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**Federal Railroad
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Results From the Car Coupling Impact Tests of Intermodal Trailers and Containers

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**Office of Research and Development
Washington, D.C. 20590**

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Final Report

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16. Abstract

Results are presented from the car coupling impact and lift/drop tests which were conducted during April 1985 at the Transportation Test Center, Pueblo, Colorado, under the Safety Evaluation of Intermodal and Jumbo Tank Hazardous Material Cars Program. The program was conducted to develop information which can be used to analyze the safety of transporting hazardous material containers by rail in Trailer on Flat Car (TOFC) or Container on Flat Car (COFC) service. One hundred and six separate car coupling impact tests were made. These tests included 10 different arrangements of cargo tanks (tank trailers) and intermodal tank containers mounted on a flat car. The tests revealed no tendency for the trailers or containers to become dislodged from the flat car during the impact, although the design load on the container pedestal supports was exceeded on some of the higher speed tests. The trailer and container securement forces were significantly larger for impacts on the A end of the car than on the B end. This showed that the properties of end-of-car cushioning devices were different at each end of the car. The tests produced only minor apparent damage on the trailers and containers, which did not affect the structural integrity of the tanks. There was, however, some damage to vents and valves which allowed some release of liquid. Eight drop tests were conducted on the tank trailers where the front landing gear support legs of the trailer were lifted off the ground and allowed to fall a short distance. These tests caused significant damage to the support legs of the trailer.

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PREFACE

The work described in this report was conducted by IIT Research Institute (IITRI) under authorization of the Federal Railroad Administration (FRA) Contract No. DTFR53-81-C-00016, Task Order VC-5, and Contract No. DTFR53-85-P-00485. The work under these contracts included providing assistance in planning the Safety Evaluation of Intermodal and Jumbo Tank Hazardous Material Cars Test Program, and monitoring and preparing the final report for the car coupling impact tests conducted under this program. The test data were provided by the Transportation Test Center (TTC).

The tests were conducted at TTC by the Association of American Railroads (AAR) under the direction of Mr. Firdausi Irani. Ms. Nancy Lightfoot and Mr. Kerry D. Hopkins assisted Mr. Irani in carrying out the test program and assembling the test data. The author also wishes to acknowledge Mr. George Kachadourian and Ms. Diane E. Boone of the MITRE Corporation, Metrek Division, for their assistance in planning the tests, monitoring certain of the test activities and helping in the evaluation of the test results.

The FRA Contracting Officer's Technical Representative on this project was Mrs. Claire L. Orth. The author wishes to acknowledge the assistance provided by her during the conduct of the work.

Respectfully submitted,

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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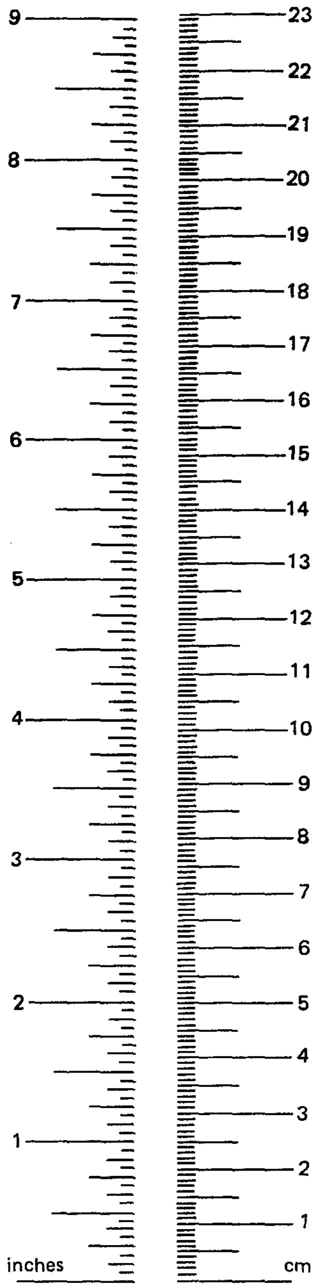
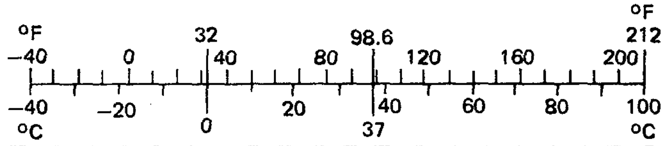
*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

This report presents results from the car coupling impact and lift/drop tests which were conducted during April 1985 at the Transportation Test Center (TTC), Pueblo, Colorado, under the Safety Evaluation of Intermodal and Jumbo Tank Hazardous Material Cars Program. Other types of tests were conducted under this program including vibration tests on the Vibration Test Unit (VTU), track tests, and derailment tests. All tests were performed at TTC.

The overall objective of the testing program was to develop information which could be used to analyze the safety of transporting hazardous material containers by rail in Trailer on Flat Car (TOFC) or Container on Flat Car (COFC) service which are currently approved for motor carrier use. At the present time, there are no specific requirements governing the use of highway trailers or containers, including intermodal IM 101 or IM 102 portable tanks, to transport hazardous materials in TOFC/COFC service. The TOFC shipment of regulated commodities in interchange service is prohibited by the Association of American Railroads (AAR) regulations (AAR.600), but individual railroads may choose to provide this service if Federal Railroad Administration (FRA) approval is obtained. Department of Transportation (DOT) regulations state that cargo tanks or portable tanks cannot be used except under conditions approved by the Associate Administrator for Safety of the Federal Railroad Administration (CFR 174.61 and 174.63). There has been an increasing number of requests for the approval of TOFC/COFC hazardous material shipments and technical data pertaining to questions of safety is required to help evaluate these requests.

1.1 OBJECTIVES

The overall objective of the car coupling impact tests was to determine the dynamic loads and responses of various TOFC/COFC arrangements with highway tank trailers* and intermodal tank containers. The impacts which occur during car coupling switchyard operations are one of the most severe environments encountered in railroad service. The specific objectives included:

- Investigation of the tendency of a container or trailer to become dislodged from a flat car under normal classification yard movements,
- Understanding of the structural dynamic phenomena associated with a high deceleration stop of the car so that calculations can be made of the expected results under more severe conditions,
- Determination of the forces at the points of attachment so that the adequacy of present requirements for securement devices can be assessed, and
- Development of acceptable instrumentation techniques for measuring the tendency of the container or trailer to become dislodged from the car so that these techniques would be available when derailment tests are conducted.

The overall objective of the lift/drop tests was to assess the potential for accumulating damage during the loading and unloading of tank trailers and containers. These tests were restricted to tank trailers.

1.2 SCOPE

The scope of the car coupling impact tests included 106 separate test runs, which were subdivided into 10 separate test series. Each test series considered a different arrangement of tank trailers and/or intermodal containers mounted on a flat car.

The scope of the lift/drop tests included 9 separate lift tests to determine the deflection curve of a tank trailer under different loading conditions and 8 drop tests where the front landing gear support legs of the trailer were lifted off the ground and allowed to fall a short distance.

1.3 ORGANIZATION OF THIS REPORT

The background for both the car coupling impact tests and the lift/drop tests is presented in Section 2. Sections 3 and 4, respectively, deal with the test procedures and results of the car coupling impact tests. Section 5 deals with the procedures and results of the lift/drop tests. Section 6 summarizes the conclusions for both types of tests.

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*The term "tank trailer" is used throughout this report to describe the highway tank trailers used in the tests. In the Code of Federal Regulations (CFR) these tanks are referred to as "cargo tanks". (See for example CFR 178.340 to 178.343.)

2. BACKGROUND

2.1 GUIDELINES FOR CAR COUPLING IMPACT TESTS

The test plan for the car coupling impact tests was developed after considering the requirements of existing specifications. At the present time there are no performance test requirements for verifying the structural integrity of tank trailers in TOFC service under car coupling impact conditions. The AAR Tank Car Specifications (Section AAR.600-15d) include a car coupling impact test which is to be used to verify the structural integrity of intermodal tank containers in COFC service.

The AAR specifications which relate to the car coupling impact environment are summarized in this section. All but one of the test series conducted under this program followed the procedures outlined in AAR Specification M-928, which is used to demonstrate the effectiveness of flat car or trailer hitch cushioning for limiting trailer hitch loads. The flat car containing a trailer or container was impacted into standing loaded hopper cars at speeds of 4, 6, 8 and 10 mph. One set of tests was made following the AAR.600-15d procedures where a standing car on which the container is mounted was impacted by a loaded hopper car.

There are five AAR specifications which pertain to the structural integrity and securement of tank trailers and intermodal containers in the car coupling impact environment. These are summarized as follows:

AAR Specification M-928 covers the structural adequacy and testing of highway semi-trailer hitches which are used on freight cars. The intent of the specification is that the hitch structure at the trailer king pin will not be subjected to a longitudinal force greater than 210 kips at a car impact of 10 mph. Tests are prescribed to demonstrate that the hitch can withstand, without damage, the loads from car impacts. The tests include a series of impact tests. The hitch is installed on a flat car which is loaded with two 40 ft trailers. The car is impacted at speeds from 4 to 10 mph in both directions against loaded cars. The cushioning on the flat car or within the hitch itself must be such to limit the king pin longitudinal force to 210 kips at a 10 mph impact speed.

AAR Specification M-931 pertains to the design of highway trailers used in TOFC service. The design criteria given for horizontal shear load at the king pin is 3.5 times the maximum gross weight of the trailer in both directions. A static test is specified for demonstrating the ability to carry the load.

AAR Specification M-943 pertains to the design of container chassis for TOFC service. (Note that this specification states that the chassis covered by this specification are not suitable for transportation of hazardous materials in tank containers.) The design requirements concerning king pin forces are similar to those of M-931. A maximum longitudinal load 3.5 times the maximum gross weight is specified. A static test is specified for demonstrating the ability to carry the load.

AAR Specification M-952 pertains to intermodal container support and securement systems for freight cars. Tests are prescribed to demonstrate the adequacy of the securement device. A static test is conducted to demonstrate that a corner support system can sustain a longitudinal load of 67,200 lbs in the direction from which the corner support structure would receive the container force during a switching impact. An impact test is prescribed to demonstrate that when the securement system is installed on a flat car the container will not subject the system to a total longitudinal force exceeding 135,000 lbs during a 10 mph impact. The test involves installing the securement system on a flat car, loading the car with two 40 ft intermodal containers, and then impacting the car into standing cars at speeds from 4 to 10 mph.

The AAR Specifications for Tank Cars, Section AAR.600, pertains to the acceptability of tank containers used in COFC service. Section 15, Paragraph d, of this specification describes an impact test for determining the structural adequacy of a tank container. The tank container is placed on a free-standing car and impacted by a loaded car at increasing speeds until a longitudinal load on the container is developed which is equal to 4 times its gross weight. The tank container must give no evidence of visible damage under this test condition. Section 19, Paragraph b, of this specification states that each corner securement must be capable of sustaining a longitudinal load of 78,400 lbs without incurring distortion that would render it unsatisfactory for normal operation.

2.2 GUIDELINES FOR LIFT/DROP TESTS

The potential for accumulating damage during loading and unloading of tank containers or trailers was assessed by performing tests which simulate the loads and shock motions which occur during these operations. The problem is likely to be more critical with tank trailers than with IM tank containers. The IM tank containers are fairly rigid structures because of their containment within a skid and framework structure, whereas the tank trailers tend to be long slender structures with lower fundamental frequencies.

To examine the potential problems with tank trailers, trailer lift/drop tests were performed. The purpose of the tests was to compare results from tests prescribed by the AAR for trailers which are used in TOFC services with the results from the vibration and car coupling impact tests. The data was to be reviewed to determine if the AAR specifications describe a severe enough condition for trailers which are intended to be used for hazardous material service. The tests were concerned with establishing the deflection curve of the trailer under different loading situations in order to gain an indication of the dynamic and static response of the structure. The tests were based in part on tests described in AAR M-931 for highway trailers used in TOFC service. The criterion for the successful completion of the M-931 tests is that the trailer should remain serviceable and should not show permanent deformation resulting in any abnormality which would make it unsuitable for use.

2.2.1 LIFT TEST

The lift test described in Section 6.4 of AAR M-931 requires that the tank trailer be supported equally on four lift shoes (or their equivalent) each having a bearing area of approximately 4 x 18 in. at the lifting pads. The trailer is then loaded to 1.7 times its gross weight and the load held for a period of at least 5 minutes.

2.2.2 DROP TEST

The test procedures outlined in Section 6.7.2 of AAR M-931 require that the trailer be uniformly loaded to produce a load of 32,500 lbs on the trailer support with the trailer support legs extended to position the king pin support plate 46 to 48 in. above the test surface. The front end of trailer is elevated by a tractor until the support legs are 3 to 3-1/2 in. above the test surface. The tractor must not engage the king pin and is to extend under the front of the trailer the minimum distance required to support the trailer in a static condition. The tractor is then accelerated abruptly permitting the trailer to drop. The trailer landing gear is to impact on an asphalt test surface which is to be level and smooth. The trailer must withstand 10 nominal 3 in. drops.

