also, correlation is made between coupler force and the recorded car floor longitudinal accelerations.

The longitudinal, vertical, and transverse peak values recorded on the XM 475 container, exterior and interior, during Conditions A and B are compared in Figures 17 through 22. Figures 17 and 18 indicate that longitudinal responses of the container, exterior and interior, are similar up to about a 6-mile-per-hour impact velocity. Above that velocity, the carriage suspension system provides only a small gain in shock attenuation up to impact velocities of 8.5 miles per hour. However, Figures 19 through 22 show that the carriage suspension system does effectively attenuate the imposed vertical and transverse accelerations.

The recorded peak values on the XM 476 container during Condition A cannot be compared to the values obtained on the XM 475, since failure of the end blocking began at the 8-mile-per-hour impact. The recorded values would have been higher if the blocking failure had not attenuated the shock force, as is evident from the longitudinal curve in Figure 23.

TRANSPORT SYSTEM ANALYSES

Container Shock Mounting System

The interior carriage structure is mounted on a three-degree-of-freedom shock-absorbing system. A comparison of peak-response values on the exterior and interior of the XM 475 showed that maximum attenuation occurred in the vertical and transverse planes and that attenuation in the longitudinal plane was relatively small.

Container Restraint Arrangements

Of the two types of restraining arrangements evaluated, the arrangement shown in Figures 1 and 2 provides greater structural integrity since longitudinal loads are transmitted to the base structure through the fork-lift receptacles rather than through the skids which are inherently weak; also, the bearing area (provided to resist longitudinal forces) in the arrangement illustrated in Figures 1 and 2 is 4.5 times greater than in the arrangement which failed. This larger bearing area, in effect, reduces the unit stresses on the timber blocking by 78 percent.

Recommended Restraining Arrangement

The restraining arrangement shown in Figures 1 and 2 is applicable to the XM 474, XM 475, and XM 476 containers. In addition to replacing the many arrangements depicted in Savanna Army Depot Drawing No. 5425, it offers other significant advantages, as follows:

1. Prepositioning of the transverse blocking is not required, since no nails are required under the container.

2. Less longitudinal space on the car is required.
3. The longitudinal blocking members also provide transverse restraint, which simplifies the arrangement.

In view of its simplicity and the other advantages enumerated, the restraining arrangement illustrated in Figures 1 and 2 is recommended for shipment of the XM 474, XM 475, and XM 476 containers on both CONUS and foreign service railcars.

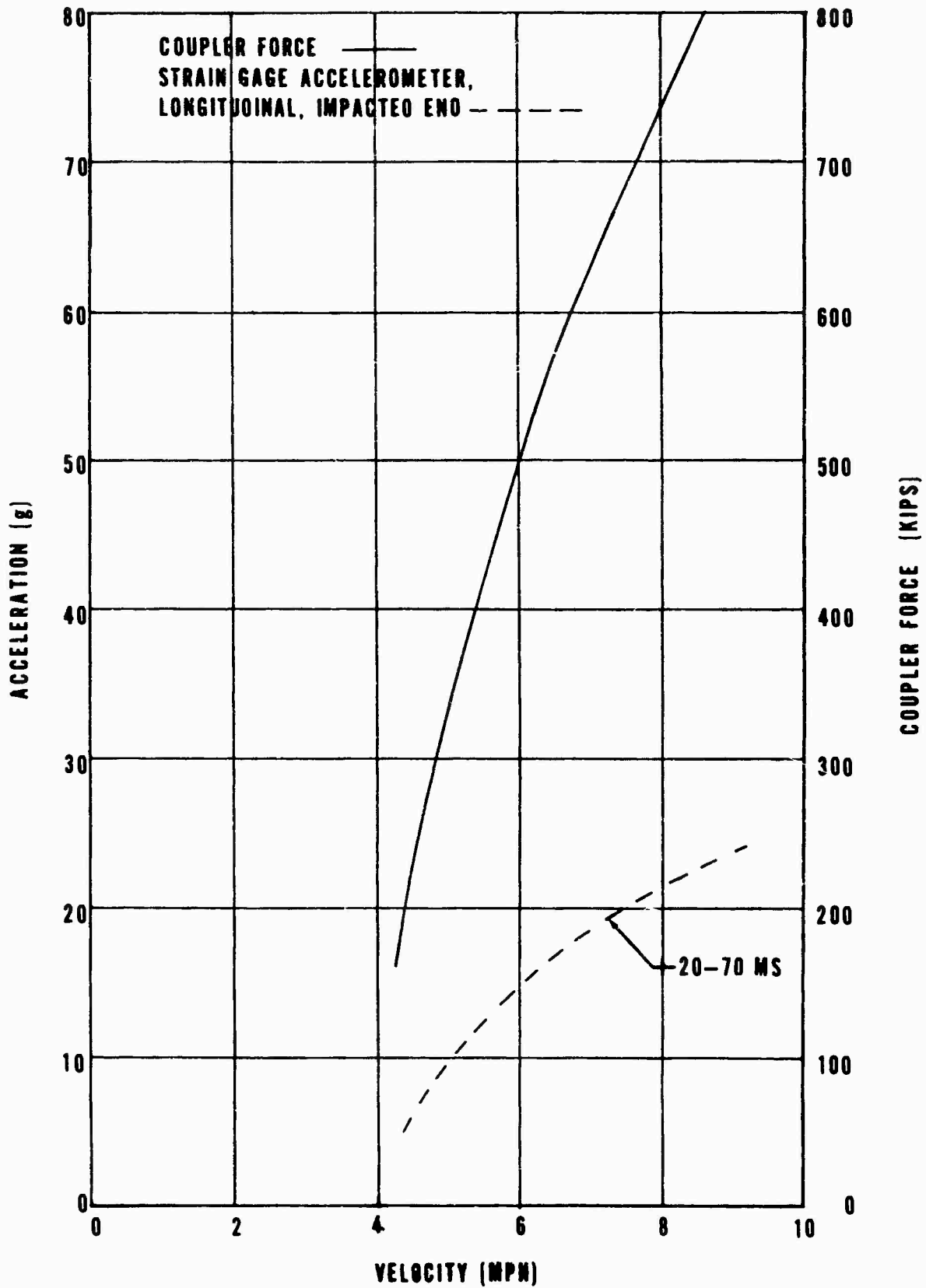


Figure 15. Coupler Force Versus Longitudinal Acceleration - Car Floor (Condition A, Figure 8).

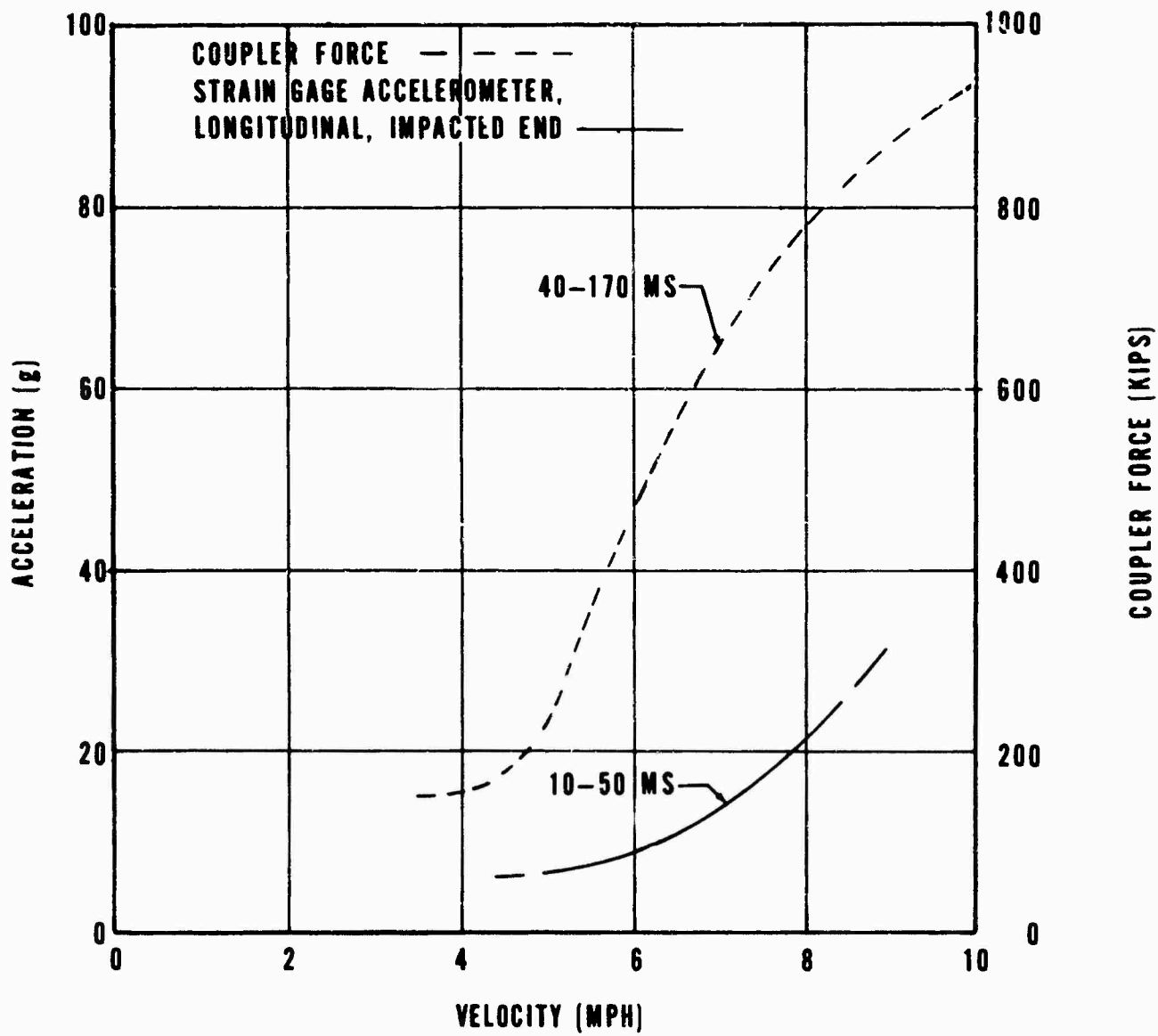


Figure 16. Coupler Force Versus Longitudinal Acceleration - Car Floor
 (Conditions B and C for Coupler, Condition B for
 Accelerometer, Figure 8.)