3. TEST PROCEDURES AND CONFIGURATIONS

This section describes the test equipment, procedures, instrumentation and configurations for the car coupling impact tests.

3.1 EQUIPMENT

The freight car used in the tests was a TWIN 45 TTX car (No. 978174). It had an empty weight of 70,900 lbs and a load limit of 149,000 lbs. The car was equipped with Freightmaster end-of-car cushioning units and was built in October 1974.

Two tank trailers supplied by Montgomery Tank Lines were used (Nos. MTLZ6961 and MTLZ6970). They were 6,900 gallon, MC307 trailers with an approximate empty weight of 14,000 lbs. This type of tank trailer is illustrated in Figure 1.

Three 20 ft intermodal tank containers were used. Two were supplied by EUROTAINER and one was owned by the FRA. The nameplate data on these containers is summarized in Table 1. Each of these containers had its own unique framework design as illustrated in Figure 2. The containers are illustrated in Figures 3 to 5.

EUROTAINER container No. FR 2075, shown in Figure 3, utilizes a central saddle and cylindrical extensions of the tank to support the tank within the framework. The cylindrical extensions are welded to end panels. The beams which make up the framework have substantial cross sections which make them fairly rigid members. the framework is braced in the longitudinal direction by diagonal members. It is braced in the transverse direction by the panels at each end of the framework which are attached to the cylindrical tank extensions. The saddle and two cylindrical extensions give this structure a high degree of strength to resist longitudinal inertial loads.

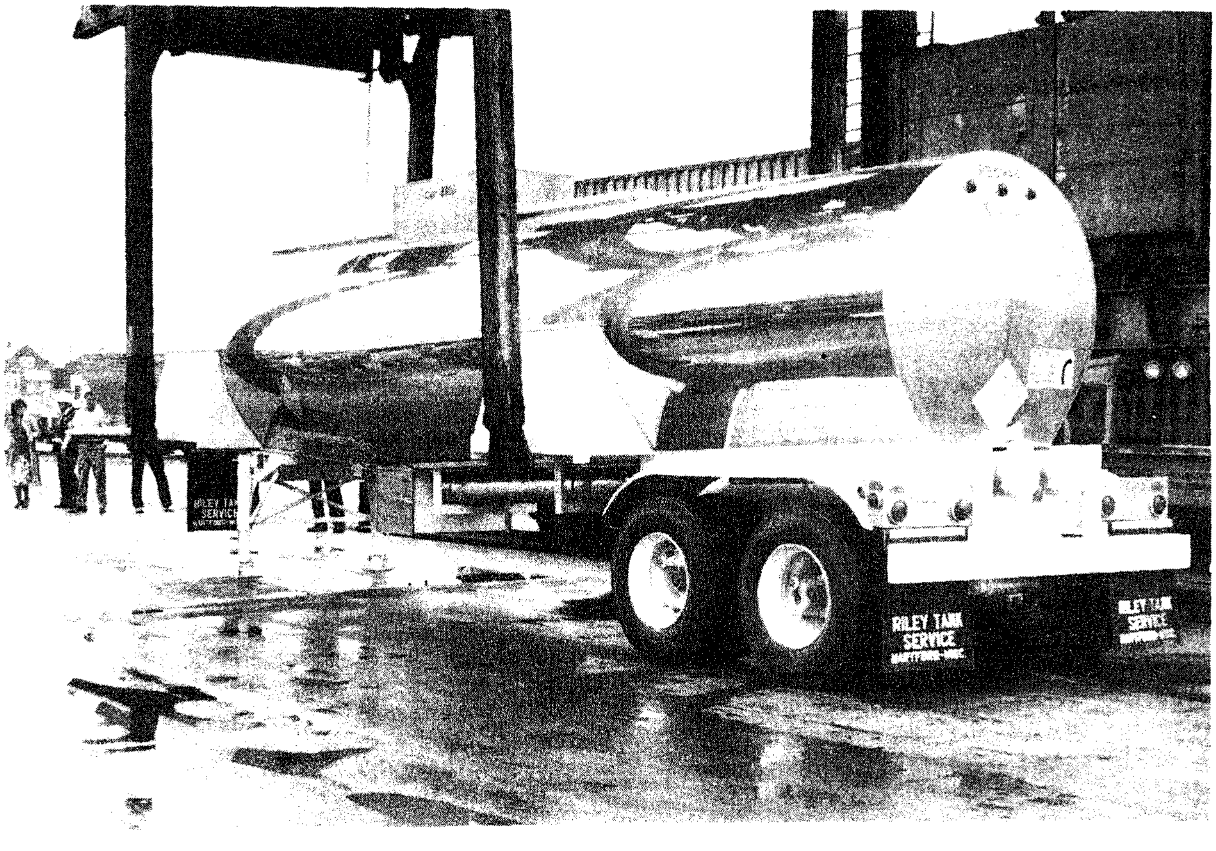


FIGURE 1. TYPE OF TANK TRAILER USED IN TEST

TABLE 1. CONTAINER DATA
(from nameplates)

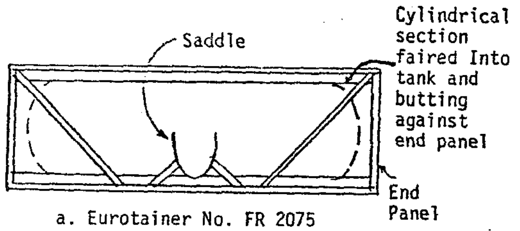
	EUROTAINER		DOT
Number	SELS 716005 FR 2075	SELS 914064 FR 2074	BLSU 300019 US 2272
Designation	IM102	IM102 E7516	--
Max Gross Weight	52,910 lbs	52,910 lbs	67,196 lbs
Tare Weight	6,835 lbs	6,395 lbs	6,437 lbs
Max Allowable Load	--	46,520 lbs	--
Liquid Capacity	20,600 l	19,800 l	21,000 l
Diameter	2,180 mm	2,100 mm	2,200 mm
Shell Thickness	---------3mm (actual)--------		3mm ("effective shell thickness")
Shell Thickness, Equiv. Mild Steel	---------"standard"----------		3.97mm
Material	26 CNDT 17-12/316TI	26 CNDT 17-12/316TI	--
Built	1974	1974	Oct 1983
Manufacturer	--	--	BSL
Max Working Pressure	25 psi	25 psi	25.39 psig
Test Pressure	37 psi	37 psi	38.01 psig

EUROTAINER container No. FR 2074, shown in Figure 4, utilizes members of slightly smaller cross section to form the basic structural configuration at the extremities of the container. It also utilizes a number of lighter members to reinforce this structure. There are 5 ring stiffeners on the tank. The lower portions of 4 of these are welded to saddles which support the tank. These in turn are connected to fairly light transverse partitions which are connected to members of the intermediate framework. This container is not nearly as strong in resisting longitudinal inertial loads as container FR 2075. Longitudinal loads are taken through the saddles and then, in turn, through shear in the light partitions. Although there are some reinforcing gussets in the lower longitudinal framework members, these partitions provide minimal strength in the longitudinal direction. The container is braced in both the longitudinal and transverse directions by the light intermediate structural members.

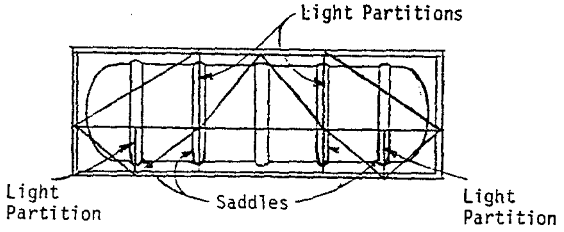
The DOT/FRA container No. US 2272, shown in Figure 5 utilizes fairly heavy structural members to form the primary structure of the framework. The tank is supported by two cylindrical sections, slightly smaller in diameter than the tank, which are welded to the ellipsoidal ends of the tank and the panels at the two ends of the framework. There is no saddle support for the tank. The framework is braced in the longitudinal direction by two sets of diagonal members. The end panels provide rigidity in the transverse direction. This container provides substantial resistance to longitudinal inertial loads from the tank through the use of the cylindrical sections welded to the reinforced end panels.

3.2 TEST PROCEDURES

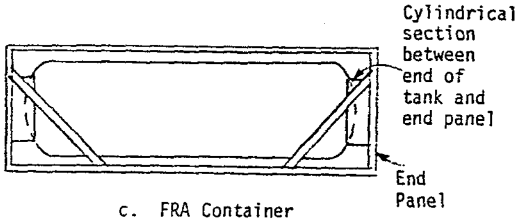
The procedures for conducting the car coupling impact tests generally followed those outlined in AAR Specifications M-952 and M-928. The trailer or container was loaded with water and installed on the TTX car which became the hammer car. The anvil cars included three hopper cars each loaded with dry sand to an approximate gross rail weight of 220,000 lbs. The hand brake was set on the third car. The impact tests were run at speeds, 4, 6, 8 and 10 mph in both directions.



a. Eurotainer No. FR 2075



b. Eurotainer No. FR 2074



c. FRA Container

FIGURE 2. SKETCHES OF INTERMODAL CONTAINERS SHOWING PRINCIPAL STRUCTURAL FEATURES OF EACH DESIGN

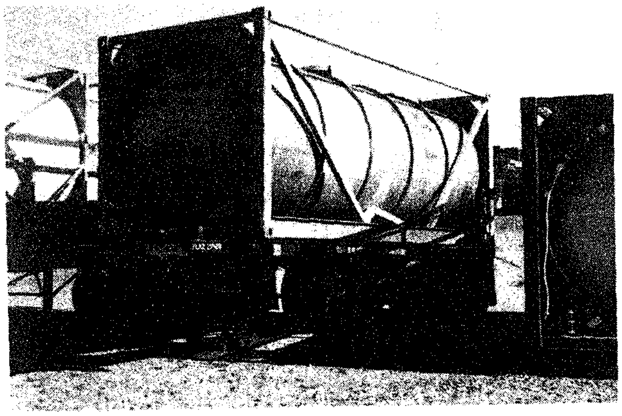


FIGURE 3. EUROTAINER TANK CONTAINER NO. FR 2075

FIGURE 4. EUROTAINER TANK CONTAINER NO. FR 2074

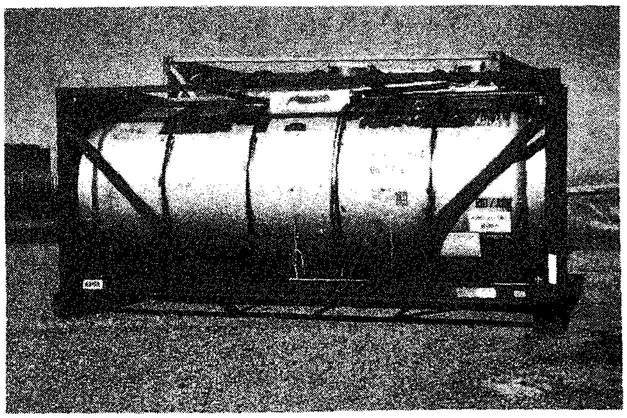


FIGURE 5. DOT/FRA INTERMODAL TANK CONTAINER NO. US 2272

The tests were conducted on the LIMRV test track behind the Roll Dynamics Laboratory building at TTC. This track is on an approximate one percent grade. The standing cars were positioned on the track and the test car pulled back from these cars an appropriate distance so that when it was released it would strike the standing cars at the desired speed.

The signal conditioning and recording equipment for the instrumentation system were installed in a van which was driven along side of the test car. The cables connecting the transducers on the test car with the equipment in the van were bundled together and allowed to drag on the ground. Typical test arrangements are shown in Figures 6 and 7.

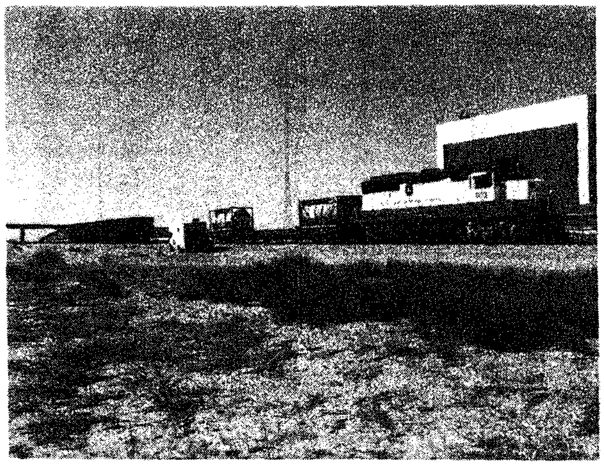


FIGURE 6. ARRANGEMENT OF ANVIL CARS AND TEST CAR ON TEST TRACK

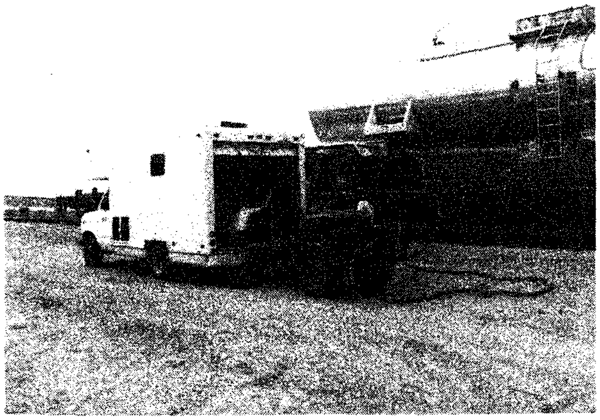


FIGURE 7. INSTRUMENTATION VAN AND CABLE CONNECTION TO TEST CAR

One series of tests, the final series, was conducted in accordance with the requirements for AAR.600-15d. To follow this test procedure a loaded intermodal container was placed on a free-standing flat car. A loaded hopper car was then impacted into the standing car. The container was placed on the opposite end of the car from the struck end in order to be able to measure the longitudinal loads with the load cell fixtures. The moving loaded car coupled into the free standing flat car and then the two cars moved together and coupled into backup cars which stopped their motion. The requirement for the AAR.600 test is to impact at increasing speeds until a 4g longitudinal load is developed on the container.

3.3 INSTRUMENTATION

The transducers which were used on the test were selected to define the forces and dynamic behavior of the railroad flat car and the trailer or container mounted on the car. The test measurements included:

- Acceleration of the flat car,
- Coupler force,
- Forces acting between the trailer or container and the flat car at the points of their interconnection,
- Displacement measurements at the rear of the tank trailer to measure the tendency for it to jump upward and lose its contact with the restraining rails, and
- Liquid level in the tank (so called "slosh" gages).

The dynamic measurement of the interconnection forces was difficult. Specially built instrumented king pins were used to measure the longitudinal force at the hitch for securing the trailers. A specially constructed fixture was used to position load cells for the measurement of longitudinal forces on the container. This fixture is illustrated in Figures 8 and 9. The slosh gages were difficult to maintain in the harsh environment associated with car coupling impacts and were operable on only a small number of the impact tests. Table 2 contains a list of the instrumentation channels used on the tests.

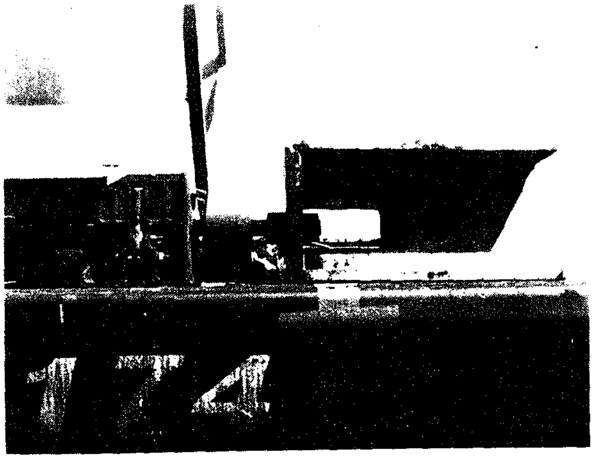


FIGURE 8. LOAD CELL AND SUPPORT FIXTURE USED TO MEASURE LONGITUDINAL CONTAINER LOADS

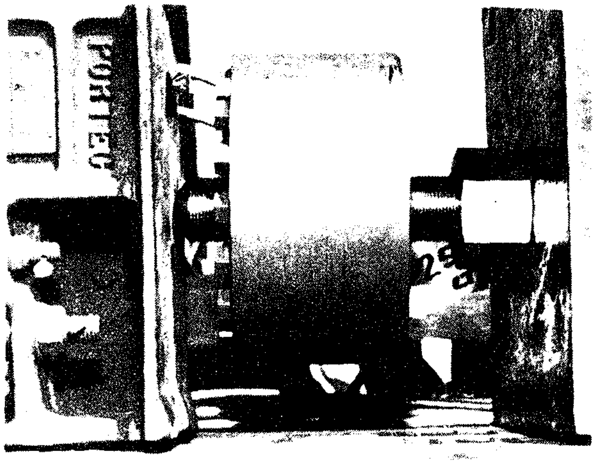


FIGURE 9. DETAIL OF LOAD CELL AND SCREW USED TO DEVELOP PRELOAD FOR MEASUREMENT OF LONGITUDINAL CONTAINER LOADS

3.4 TEST CONFIGURATIONS

The car coupling impact test series were conducted under different test configurations which were designated as Configurations 2, 3A, 3B, 4A, 4B, 4C, 4D, 4E, 6 and 7. The conditions associated with Configurations 2 through 6 are summarized below.

	"A" End of Flat Car		"B" End of Flat Car	
Test Configuration and Impacting Directions	Trailer or Container	Water Load in Tank (volume filled, percent)	Trailer or Container	Water Load in Tank (volume filled, percent)
2 (A and B)	-	-	Trailer	94.2
3A (A and B)	Trailer	94.2	Trailer	94.2
3B (A and B)	Trailer	94.2	Trailer	80.0
4A (A and B)	IM Container	92.6	Trailer	80.0
4B (A and B)	IM Container	80.0	Trailer	80.0
4C (A end)	-	-	IM Container	92.6
4C (B end)	IM Container	92.6	-	-
4D (A end)	-	-	IM Container	80.0
4D (B end)	IM Container	80.0	-	-
4E (A end)	-	-	IM Container	92.6
6 (A and B)	IM Container on Bogie	80.0	IM Container on Bogie	92.6

The tests on Configurations 2 through 4D and 6 were conducted by impacting the flat car on which the container or trailers were mounted into standing cars in both directions at nominal speeds of 4, 6, 8 and 10 mph. The Configuration 4E impact tests were made in only one direction and the Configuration 7 tests involved impacting the standing test car with a moving car.

Configuration 2 tests were used to determine the response of a single tank trailer. The trailer, loaded with water to its maximum gross weight (94.2% full), was mounted at the B end of the flat car as shown in Figure 10.

Configuration 3A and 3B tests were used to determine the responses of two trailers on the flat car. Both trailers were loaded to their gross weight capacity with water (94.2% full) for the Configuration 3A tests. The tank trailer at the B end of the car was unloaded to an 80% full condition for the Configuration 3B tests. This configuration is illustrated in Figure 11.

Configuration 4A and 4B tests were used to determine the response of one intermodal container and one trailer on the flat car. The tank trailer was mounted on the B end of the flat car and an intermodal container on the A end of the car as illustrated in Figure 12. The tank trailer was 80% full. On the Configuration 4A tests the container was 92.6% full, loaded to its maximum allowable gross weight. The container was 80% full for the 4B tests.

Configuration 4C and 4D tests were used to examine the effects of A and B end impacts under a similar set of test conditions. A single loaded intermodal container was placed on the flat car. The container was placed at the opposite end of the car from the striking end. This orientation was necessary for the measurement of longitudinal loads on the container securement pedestals. The 4C tests were conducted with the container loaded to its maximum gross weight (92.6% liquid full). The 4D tests were conducted with the container 80% full.

Configuration 4E tests were run to examine the reliability of the method for measuring peak longitudinal securement forces on the containers. A load cell arrangement was used for this measurement. Load cells were placed between rigid blocks secured to the base of the flat car and the front faces of the forward pedestal supports on each side of the container. Compressive preloads were put on the load cells to insure that the load path would pass through the load cells during the impact. There was the possibility of an alternate load path through friction at the base of the container corner support and the horizontal surface at the base of the pedestal resting on the flat car. This alternate load path would be present at both the forward container supports and the rear container supports. The container was 92.6% full for the Configuration 4E tests. The first set of test runs was made with the same setup used in earlier tests. A second set of test runs was made with all of the friction surfaces lubricated with a generous amount of grease.

Configuration 6 tests were used to determine the response of intermodal containers mounted on bogies. Two bogies containing intermodal containers were loaded on the flat car as shown in Figure 13. The container on the A end bogie was loaded 80% full. The container on the B end bogie was loaded 92.6% full.

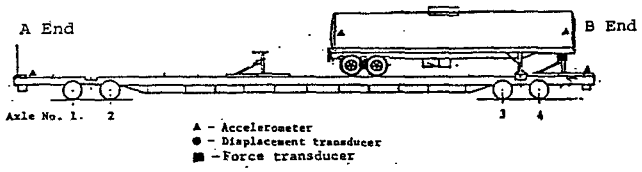


FIGURE 10. CONFIGURATION 2 TEST ARRANGEMENT

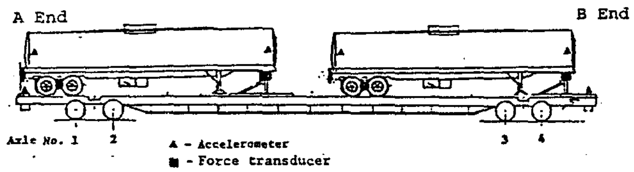


FIGURE 11. CONFIGURATION 3 TEST ARRANGEMENT

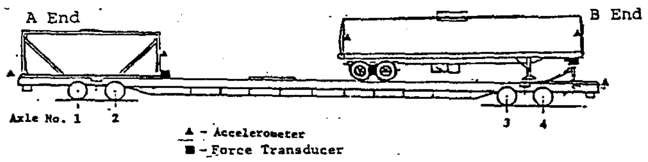


FIGURE 12. CONFIGURATIONS 4A AND 4B TEST ARRANGEMENTS

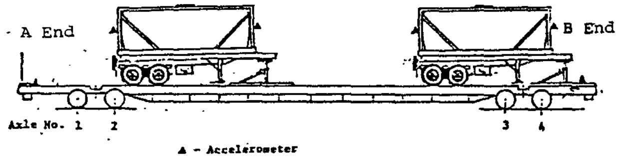


FIGURE 13. CONFIGURATION 6 TEST ARRANGEMENT

Configuration 7 tests were conducted in accordance with the requirements of AAR.600-15d. One tank container, the DOT/FRA container, was fully loaded (92.6% full), and was placed on the B end of the flat car. This car was positioned as an anvil car and struck by a loaded hopper car.

TABLE 2. INSTRUMENTATION: TOFC/COFC IMPACT TESTS

Measurement Parameter	Measurement No.	Location	Direction	Expected Range (0-Peak)
Flat car acceleration	1	A end-center	longitudinal	20g
	2	A end-center	vertical	5g
	3	A end-center	lateral	2g
	4	B end-center	longitudinal	20g
	5	B end-center	vertical	5g
	6	B end-center	lateral	2g
Flat car coupler force	7	Striking end	longitudinal	1200 kip
Trailer hitch king pin force	8	Trailer hitch (A end)	longitudinal	210 kip
	9	Trailer hitch (B end)	longitudinal	210 kip
Trailer and/or container acceleration (A end)	10	Tandem end-center	longitudinal	20g
	11	Tandem end-center	vertical	5g
	12	Tandem end-center	lateral	5g
	13	Hitch end-center	longitudinal	20g
	14	Hitch end-center	vertical	5g
	15	Hitch end-center	lateral	5g
Trailer and/or container acceleration (B end)	16	Tandem end-center	longitudinal	20g
	17	Tandem end-center	vertical	5g
	18	Tandem end-center	lateral	5g
	19	Hitch end-center	longitudinal	20g
	20	Hitch end-center	vertical	5g
	21	Hitch end-center	lateral	5g
Trailer displacement (with respect to flat car)	22	Tandem end-right side	vertical	12 in.
	23	Tandem end-left side	vertical	12 in.
Container longitudinal support force	25	Leading end-front left side corner support	longitudinal	70 kip
	26	Leading end-front right side corner support	longitudinal	70 kip
Liquid level (slosh gage) Trailer/container A end	27	Tandem end	vertical	40 in.
	28	Hitch end	vertical	40 in.
Trailer/container B end	29	Tandem end	vertical	40 in.
	30	Hitch end	vertical	40 in.

4. TEST RESULTS

This section describes the results of the car coupling impact tests.

4.1 CONFIGURATION 2 TESTS

The results from the Configuration 2 tests are summarized in Table 3. Peak coupler and hitch pin forces are plotted in Figure 14. The instrumented coupler was not functioning during the A end impacts.

The hitch pin forces were significantly larger for the A end impacts than for the B end impacts. This was found to be due to differences in the properties in the flat car's end-of-car cushioning devices rather than the orientation of the tank trailer. This is discussed later in Section 4.8.2. The peak hitch pin forces were well below the 210 kip maximum given in AAR Specification M-928.

The maximum longitudinal accelerations measured on the flat car occurred shortly after the initial impact of the car. The accelerometer records show a strong response at approximately 70Hz and the peak values generally occurred during the first or second oscillation at this frequency. A lower frequency component of acceleration is also evident on the records which is similar to the coupler force record. The maximum values of this component of acceleration have been estimated and are included in the tabulated results.