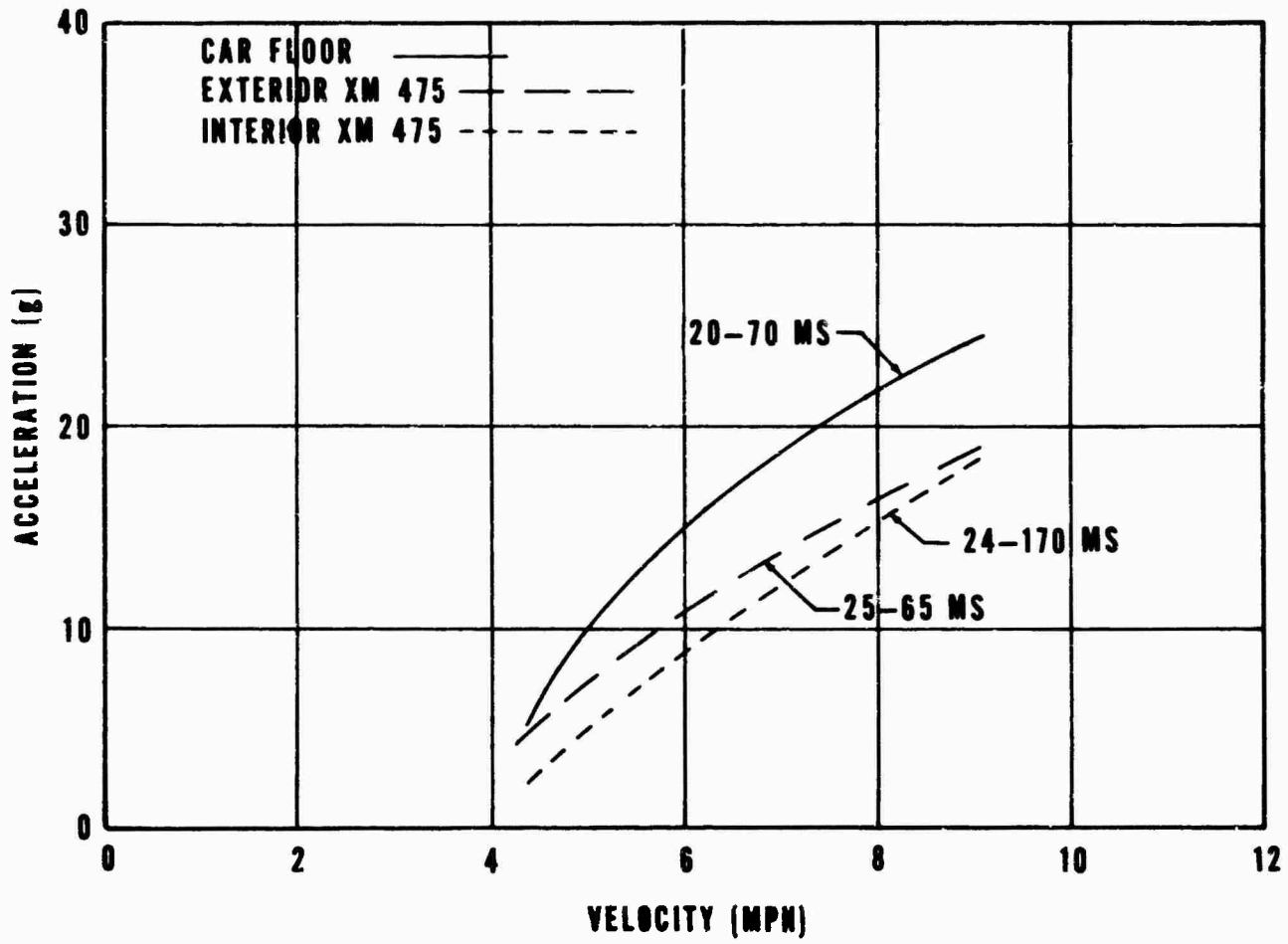


Figure 17. Longitudinal Accelerations - Car Floor and Exterior and Interior of XM 475 (Condition A, Figure 8).