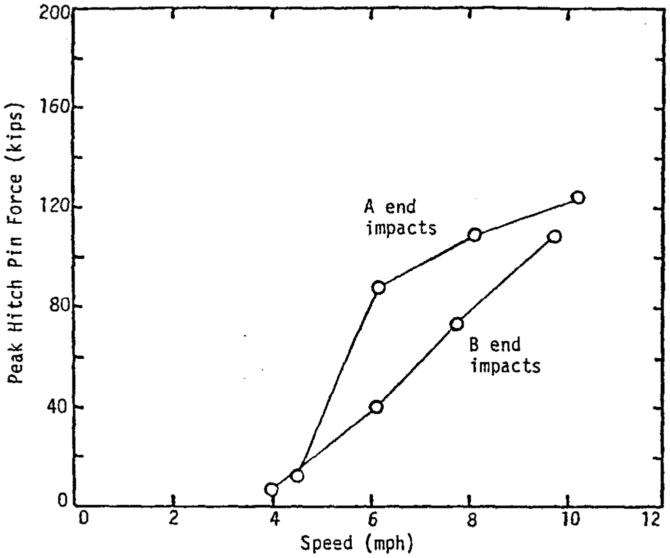
It is apparent from the data that the sloshing of the liquid in the tank affects the dynamic behavior of the impact. The maximum values of the flat car low frequency component of longitudinal acceleration are about twice what would be expected from the gross weight of the car and the maximum coupler force. This indicates that the inertial load of the liquid in the tank is spread over a longer period of time than the time it takes for the couplers to fully engage. The effects of liquid slosh are also shown by the fact that the maximum load on the trailer hitch pin occurs after the maximum coupler force has been reached. The delay ranges from approximately 0.5 seconds at the 4 mph impact to the 0.18 seconds at the 10 mph impact.

The records of the vertical accelerometers on the flat car show that several frequencies of vibration are present. The accelerometers show a strong response at approximately 70Hz. Components at approximately 7 and 20Hz also appear during some tests. The maximum values were associated with the 70Hz oscillation and range from approximately ±1g on the 4 mph impact to ±2g on the 10 mph impact.

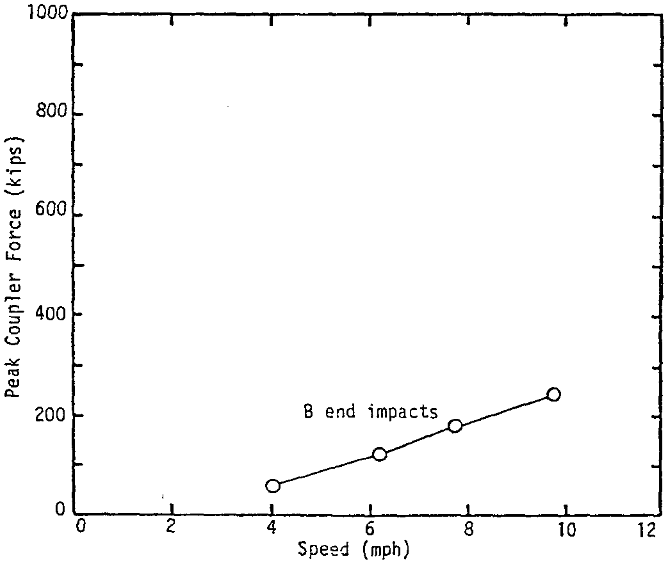
The displacements measured between the trailer and flat car at the tandem axles show that there was a negligible lift of the trailer. The direction of the impact has no significant effect on the magnitude of this displacement.

TABLE 3. SUMMARY OF RESULTS FROM CONFIGURATION 2 TESTS

Test Configuration	Test Run No.	Impacting End of TTX Car	Impact Speed (mph)	Maximum Coupler Force (kips)	Maximum Hitch Pin Force (kips)	Longitudinal Acceleration TTX Car			Maximum Vertical Displacement of Trailer Tandem Axle (in.)
						Maximum (g) A End	B End	Average Maximum of Low Frequency Component (g)	
2	8	B	4.0	56	7	1.9	4.3	0.6	0.13
	9	B	6.1	116	40	4.5	4.1	1.5	0.22
	10	B	7.7	176	74	5.7	4.9	2.3	0.31
	11	B	9.7	239	108	8.4	4.9	2.8	0.44
2	13	A	4.5	-	13	3.0	3.1	0.5	0.17
	15	A	6.2	-	88	7.2	4.1	2.2	0.28
	16	A	8.1	-	109	7.2	5.7	3.9	0.28
	17	A	10.2	-	124	7.4	15.8	3.7	0.44



a. Peak Trailer Hitch Pin Force Vs. Impact Speed



b. Peak Coupler Force Vs. Impact Speed

FIGURE 14. CONFIGURATION 2 TEST RESULTS

4.2 CONFIGURATION 3 TESTS

The results for the Configuration 3A and 3B tests are summarized in Table 4. The peak coupler and hitch pin forces are plotted in Figure 15 for the 3A tests and in Figure 16 for the 3B tests. These forces are significantly larger for A end impacts than for B end impacts. The maximum hitch pin forces are again well below the 210 kip maximum given in AAR Specification M-928. The hitch pin forces for the B end trailer are slightly larger than for the A end trailer on the A end impacts. The results shown in Table 4 indicate that the peak hitch forces for the trailer, which was 80% full, are significantly lower than for the trailer which was 94.2% full. This difference is more than can be accounted for by the difference in mass. This indicates that increasing the outage in the trailer results in additional decoupling of the inertial load of the liquid.

The maximum longitudinal accelerations measured on the flat car occurred shortly after the initial impact of the cars on the B end impact tests and the 4 mph A end impact test. The maximum longitudinal acceleration on the higher speed A end impact tests occurred when the end-of-car cushioning device was close to being bottomed out. There was a large sudden increase in the coupler forces at this time. The accelerometer records show a strong response at approximately 70Hz. A lower frequency component of acceleration is also evident on the records which is similar to the coupler force record. The maximum values of this component of acceleration have been estimated and are included in the tabulated results.

The data show that the sloshing of the liquid in the tank has an effect on the dynamic behavior of the impact, although the effects are somewhat different from the Configuration 2 tests. The maximum values of the low frequency component of longitudinal flat car acceleration are significantly larger than what would be expected from the maximum gross weight of the car and the maximum coupler force on the B end and low speed A end impacts. This occurs for both the 3A and 3B Configurations. It indicates that the liquid in the tank is not being decelerated at the same rate as the car. The shape of the coupler force record on these tests shows a gradual increase to the maximum value as the cushioning device behind the coupler is displaced, which is what would be expected. On the higher speed A end impacts the maximum values of low frequency longitudinal acceleration are only slightly greater than expected. The shapes of the coupler force records on these tests show an erratic behavior as the end-of-car cushioning device reaches the end of its stroke. There are rapid fluctuations in the coupler force record. The peak force is associated with one of these fluctuations. The peak trailer hitch pin forces also coincide closely with the peak coupler force. This indicates that the inertia of the fluid is more closely coupled to the deceleration of the car under these conditions.

TABLE 4. SUMMARY OF RESULTS FROM CONFIGURATION 3A AND 3B TESTS

Test Configuration	Test Run No.	Impacting End of TTX Car	Impact Speed (mph)	Maximum Coupler Force (kips)	Maximum Hitch Pin Forces		Longitudinal Acceleration TTX Car		
					A End (kips)	B End (kips)	Maximum (g) A End	Maximum (g) B End	Average Maximum of Low Frequency Component (g)
3A	67	B	4.1	84	12	10	2.3	6.3	0.5
	68	B	6.2	194	46	48	4.2	5.1	0.9
	69	B	8.2	245	54	55	6.3	7.8	2.3
	70	B	10.0	350	111	103	6.6	4.6	3.4
3A	72	A	4.4	135	15	18	3.8	2.6	0.7
	74	A	6.1	320	71	79	4.6	6.3	3.3
	75	A	8.3	410	73	85	10.2	14.0	2.4
	77	A	10.3	810	142	145	7.8	16.0	4.0
3B	82	B	3.8	59	7	6	1.8	-	0.5
	83	B	6.4	160	60	30	3.7	-	1.3
	84	B	8.3	250	94	39	5.4	-	2.4
	85	B	10.1	340	109	55	5.4	-	3.0
3B	78	A	4.1	169	38	21	2.4	2.0	1.3
	79	A	6.5	300	81	48	4.2	7.2	2.5
	80	A	8.2	410	100	55	10.3	17.0	2.3
	81	A	10.4	710	160	85	9.8	-	3.1

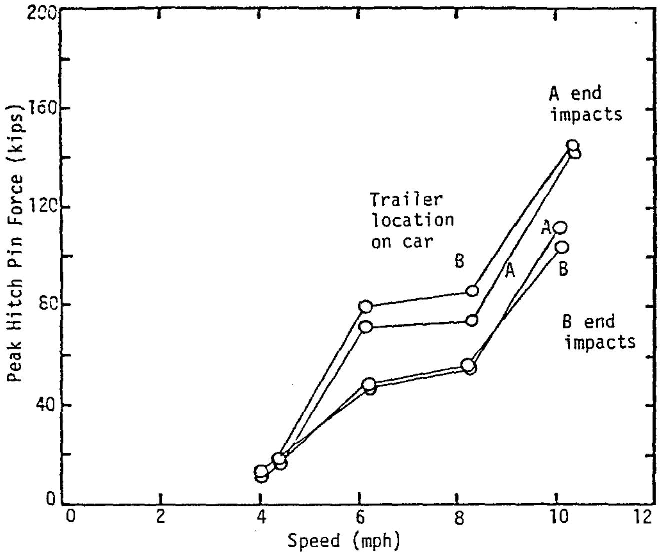
The records from the vertical accelerometers on the flat cars show several frequencies of vibration are present. The accelerometers show a strong response at approximately 70Hz. Components at approximately 7 and 20Hz are also present during some of the tests. The maximum accelerations range from approximately 1g at 4 mph to 2.5g at 10 mph on the B end impacts. The maximum values are slightly larger on the A end impacts ranging from about 1g at 4 mph to 4g at 10 mph.

4.3 CONFIGURATION 4A AND 4B TESTS

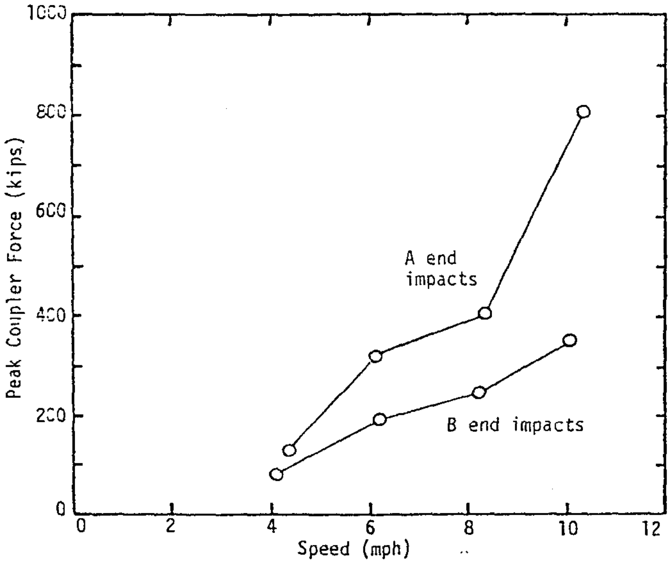
The results for the Configuration 4A and 4B tests are summarized in Table 5. The peak coupler, hitch pin and container securement forces are plotted as a function of impact speed in Figures 17 and 18. Figure 17 shows the results for the Configuration 4A tests and Figure 18 for the Configuration 4B tests. The peak trailer hitch pin forces are significantly larger for the A end impacts than for the B end impacts. The container support forces could only be measured for the B end impacts. They show that a peak force of 149 kips was reached at the 10.1 mph impact speed on the Configuration 4A tests. This exceeds the 135 kip test load given in AAR Specification M-952. The maximum container support force was slightly lower for the Configuration 4B tests where there was increased outage in the intermodal tank.

The maximum longitudinal acceleration measurements on the flat car occurred shortly after the initial impact of the cars on the B end impact tests. On the A end impact tests the maximum longitudinal acceleration generally occurred when the end-of-car cushioning device was close to the end of its stroke. There were very large fluctuations in the coupler force at this time. The accelerometer records show a strong response at approximately 70Hz and the peak values generally occurred at this frequency. A lower frequency component of acceleration is also evident which is similar to the coupler force record. The maximum values of this component of acceleration have been estimated and are included in the tabulated results.

There is some evidence that liquid sloshing is affecting the dynamic behavior of the impact although the effects appear to be less than on the Configuration 2 and 3 tests. The number of cases where the low frequency component of longitudinal acceleration can be compared with the acceleration implied by the ratio of the maximum coupler force to the mass of the test car are less than on other test series. There are two reasons for this, the lack of coupler force data on Test Run Nos. 18 to 21 and the large high frequency component of the accelerometer records on Test Run Nos. 25, 32 and 33. On most of the remaining test runs the low frequency component of the acceleration is significantly larger than the acceleration which would be expected considering the maximum coupler force and the gross weight of the test car. This indicates a lag in coupling of the inertial force of the liquid to the deceleration of the flat car. There is, however, generally less than a 0.1 sec lag in the development of the maximum hitch pin and container securement forces and the maximum coupler force. There is a significant reduction in the longitudinal container securement forces on the Configuration 4B tests in comparison with the Configuration 4A tests only on the 10 mph impact.