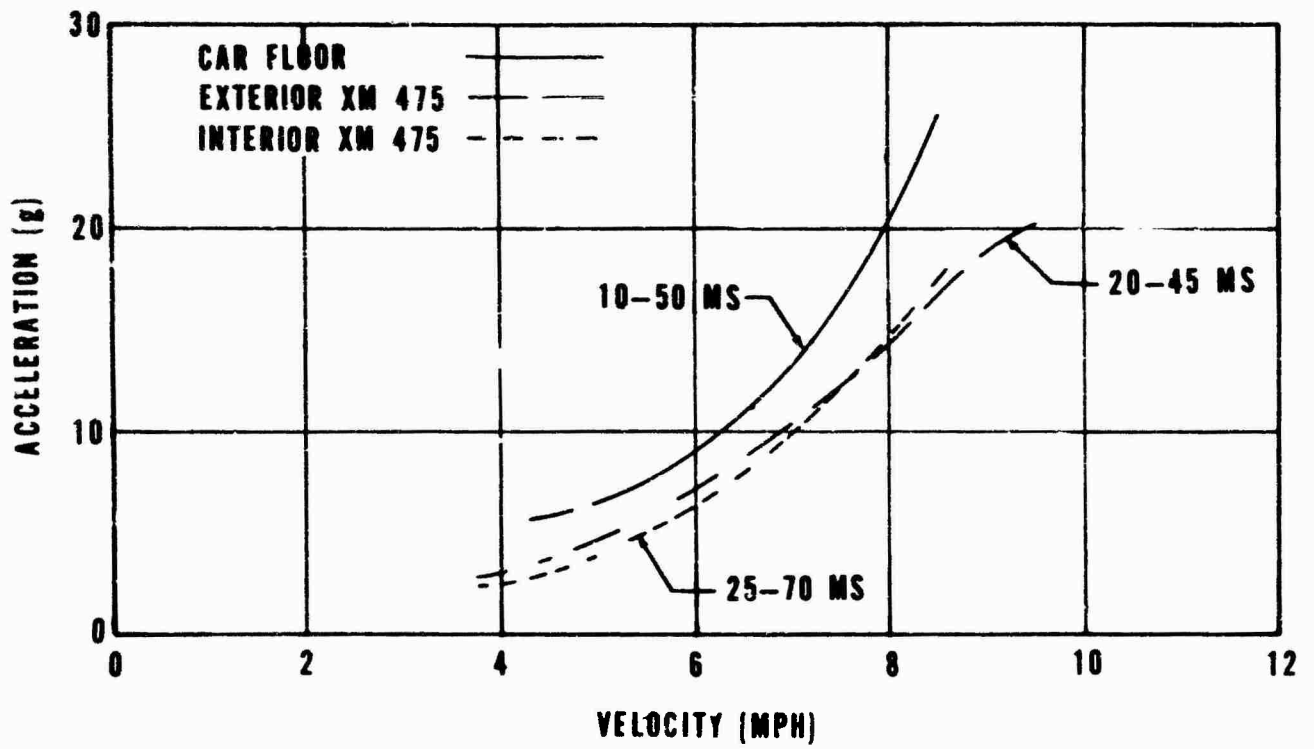


Figure 18. Longitudinal Accelerations - Car Floor and Exterior and Interior of XM 475 (Condition B, Figure 8).

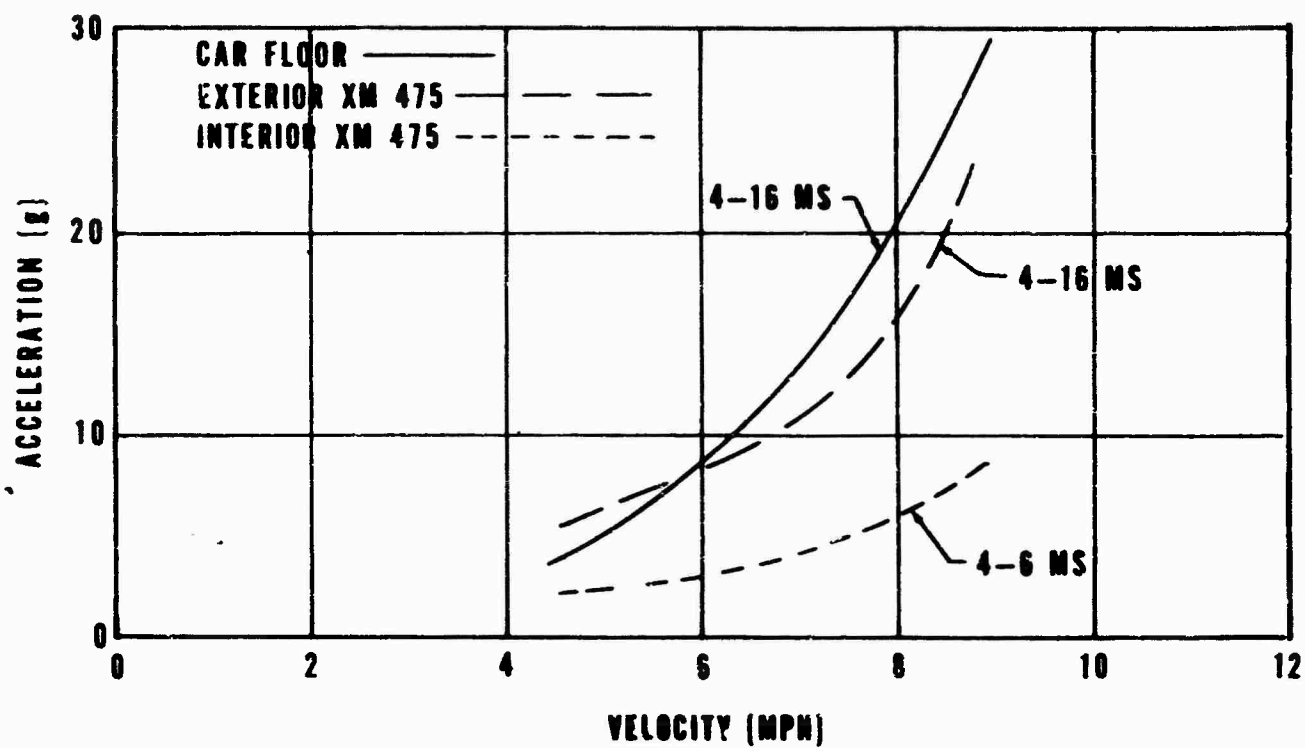


Figure 19. Vertical Accelerations - Car Floor and Exterior and Interior of XM 475 (Condition A, Figure 8).