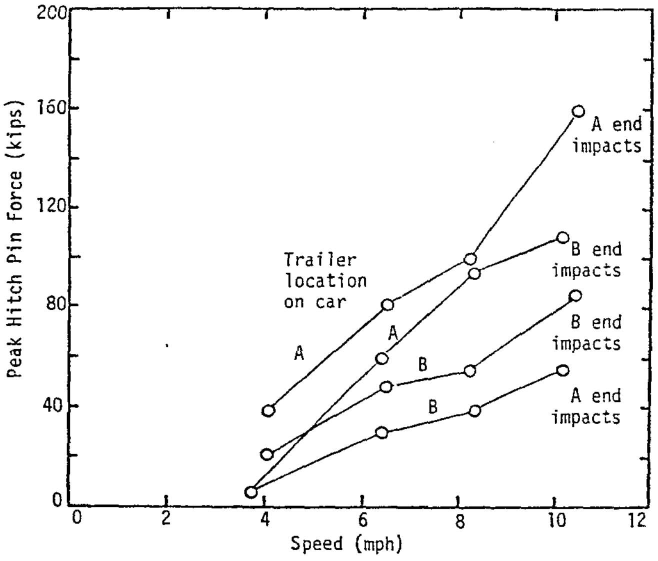


a. Peak Trailer Hitch Pin Forces Vs. Impact Speed

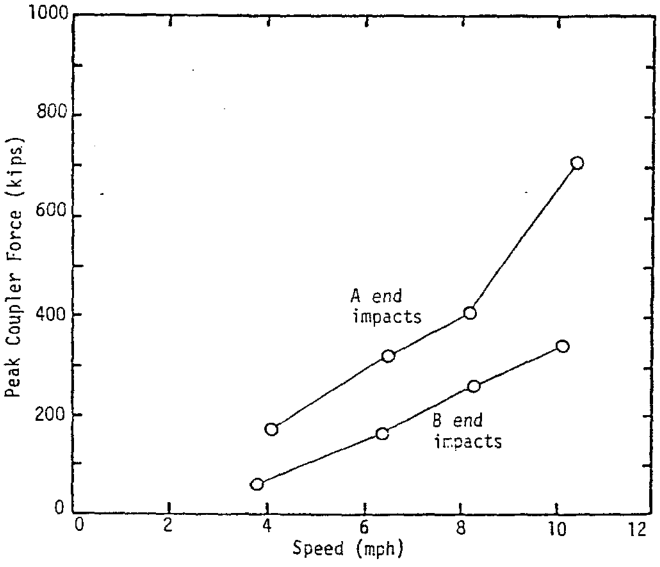


b. Peak Coupler Force Vs. Impact Speed

FIGURE 15. CONFIGURATION 3A TEST RESULTS



a. Peak Trailer Hitch Pin Forces Vs. Impact Speed



b. Peak Coupler Force Vs. Impact Speed

FIGURE 16. CONFIGURATION 3B TEST RESULTS

This indicates that the increased outage in the container in the 4B tests did not have a significant effect in this test series.

The records from the vertical accelerometer on the flat car show several frequencies of vibration are present. The records show a strong response at approximately 70Hz. Components at approximately 7 and 20Hz also are present during some impacts. The maximum values are associated with the 70Hz oscillation and were within approximately ±2g on the tests with B end impacts. On the A end impact tests the maximum vertical accelerations ranged between approximately ±1g at 4 mph to ±4g at 10 mph.

4.4 CONFIGURATION 4C AND 4D TESTS

The results for the Configuration 4C and 4D tests are summarized in Table 6. The peak coupler and container securement forces are plotted as a function of impact speed in Figures 19 and 20. Figure 19 shows the results for the Configuration 4C tests and Figure 20 for the Configuration 4D tests. The position of the container on the flat car was changed between the A end and B end impacts so that the container securement forces could be measured for both directions of impact. The container was always located opposite the impacting end of the car.

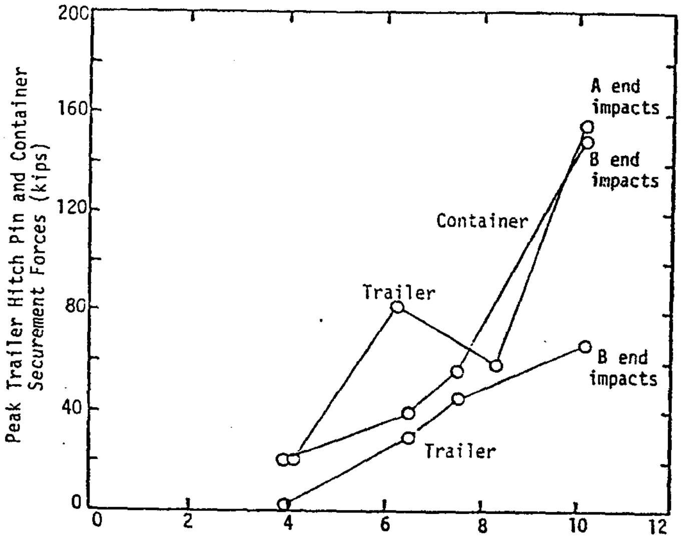
The results were similar to Configuration 4A and 4B tests. The peak container securement forces were significantly larger for the A end impacts. A peak force of 209 kips was reached at the 10.0 mph impact on the Configuration 4C tests. This exceeds by a large margin the 135 kip test load given in AAR Specification M-952 and the 157 kip container securement design load given in AAR.600-19b. These loads were also exceeded in the 10 mph B end impact test, but not by as large a margin. The maximum container support forces were significantly lower for the Configuration 4D tests where there was increased outage in the intermodal container tank. A peak force of 114 kips was reached on the 10.0 mph A end impact.

The records from the vertical accelerometer on the flat car show several frequencies of vibration are present. The records show a strong response at approximately 70Hz. Components at approximately 7 and 20Hz also are present during some tests. The maximum values are associated with the 70Hz oscillation and were within approximately ±4g on the 8 and 10 mph Configuration 4C tests with B end impacts. On the 4 and 6 mph tests at this condition, where there was some indication of erratic end-of-car cushioning performance, the values were slightly larger, ±6g. The maximum values associated with the Configuration 4C A end impacts were generally within ±4g and showed little speed dependence. The maximum vertical accelerations on the Configuration 4D tests showed little speed dependence in the 6 and 10 mph range. Maximum values were within the ±2g range for the B end impacts and ±6g for the A end impacts. Maximum values were approximately ±1g for the 4 mph test runs.

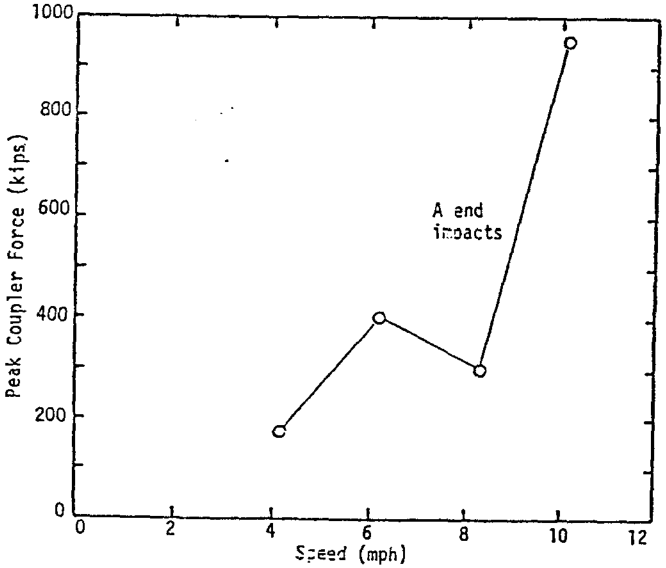
TABLE 5. SUMMARY OF RESULTS FROM CONFIGURATION 4A AND 4B TESTS

Test Configuration	Test Run No.	Impacting End of TTX Car	Impact Speed (mph)	Maximum Coupler Force (kips)	Maximum Hitch Pin Force (kips)	Maximum Container Pedestal Forces			Longitudinal Acceleration TTX Car		
						Right Side (kips)	Left Side (kips)	Sum (kips)	Maximum (g) A End	Maximum (g) B End	Average Maximum of Low Frequency Component (g)
4A	18	B	4.0	-	1	6	14	20	6.1	2.4	0.6
	19	B	6.5	-	29	13	26	39	7.1	5.7	1.6
	20	B	7.5	-	45	24	32	56	9.6	15.2	2.6
	21	B	10.1	-	66	81	68	149	10.0	16.6	3.4
4A	30	A	4.2	176	20	-	-	-	1.8	4.4	1.6
	31	A	6.2	400	81	-	-	-	5.5	3.5	3.3
	32	A	8.3	300	58	-	-	-	5.5	4.4	*
	33	A	10.1	960	155	-	-	-	7.1	4.4	*
4B	34	B	3.8	68	3	4	6	10	1.7	2.2	0.3
	35	B	5.7	168	18	19	21	40	3.2	3.2	1.2
	36	B	8.2	300	43	40	47	87	5.5	3.4	1.9
	37	B	10.1	420	52	50	70	120	6.7	4.9	3.6
4B	22	A	4.1	98	14	-	-	-	5.2	1.7	1.0
	23	A	6.1	230	37	-	-	-	3.7	3.6	1.8
	24	A	8.1	390	73	-	-	-	5.5	18.0	3.8
	25	A	10.0	770	144	-	-	-	9.2	18.0	*

*Impossible to estimate because of high amplitudes of high frequency components of records



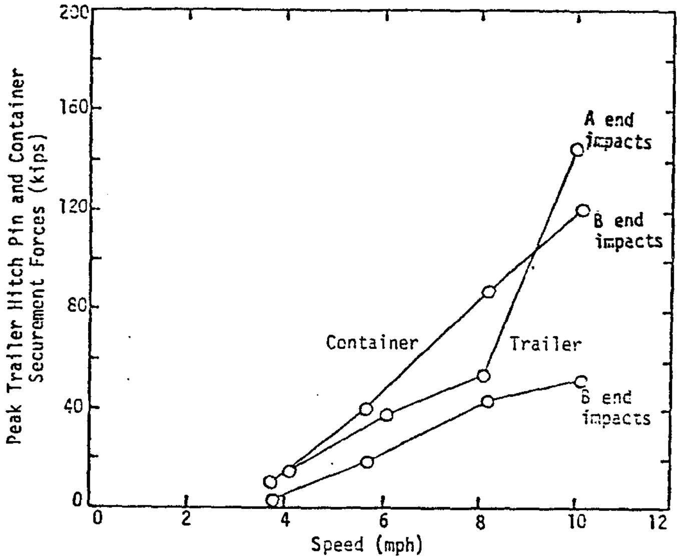
a. Peak Trailer Hitch Pin and Longitudinal Container Securement Forces Vs. Impact Speed



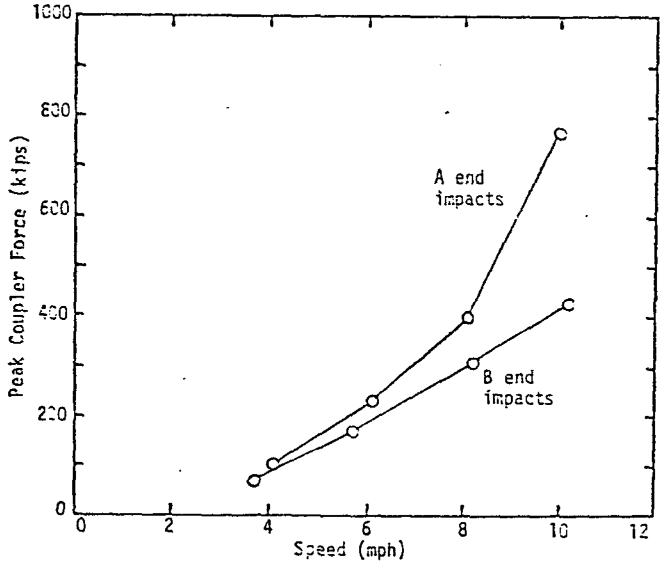
b. Peak Coupler Force Vs. Impact Speed

FIGURE 17. CONFIGURATION 4A TEST RESULTS

The maximum longitudinal acceleration measurements on the flat car occurred shortly after the initial impact of the cars on the B end impact tests, except for the test runs 38 and 39 where there was an indication of erratic behavior of the end-of-car cushioning unit. On the A end impact tests the maximum longitudinal accelerations generally occurred when the end-of-car cushioning device was close to the end of its stroke. There were very large fluctuations in the coupler force at this time. The accelerometer records show a strong response at approximately 70Hz and the peak values generally occurred at this frequency. A lower frequency component of acceleration is also evident which is similar to the coupler force record. The maximum values of this component of acceleration have been estimated and are included in the tabulated results.



a. Peak Trailer Hitch Pin and Longitudinal Container Securement Forces Vs. Impact Speed



b. Peak Coupler Force Vs. Impact Speed

FIGURE 18. CONFIGURATION 4B TEST RESULTS

TABLE 6. SUMMARY OF RESULTS FROM CONFIGURATION 4C AND 4D TESTS

					Maximum Container Pedestal Forces			Longitudinal Acceleration TTX Car		
Test Configuration	Test Run No.	Impacting End of TTX Car	Impact Speed (mph)	Maximum Coupler Force (kips)	Right Side (kips)	Left Side (kips)	Sum (kips)	Maximum (g) A End	Maximum (g) B End	Average Maximum of Low Frequency Component (g)
4C	38	B	4.2	270	44	44	88	5.7	5.1	*
	39	B	6.0	380	52	57	109	8.7	7.1	*
	40	B	8.1	300	44	51	95	3.9	3.9	2.0
	41	B	10.1	530	70	93	163	4.3	4.3	2.9
4C	46	A	4.3	180	24	16	40	1.7	1.9	1.1
	47	A	6.5	400	37	34	71	4.3	5.6	2.5
	48	A	7.9	470	41	33	74	9.7	12.7	2.2
	49	A	10.0	860	107	102	209	6.7	13.9	4.2
4D	42	B	4.2	108	6	3	9	2.2	4.8	0.7
	43	B	6.0	148	10	7	17	2.1	3.0	1.3
	44	B	7.7	280	19	19	38	3.5	3.4	2.1
	45	B	10.1	420	35	43	78	4.1	4.1	2.9
4D	50	A	4.0	72	4	2	6	5.0	1.8	0.6
	51	A	6.1	350	23	20	43	4.2	4.5	3.2
	52	A	7.9	470	32	23	55	6.5	7.3	4.1
	53	A	10.0	860	61	53	114	9.2	-	*

*Impossible to estimate because of high amplitudes of high frequency components of records

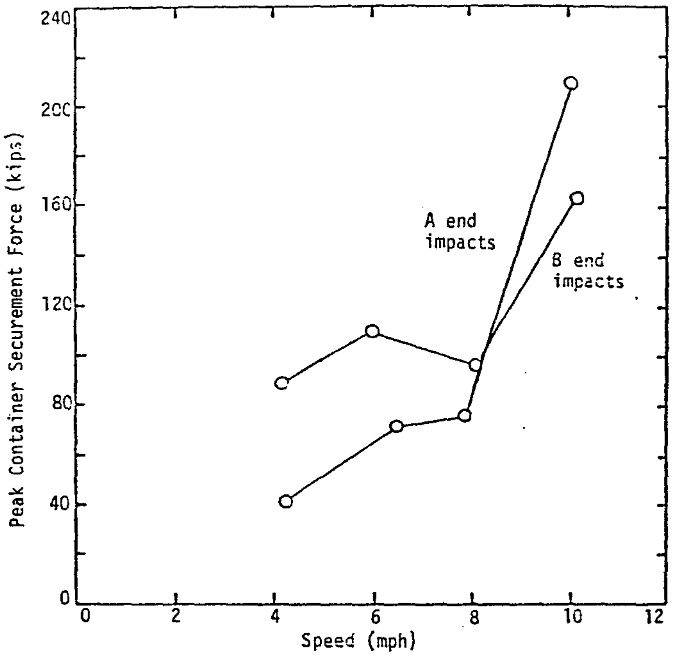
The data show that sloshing is affecting the dynamic behavior of the impact. This is evident from a comparison of the ratios of the maximum container securement force to the maximum coupler force under different test conditions. The weight of the container was approximately 35 percent of the total car weight on the Configuration 4C runs. The average force ratio was 0.31 on the B end impacts and 0.20 on the A end impacts. This indicates lower inertial coupling of the fluid within the tank on the A end impacts. The reduced coupling on the A end impacts is probably due to the large transients in the coupler force. The force ratio averaged only 0.12 on the Configuration 4D tests where there was a greater outage in the tank. This shows the reduced inertial coupling of the fluid with increased outage. On these tests the weight of the container was approximately 32 percent of the total weight of the car. Comparison of the force versus time records also shows that the container securement forces were closer to being in phase with the coupler force on the B end impacts than on the A end impacts.

4.5 CONFIGURATION 4E TESTS

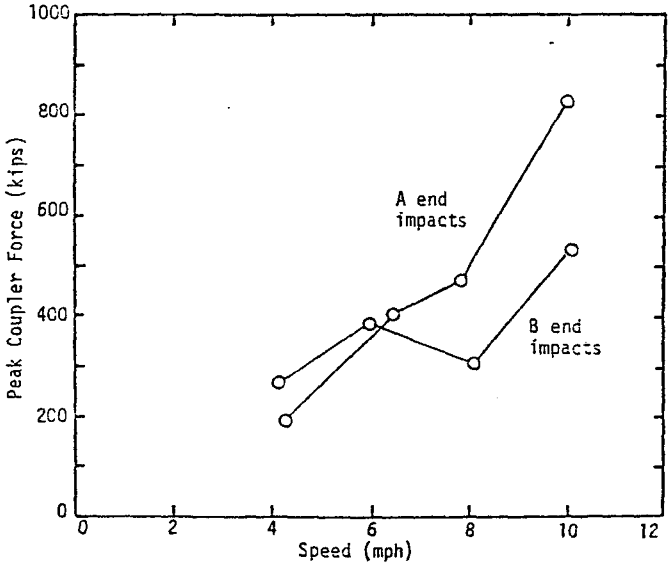
The results for the Configuration 4E tests are summarized in Table 7. The peak coupler and container securement forces are plotted as a function of impact speed in Figure 21.

As explained earlier, these tests were run to examine the reliability of the method for measuring longitudinal securement forces on the container. Two sets of test runs were made, one with the conventional placement of the container in the pedestal supports (termed dry pedestal supports) and the other with all friction surfaces in the pedestals lubricated with grease.

Comparing the results from the two sets of tests as presented in Figure 21 shows no significant differences in the maximum peak container securement forces for the dry and lubricated tests. This indicates that the load cell arrangement was not being significantly affected by the alternate path through the friction surfaces. It demonstrates the validity of the measurement of longitudinal container loads for other test configurations. Peak longitudinal container securement forces exceeded the 135 kip test load given in AAR Specification M-952 and the 157 kip container securement design load given in AAR.600-19b on the 8 and 10 mph impacts.



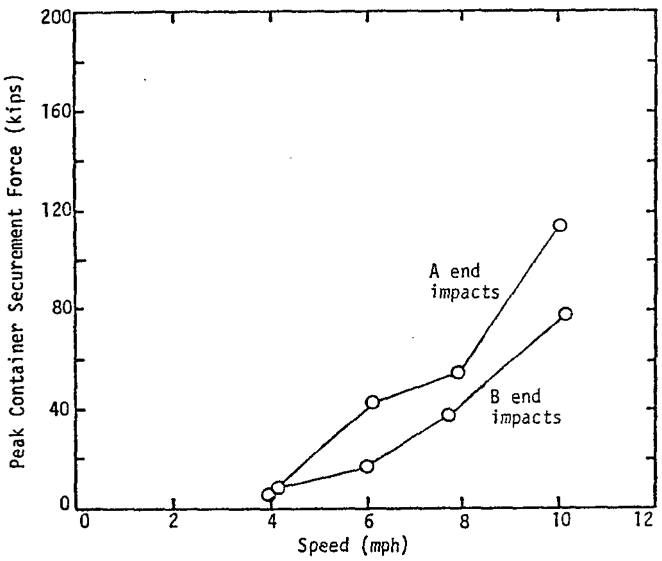
a. Peak Longitudinal Container Securement Force Vs. Impact Speed



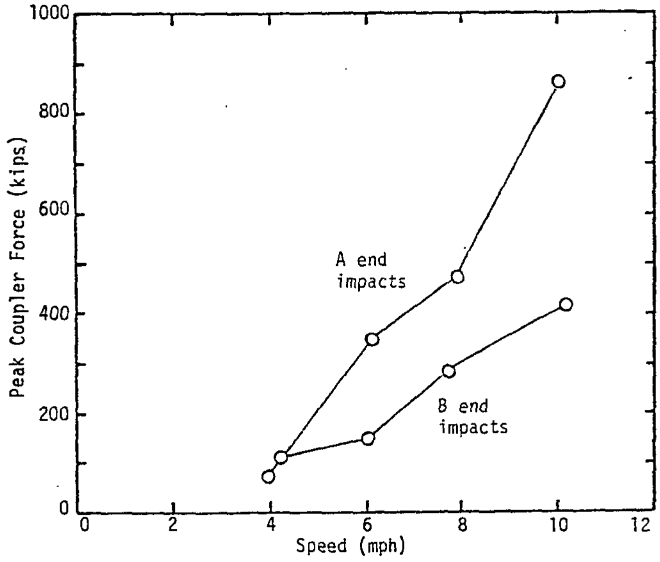
b. Peak Coupler Force Vs. Impact Speed

FIGURE 19. CONFIGURATION 4C TEST RESULTS

The peak coupler and container forces recorded on this test series are somewhat below those recorded on the A end impacts on the Configuration 4C tests although these are comparable test configurations. This cannot be completely explained. An examination of the coupler force-time record indicates a variety of responses to the impact load. The ratios of the maximum container securement force to the maximum coupler force are similar to those observed in the Configuration 4C A end impact tests indicating similarity in the coupling of the inertial load of the liquid in both test series.



a. Peak Longitudinal Container Securement Force Vs. Impact Speed



b. Peak Coupler Force Vs. Impact Speed

FIGURE 20. CONFIGURATION 4D TEST RESULTS

TABLE 7. SUMMARY OF RESULTS FROM CONFIGURATION 4E TESTS

Test Configuration	Test Run No.	Impacting End of TTX Car	Impact Speed (mph)	Maximum Coupler Force (kips)	Maximum Container Pedestal Forces			Longitudinal Acceleration A End of TTX Car	
					Right Side (kips)	Left Side (kips)	Sum (kips)	Maximum (g)	Maximum of Low Frequency Component (g)
4E Dry Pedestals Supports	86	A	3.5	31	2	4	6	3.2	0.3
	87	A	4.2	47	8	5	13	1.7	0.8
	88	A	5.8	162	34	24	58	5.9	1.3
	90	A	6.3	190	47	36	83	4.4	1.7
	89	A	6.9	260	53	46	99	6.7	2.5
	92	A	8.2	340	78	68	146	13.0	3.4
	91	A	10.2	290	78	68	146	9.9	2.7
4E Lubricated Pedestal Supports	93	A	3.3	33	7	3	10	4.2	0.3
	94	A	5.6	-	32	23	55	10.5	1.0
	97	A	6.6	250	54	46	100	4.4	2.7
	96	A	6.9	-	54	43	97	4.2	2.7
	95	A	7.3	-	66	53	119	5.5	2.5
	98	A	8.5	440	82	75	157	6.3	3.6
	99	A	10.7	380	80	81	161	8.4	3.8

The characteristics of the longitudinal and vertical TTX car body acceleration data are similar to that observed on the A end impact Configuration 4C and 4D tests.

4.6 CONFIGURATION 6 TESTS

The results from the Configuration 6 tests are summarized in Table 8. Peak coupler forces are plotted in Figure 22. Instrumented hitch pins could not be used on these tests. Peak coupler forces are significantly larger for A end impacts than for B end impacts.

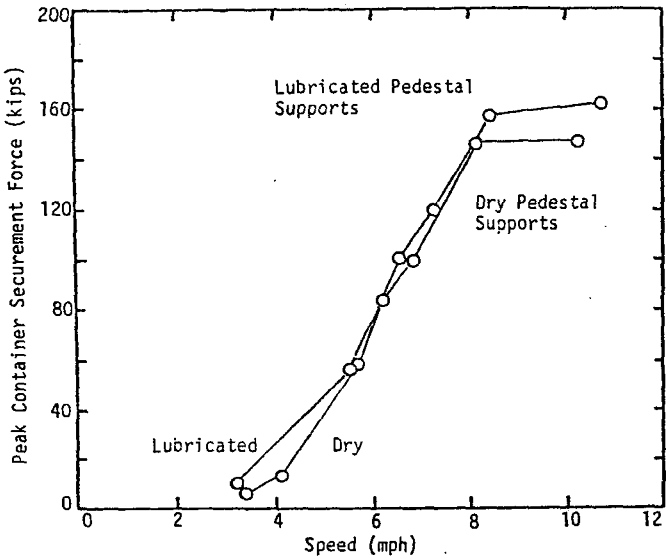
The maximum longitudinal acceleration measurements on the flat car occurred shortly after the initial impact of the cars on the B end impact tests. On the A end impact tests the maximum longitudinal acceleration generally occurred when the end-of-car cushioning device was close to the end of its stroke. There were large fluctuations in the coupler force at this time. The accelerometer records show a strong response at approximately 70Hz and the peak values generally occurred at this frequency. A lower frequency component of acceleration is also evident which is similar to the coupler force record. The maximum values of this component of acceleration have been estimated and are included in the tabulated results.

The records from the vertical accelerometer on the flat car show several frequencies of vibration are present. The records show a strong response at approximately 70Hz. Components at approximately 11 and 20Hz also are present during some tests. The maximum values were associated with the 70Hz oscillation and were within approximately ±6g.