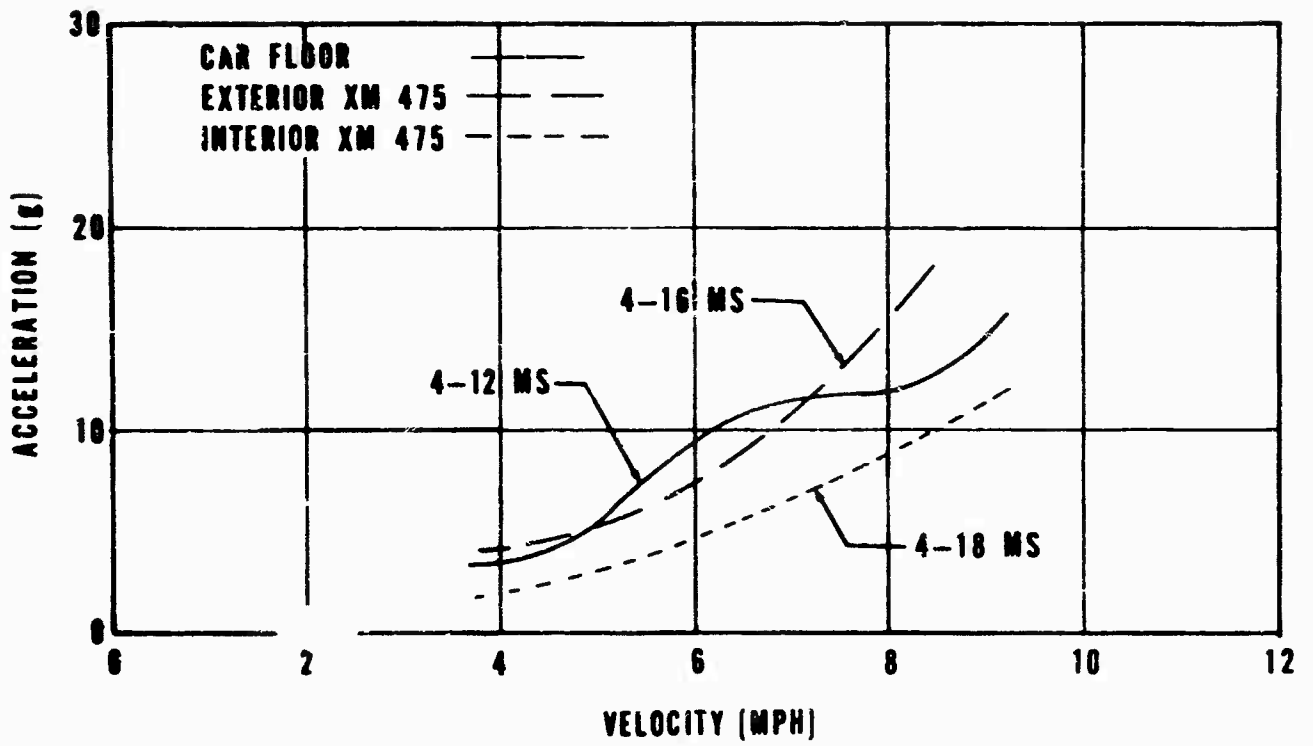


Figure 20. Vertical Accelerations - Car Floor and Exterior and Interior of XM 475 (Condition B, Figure 8).

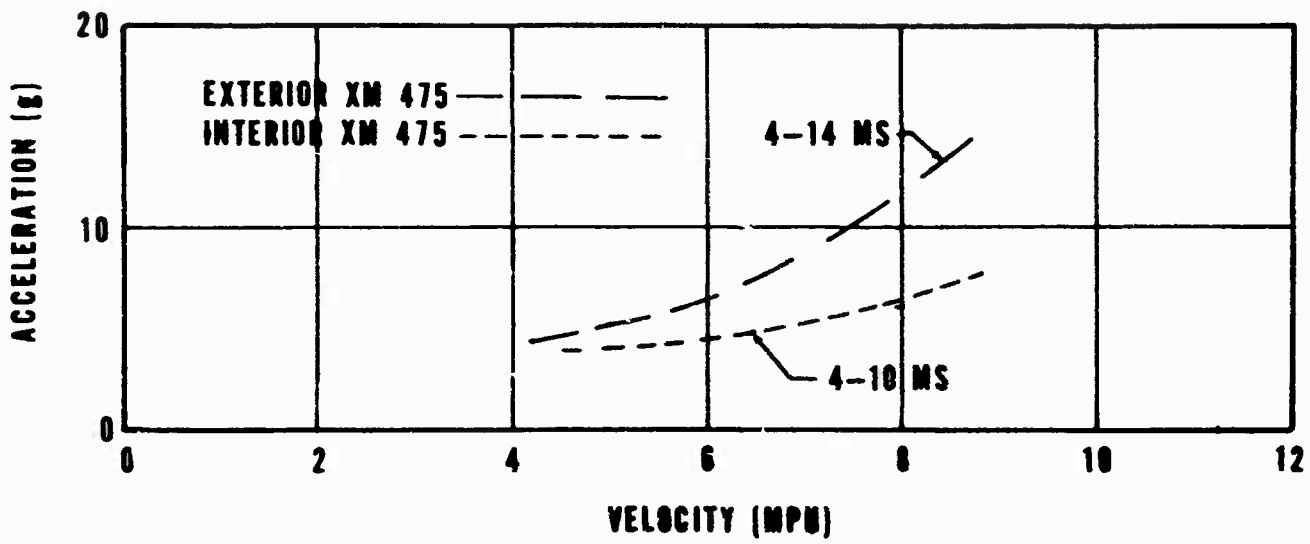


Figure 21. Transverse Accelerations - Car Floor and Exterior and Interior of XM 475 (Condition A, Figure 8).