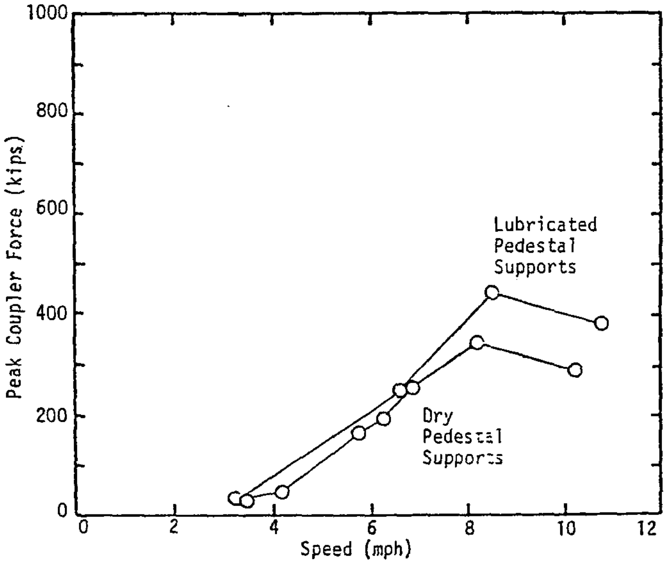
The records from the vertical accelerometer mounted at the tandem axles on the A end bogie show a response that is predominately at 70Hz. A second response at approximately 10Hz is evident on some records at the time when the maximum coupler force is reached. The maximum values given in Table 8 are associated with the 70Hz frequency.

4.7 CONFIGURATION 7 TESTS

The results for the Configuration 7 tests are summarized in Table 9. Peak coupler and container securement forces are shown in Figure 23. The objective of this test was to develop a 4g longitudinal load at the container pedestal supports. This would require the development of a 197 kip load for the loaded intermodal container which was used in the tests. The data shows that the maximum longitudinal load which was achieved was 153 kips. Tests were conducted at speeds up to 11.2 mph. Tests were not conducted beyond this speed because of the danger of a derailment. The plot of peak coupler forces shows that the maximum impact force was achieved on the 9.3 mph impact. Figure 23 also shows the peak coupler force which occurred when the hopper and flat car struck the standing cars.



a. Peak Longitudinal Container Securement Force Vs. Impact Speed



b. Peak Coupler Force Vs. Impact Speed

FIGURE 21. CONFIGURATION 4E TEST RESULTS

The maximum longitudinal accelerations measured on the flat car occurred either shortly after the initial impact of the car or when the maximum coupler force was attained as the end-of-car cushion unit reached the end of its stroke. The accelerometer record shows a strong response at approximately 70Hz and the peak values occurred at this frequency. A lower frequency component of acceleration is also evident on the records which is similar to the coupler force record. The maximum values of this component of acceleration have been estimated and are included in the tabulated results.

It is interesting to note that on Test Run No. 104 the estimate of the maximum low frequency component of longitudinal acceleration of the car is 4.2g which is above the desired 4g test condition. The estimate of maximum acceleration using the maximum coupler force (first impact) and the gross weight of the car (120,000 lbs) is 3.9g. However, the maximum longitudinal load measured at container pedestals represents only a 3.1g load based on the loaded weight of the container (49,300 lbs). This shows that some sloshing of the liquid is taking place which spreads out the inertial load. This tends to reduce the peak longitudinal load on the container.

The records of the vertical accelerometers on the flat car show that several frequencies of vibration are present. The accelerometers show a strong response at approximately 70Hz. Components at approximately 20 and 35Hz also appear during some tests. The maximum values were associated with the 70Hz oscillation and range from approximately ±1g on the 4 mph impact to ±4g on the 10 mph test (first impact data).

4.8 ADDITIONAL RESULTS

4.8.1 TRAILER AND CONTAINER DAMAGE

The trailers and containers used in the tests sustained only minor apparent damage. The jackets on both tank trailers separated at the second seam from the front of the trailer. This is shown in Figure 24. The separation was greater on the trailer that was used in the Configuration 2, 3 and 4 tests. The displacement exceeded the distance the jacket sheets were overlapped. When the impact direction was reversed, the jacket sheets butted against each other and began to tear. The jacket on the second trailer, which was used only in the Configuration 3 tests, also showed jacket displacement at this seam location, but the movement was not sufficient to separate the jacket sheets. When the impact direction was reversed, the jacket on this trailer moved back towards its normal position.

Intermodal Container FR 2075 sustained minor damage to the gusset plates connecting the lower framework members to two of the transverse partitions. This is shown in Figures 25 and 26. Longitudinal load on this container is taken in shear through relatively thin partitions which are attached to the tank. These partitions are fairly flexible and obviously displace under severe longitudinal loads. At the bottom of the

TABLE 8. SUMMARY OF RESULTS FROM CONFIGURATION 6 TESTS

Test Configuration	Test Run No.	Impacting End of TTX Car	Impact Speed (mph)	Maximum Coupler Force (kips)	Longitudinal Acceleration TTX Car			Maximum Vertical Acceleration of A End Bogie at Tandem Angle (g)
					Maximum (g) A End	Maximum (g) B End	Average Maximum of Low Frequency Component (g)	
6	59	B	3.9	88	1.9	2.4	0.7	2.0
	60	B	6.0	184	3.8	3.9	1.6	6.4
	61	B	7.8	280	4.1	4.5	2.1	4.6
	62	B	10.0	410	4.1	5.8	3.1	6.1
6	54	A	3.5	92	0.9	1.0	0.6	1.9
	55	A	6.0	400	4.2	3.9	2.3	3.1
	56	A	7.9	480	8.8	15.6	*	4.1
	57	A	9.8	750	8.4	12.2	7.3	9.6

*Impossible to estimate because of high amplitude of high frequency component of record

container there are four thin gusset plates which connect the partitions at each end of the container to the bottom corner framework members. There was some bending in these gusset plates indicating that there had been some displacement of the partitions.

There are also several small tabs which run in the longitudinal direction between vertical framework members and the shell of the tank. These cannot tolerate much deflection and there was some indication of damage to the welds on these tabs. In addition, several of the framework members were bent slightly. This was most noticeable on the central longitudinal member at the bottom of the container. However, it could not be positively determined that this member was bent during the tests. In any event, the distortion in these members was not severe enough to preclude use of the container.

There was no indication of any damage to the structural integrity of the tanks on either the tank trailers or the IM containers.

One potential problem with both the tank trailers and containers is maintaining the integrity of the vents and valves under impact conditions. The fusible link vents on both the tank trailers (which open under high temperature) failed during the tests and released water. The bottom outlet valve on Container FR 2074 was damaged during the tests which allowed slight leakage to take place. The safety relief valve on the FRA container (US 2272) also allowed liquid to come out during the liquid surge associated with the impact.

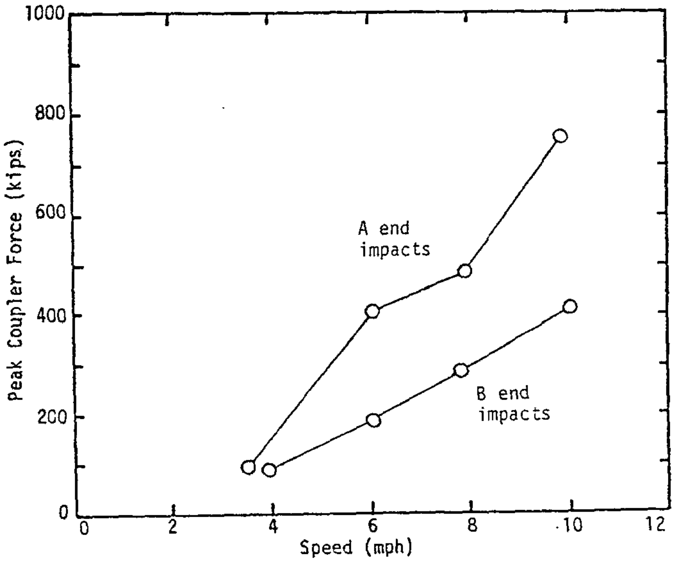


FIGURE 22. CONFIGURATION 6 TEST RESULTS

TABLE 9. SUMMARY OF RESULTS FROM CONFIGURATION 7 TESTS

				Maximum Coupler Force		Maximum Container Pedestal Forces			Longitudinal Acceleration A End of TTX Car (First Impact)	
Test Configuration	Test Run No	Impacting End of TTX Car	Impact Speed (mph)	First Impact (kips)	Second Impact (kips)	Right Side (kips)	Left Side (kips)	Sum (kips)	Maximum (g)	Maximum of Low Frequency Component (g)
7	103	A	3.7	47	260	4	7	11	1.8	0.4
	100	A	4.0	65	340	7	5	12	3.6	0.4
	101	A	6.0	91	410	20	20	40	4.2	1.3
	102	A	7.8	270	490	53	51	104	4.0	1.9
	104	A	9.3	470	860	77	76	153	6.7	4.2
	105	A	9.7	380	850	74	72	146	7.1	3.4
	106	A	11.2	410	910	77	75	152	6.5	3.8

4.8.2 EFFECT OF END-OF-CAR CUSHIONING DEVICE ON SECUREMENT FORCES

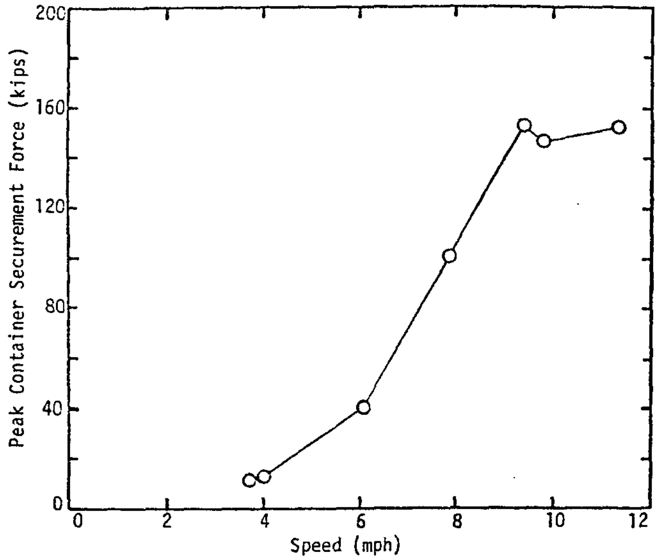
The trailer and container securement forces were significantly different for impacts on the A and B ends of the flat car, the forces being greater for A end impacts. This indicated that the properties of end-of-car cushioning devices were considerably different at each end of the car.

The differences in the performance of the end-of-car cushioning devices are evident from the coupler force-time records presented in Figures 27 and 28. Figure 27 is for B end impacts and Figure 28 is for A end impacts. Note that on the B end impacts the coupler force builds up to a nearly constant level as the cushioning device is displaced. As the speed of the impact increases the maximum forces are larger and the duration of the force becomes shorter. The A end impact data shows a completely different set of force-time characteristics. On the 2 and 4 mph impacts there is a rapid increase in force as the cushioning device reaches the end of its stroke. On the 8 mph impact there are rapid fluctuations in the force as the cushioning device nears the end of its stroke. On the 10 mph impact the force builds up to about 400 kips. Then there is a rapid drop off in force followed by a sudden increase as the cushioning device reaches the end of its stroke. These general characteristics in the force-time records were noted on all of the tests where the instrumented coupler provided data.

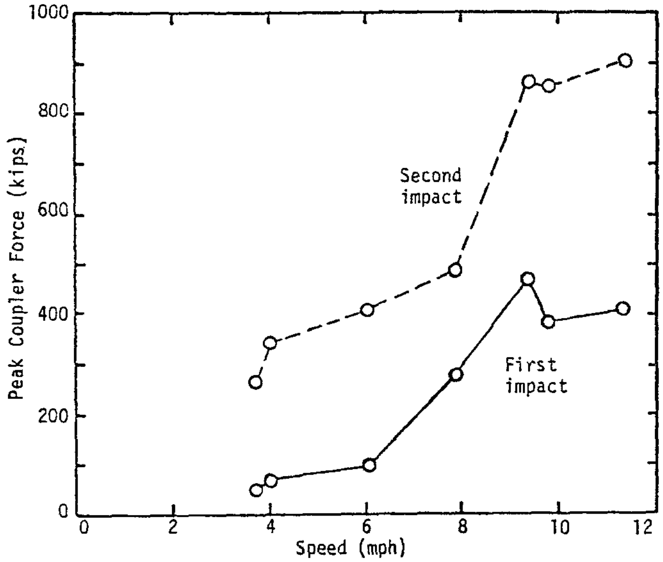
The difference in the performance of end-of-car cushioning devices raises a potential problem with securing trailers and containers on flat cars. The design criteria for the securement system is based on a properly functioning end-of-car cushioning device. If it is not working properly, the loads may be considerably higher under impact conditions and could cause failures in the securement system. End-of-car cushioning devices can have degraded properties even though there is no visible indication of damage. A visual examination is routinely performed to check for damage and cracking only.