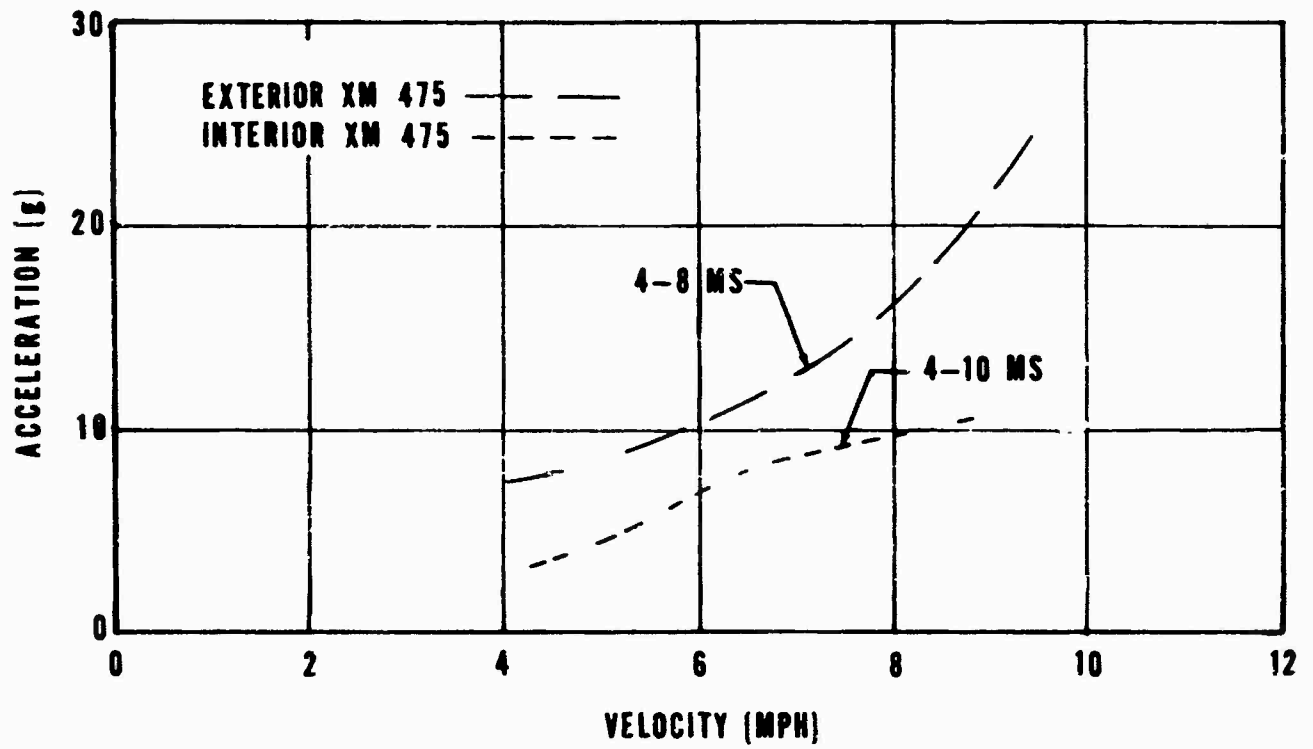


Figure 22. Transverse Accelerations - Car Floor and Exterior and Interior of XM 475 (Condition B, Figure 8).

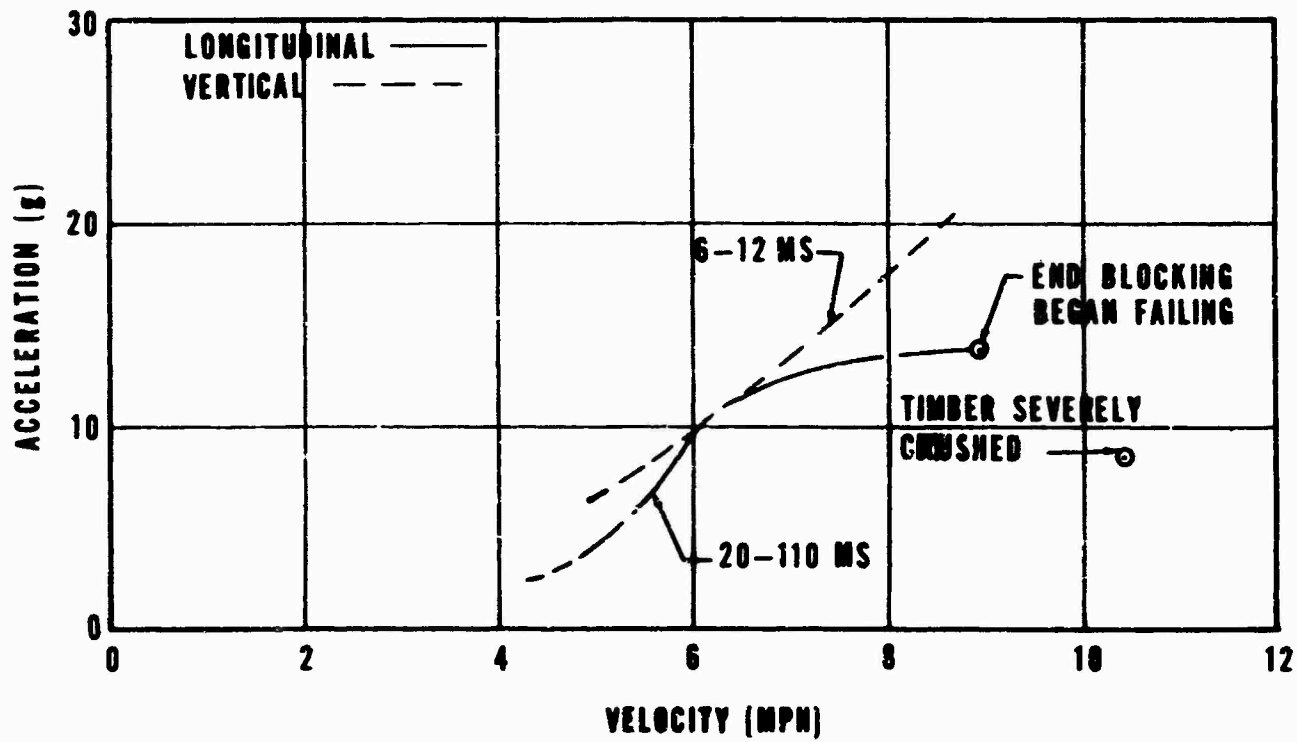


Figure 23. Longitudinal and Vertical Accelerations - Exterior of XM 476 (Condition A, Figure 8).

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ANNEX

DOCUMENTATION TABLESTABLE 1
ALL LONGITUDINAL CHANNELS

Condition	Impact Velocity (mph)	Car Floor		Exterior XM 475		Interior Carriage XM 475		Exterior XM 476	
		(g)	(ms)*	(g)	(ms)	(g)	(ms)	(g)	(ms)
A	3.5	5.2	30	3.5	30	1.9	140	3.0	20
A	4.2	5.2	50	4.6	45	2.1	85	2.5	110
A	4.5	6.9	20	4.6	40	2.1	118	2.6	70
A	4.8	4.6	50	3.9	40	2.3	170	3.3	50
A	5.3	6.2	25	6.5	25	6.0	120	5.3	25
A	5.8	13.5	20	12.2	65	9.1	100	8.7	30
A	6.2	16.3	45	8.3	45	8.5	60	10.8	52
A	8.0	21.4	70	13.3	40	14.8	36	13.1	70
A	8.9	23.8	35	21.1	32	18.3	24	13.8	70

* Pulse time in milliseconds.

TABLE 2
ALL LONGITUDINAL CHANNELS

Condition	Impact Velocity (mph)	Car Floor		Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)	(g)	(ms)
B	3.6			2.5	25	2.4	35
B	3.9			2.5	45	2.4	40
B	4.2	7.8	50	7.0	20	3.4	25
B	4.6	4.0	20	2.1	35	1.4	40
B	4.8	6.4	50	5.0	36	3.3	50
B	5.1			4.0	24	4.0	50
B	5.6			7.0	32	5.9	34
B	6.3	8.6	20	7.0	32	6.8	70
B	6.6	12.8	20	11.0	35	8.3	60
B	8.0	23.5	15	13.5	40	14.1	40
B	8.3	21.2	22	17.5	35	17.0	35
B	8.5	26.2	20	23.5	30	19.0	35
B	9.7	24.4	10	15.7	24	23.7	35
B	10.8	29.0	25	20.8	25	22.3	50
B	11.3	27.5	30	22.5	24	27.5	35

TABLE 3
ALL LONGITUDINAL CHANNELS

Condition	Impact Velocity (mpb)	Car Floor		Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)	(g)	(ms)
C	3.4	3.6	25	3.5	25	3.0	50
C	4.2	3.0	56	2.5	32	3.5	36
C	4.4	3.6	60	2.0	25	2.0	25
C	4.9	3.6	60	3.5	34	4.4	28
C	5.9	13.8	14	7.1	20	6.4	50
C	5.9	14.4	16	7.4	24	7.8	24
C	7.8	21.9	14	11.6	20	16.8	20
C	7.9	23.2	12	18.0	16	15.5	28
C	9.1	36.3	24	23.2	16	20.6	20
C	10.0	32.1	20	22.7	20	22.3	32
C	10.7	42.0	16	26.2	40	26.9	40

TABLE 4
ALL VERTICAL CHANNELS

Condition	Impact Velocity (mph)	Car Floor		Exterior XM 475		Interior Carriage XM 475		Exterior XM 476	
		(g)	(ms)	(g)	(ms)	(g)	(ms)	(g)	(ms)
A	3.5	3.2	6	3.0	6	0.7	4	3.1	6
A	4.2	6.0	6	6.4	4	1.1	4	2.6	6
A	4.5	5.2	4	7.2	4	1.6	6	8.6	6
A	4.8	3.2		3.8	4	1.2	4	3.4	8
A	5.3	2.4	16	5.5	12	2.0	6	4.5	6
A	5.8	8.7	6	9.9	8	4.7	6	12.8	8
A	6.2	7.9	12	10.6	4	4.5	6	6.1	6
A	8.0	24.3	12	15.0	16	5.0	6	21.3	6
A	8.9	24.0	6	25.4	6	9.6	6	17.4	10

TABLE 5
ALL VERTICAL CHANNELS

Condition	Impact Velocity (mph)	Car Floor		Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)	(g)	(ms)
B	3.6	3.5	4	1.4	8	1.4	4
B	3.9	3.8	4	3.8	8	1.7	4
B	4.2	4.1	10	6.0	10	2.4	6
B	4.6	2.9	4	5.9	4	1.9	6
B	4.8	4.2	6	5.8	4	3.0	6
B	5.1	7.4	4	4.4	14	1.7	8
B	5.6	6.7	4	6.7	8	4.7	18
B	6.3	11.5	4	7.8	16	6.1	7
B	6.6	10.0	4	9.6	14	5.4	8
B	8.0	11.5	12	16.8	9	8.4	5
B	8.3	14.0	6	16.0	8	10.4	4
B	8.5	10.8	8	22.1	7	10.0	6
B	9.7	19.0	4	21.0	10	9.9	8
B	10.8	14.0	6	22.9	8	11.7	10
B	11.3	15.0	5	22.0	8	12.8	6

TABLE 6
ALL VERTICAL CHANNELS

Condition	Impact Velocity (mph)	Car Floor		Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)	(g)	(ms)
C	3.4	3.5	4	4.5	6	2.2	5
C	4.2	3.5	4	6.5	4	1.7	4
C	4.4	3.5	6	3.5	10	2.0	5
C	4.9	4.5	4	8.0	4	3.4	6
C	5.9	7.0	4	14.0	4	6.2	10
C	5.9	7.5	4	8.0	10	5.6	8
C	7.8	11.5	4	15.0	8	10.4	6
C	7.9	9.0	4	12.0	4	12.9	8
C	9.1	12.0	15	18.0	10	12.1	8
C	10.0	9.1	12	16.7	8	14.6	14
C	10.7	15.2	8	22.7	10	13.4	8

TABLE 7
ALL TRANSVERSE CHANNELS

Condition	Impact Velocity (mph)	Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)
A	3.5	2.8	8	2.7	8
A	4.2	5.5	4	2.7	4
A	4.5	5.7	4	3.0	4
A	4.8	4.1	6	2.1	6
A	5.3	4.7	8	3.1	6
A	5.8	7.7	8	6.9	6
A	6.2	8.0	10	6.6	4
A	8.0	11.6	10	6.1	6
A	8.9	15.0	10	7.7	4

**TABLE 8
ALL TRANSVERSE CHANNELS**

Condition	Impact Velocity (mph)	Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)
B	3.6	3.8	4	1.9	6
B	3.9	7.3	6	3.6	4
B	4.2	10.5	4	5.9	4
B	4.6	9.0	4	2.5	4
B	4.8	8.2	4	4.1	4
B	5.1	8.6	4	3.8	6
B	5.6	13.1	6	5.7	6
B	6.3	8.2	4	8.5	4
B	6.6	14.0	4	8.1	8
B	8.0	16.6	4	8.9	4
B	8.3	16.8	4	10.0	8
B	8.5	19.1	4	10.2	4
B	9.7	27.9	6	11.8	4
B	10.8	19.3	4	13.2	8
B	11.3	22.3	8	10.0	10

TABLE 9
ALL TRANSVERSE CHANNELS

Condition	Impact Velocity (mph)	Exterior XM 475		Interior Carriage XM 475	
		(g)	(ms)	(g)	(ms)
C	3.4	8.0	4	3.0	4
C	4.2	8.7	4	3.5	4
C	4.4	7.1	4	2.6	4
C	4.9	8.7	4	4.3	10
C	5.9	12.6	5	8.9	5
C	5.9	14.6	10	7.3	4
C	7.8	18.7	10	11.4	16
C	7.9	15.9	4	9.5	4
C	9.1	15.5	10	12.9	8
C	10.0	19.3	14	13.4	8
C	10.7	18.3	4	13.6	4

TABLE 10
COUPLER FORCE

Condition	Impact Velocity (mph)	Force (kips)	Duration (ms)
A	3.5	191	125
A	4.2		
A	4.5	153	200
A	4.8	185	185
A	5.3	365	120
A	5.8	476	100
A	6.2	530	100
A	8.0	739	116
A	8.9	835	110

**TABLE 11
COUPLER FORCE**

Condition	Impact Velocity (mph)	Force (kips)	Duration (ms)
C	3.4	165	110
B	3.6	169	110
B	3.9	144	116
C	4.2	147	130
C	4.4	159	170
C	4.9	202	126
B	5.1	282	120
B	5.6	388	112
C	5.9	452	112
C	5.9	449	100
B	6.3	570	90
B	6.6	595	100
C	7.8	791	80
C	7.9	775	80
B	8.0	751	80
B	8.3	814	40
C	10.0	934	72
B	11.3	955	40

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3 REPORT TITLE PERSHING TRANSPORTABILITY STUDY, CONUS Railways, Vol. II of IV.		
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5 AUTHOR(S) (Last name, first name, initial) John H. Grier		
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11 SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY	
13. ABSTRACT CONUS railcars were used in conducting railcar impact tests on three research and development containers: the Pershing missile guidance and control section container (XM 474) and the first and second stage motor containers (XM 475 and XM 476). Data from the tests were used to determine scientifically the imposed shocks on the containers and to evaluate the structural adequacy of the tiedown and restraint arrangements when subjected to CONUS railway environments contained in Department of the Army TB 55-100. The second stage motor container, XM 476, was restrained to the railcar in conformance with Savanna Army Depot Drawing No. 5425, page 9. The guidance and control section and the first stage motor containers, XM 474 and XM 475, were restrained in accordance with the arrangement recommended in USATEA Report 66-11, <u>PERSHING TRANSPORTABILITY STUDY, Foreign Railways</u> , Volume III, dated July 1966. This study evaluates the two restraint systems to determine which system provided sufficient structural integrity to withstand the CONUS test loadings. It also presents a proposed common restraint system for CONUS and foreign rail environments. The results of this study demonstrate that the arrangement recommended in USATEA Report 66-11, Volume III, and shown in this report as Figures 1 and 2, satisfactorily withstood the test environments and provided greater structural integrity than the arrangement prescribed in the referenced Savanna Army Depot drawing. It is recommended that this system be adopted for CONUS and foreign railcar movements.		

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