4.8.3 CHASSIS DAMAGE

There was minor damage to the bogie chassis for Container FR 2074. A crack developed in a weld on a front diagonal member. This member reinforces the framework connecting the front part of the container support to the member which extends forward to the hitch connection. The damage is shown in Figures 29 and 30.



a. Peak Longitudinal Container Force Vs. Impact Speed



b. Peak Coupler Force Vs. Impact Speed

FIGURE 23. CONFIGURATION 7 TEST RESULTS

FIGURE 24. ILLUSTRATIONS OF JACKET DAMAGE ON TANK TRAILER

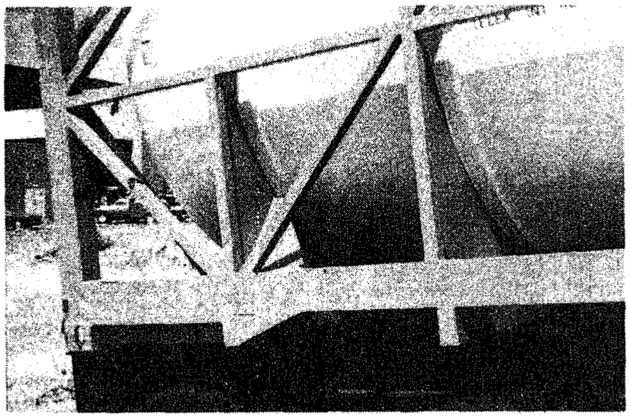


FIGURE 25. LOCATION OF GUSSET PLATE ON CONTAINER FR 2074

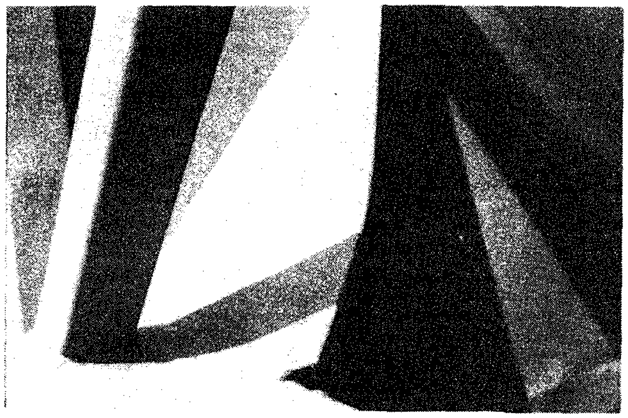


FIGURE 26. DAMAGE TO GUSSET PLATE ON CONTAINER FR 2074

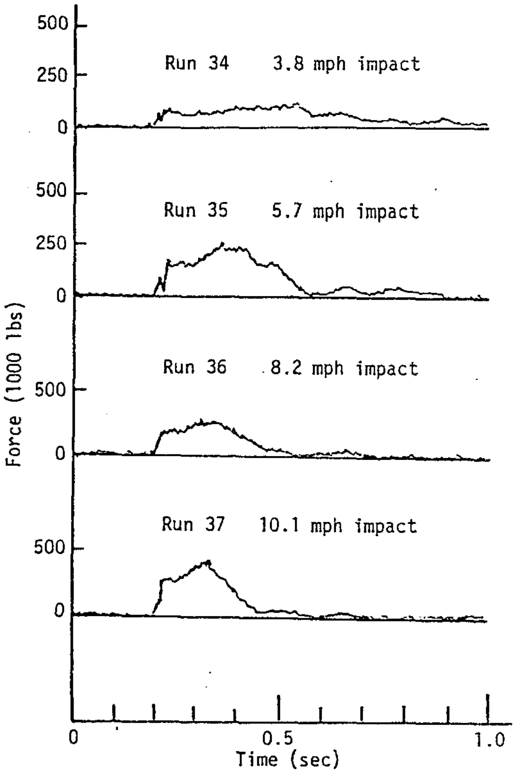


FIGURE 27. COUPLER FORCE VERSUS TIME RECORDS FROM CONFIGURATION 4B, B END IMPACT TESTS

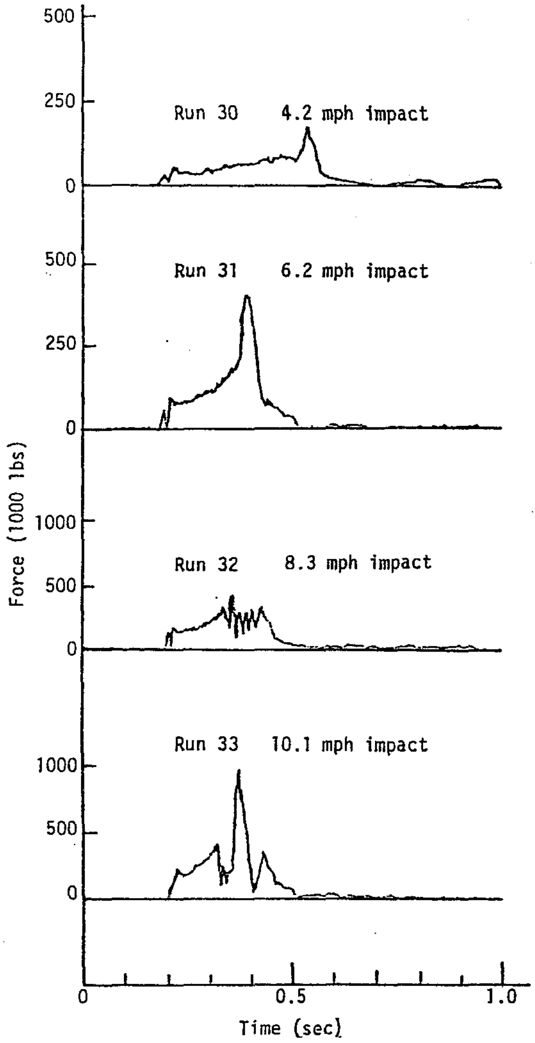


FIGURE 28. COUPLER FORCE VERSUS TIME RECORDS FROM CONFIGURATION 4A, A END IMPACT TESTS

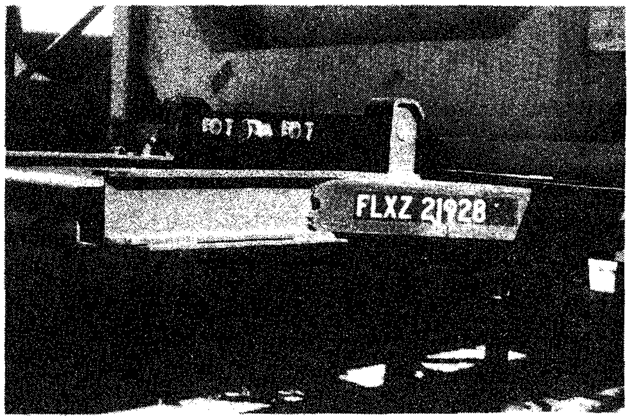


FIGURE 29. HITCH END OF INTERMODAL CONTAINER BOGIE SHOWING REGION OF DAMAGE

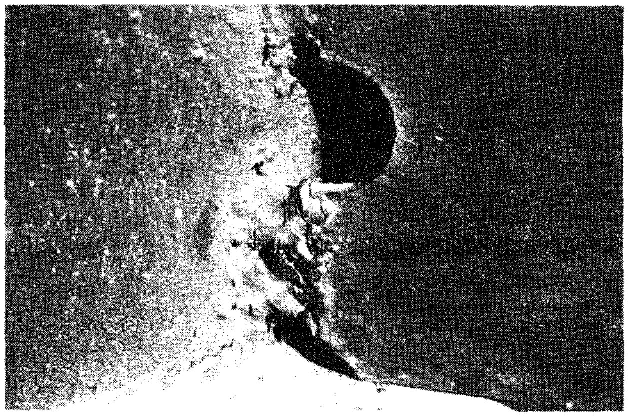


FIGURE 30. DETAIL OF CRACK IN WELD ON BOGIE

5. TRAILER LIFT AND DROP TESTS

5.1 INTRODUCTION

The potential for accumulating damage on a tank trailer during loading and unloading was assessed by performing the lift and drop tests. Both tests were concerned with establishing the deflection curve of the trailer under different loading situations in order to gain an indication of the dynamic and static response of the structure. The tests were based in part on procedures described in AAR M-931 for highway trailers used in TOFC service.

5.2 LIFT TESTS

The objective of the lift test was to establish the deflection curve of the tank trailer under both loaded and empty conditions when supported at the tandem axles and support legs, at the king pin and tandem axles and at the trailer lifting pads. The trailer was instrumented with eight vertical displacement transducers which measured the distances between their points of attachment and ground. These transducers and their locations are designated as follows:

Displacement Transducer No.	Location
	On Longitudinal Centerline of Trailer:
1	At hitch
2	7.6 ft to rear of hitch
3	20.35 ft to rear of hitch
4	41.95 ft to rear of hitch (rear end of trailer)
	At Jacking Pads:
5	Hitch end right side
6	Hitch end left side
7	Tandem end right side
8	Tandem end left side

Jacks were positioned at each jacking pad. An eight channel strip recorder was used to record displacement data.

Displacement measurements were made under six different test configurations which are defined as follows:

Configuration	Vehicle Support Condition
A	Trailer empty supported by tandem axles and support legs
B	Trailer empty supported by jacks under king pin and tandem axles
F	Trailer empty supported by jacks at lifting pads
C	Trailer full supported by tandem axles and support legs
D	Trailer full supported by jack at king pin and tandem axles
E	Trailer full supported by jacks at lifting pads

In the loaded condition the trailer was fully loaded with water. It was not possible to load the trailer to 1.7 times the nominal maximum gross weight as required by the AAR specification.

The displacement data obtained for each of the above configurations is presented in Table 10. There was no apparent change in the deflection curve between the loaded and unloaded condition that was indicated within the accuracy of the displacement measurements for the case when the trailer was supported by the tandem axles and support legs. This is indicated by the data plotted in Figure 31 which compares the average displacement data for Configurations A and C. The loaded trailer data is shown with reference to the empty trailer data. Only a rigid body displacement is indicated. Figure 32 compares the average displacement data for Configurations B and D, the trailer supported at the king pin and by the tandem axles. The loaded trailer data is shown with reference to the empty trailer data. The major effect is again a rigid body displacement, but there is a slight curvature in the loaded trailer deflection curve at the tandem axle end of the trailer. Figure 33 compares the average displacement data for Configurations E and F, the trailer supported at the lifting pads. The loaded trailer data is shown with reference to the empty trailer data. The major effect is a rigid body displacement with a slight increase in the curvature of the deflection curve. There was no indication of damage to the trailer from any of the lift tests.

TABLE 10. LIFT TEST DATA

Run No.	Configuration	Displacement Transducer Measurement with Reference to Ground (in.) 1	2	3	4	5	6	7	8
1	A	0.00	0.00	0.00	0.00	-	-	-	-
2	B	1.00	0.80	0.30	-0.20	-	-	-	-
3	A	0.00	0.00	0.00	0.00	-	-	-	-
4	B	1.30	1.00	0.50	-0.22	-	-	-	-
5	A	0.00	0.00	0.00	0.00	-	-	-	-
6	B	1.00	0.73	0.35	-0.28	-	-	-	-
7	A	0.00	0.00	0.00	0.00	-	-	-	-
8	F	1.72	1.70	1.60	1.85	2.20	2.20	2.10	1.73
9	A	0.00	0.00	0.00	0.10	-0.15	-0.35	-0.20	-0.35
10	F	1.70	1.70	1.60	1.82	2.20	2.14	2.05	1.70
11	A	0.00	0.00	0.00	0.18	-0.34	-0.60	-0.40	-0.52
12	C	0.24	0.05	-0.32	-1.04	-0.19	-0.10	-0.90	-0.72
13	D	1.80	1.10	-0.10	-1.60	-0.19	-0.10	-1.60	-1.20
14	C	0.30	0.10	-0.40	-1.00	-2.10	-2.30	-3.60	-3.00
15	E	3.40	3.00	2.40	1.80	1.60	1.80	0.10	0.40
16	C	0.35	0.10	-0.25	-1.00	-2.20	-2.40	-3.80	-3.10
17	D	1.82	1.13	0.00	-1.60	-2.85	-3.10	-4.40	-3.67
18	C	0.46	0.20	-0.35	-1.20	-	-	-	-
19	E	3.55	3.20	2.60	2.00	1.80	1.80	0.20	0.40
20	C	0.40	0.20	-0.20	-0.80	-2.70	-3.00	-4.30	-3.60

Note: + Up; - Down

5.3 DROP TESTS

This test was based on the procedures outlined in Section 6.7.2 of AAR M-931. The trailer support legs were extended to position the king pin support plate 46 to 48 in. above the test surface. The front end of the trailer was then supported by a tractor and elevated until the support legs were 3 to 3-1/2 in. above the test surface. The tractor did not engage the king pin. It extended under the front of the trailer the minimum distance required to support the trailer in a static condition. The tractor was then accelerated abruptly permitting the trailer to drop. The trailer landing gear impacted on a 1.5 in. thick pad of asphalt rolled on top of a concrete shop floor. After each drop test the landing gear and trailer were inspected thoroughly. The trailer was instrumented with vertical displacement transducers at the rear of the trailer 41.95 ft from the king pin, at the king pin, and at 20.35 ft from the king pin. Vertical displacements of the trailer body were recorded. The drop procedure was performed three times with the trailer empty (trailer weighing approximately 15,000 lbs), three times loaded with 3,450 gallons of water and twice loaded with 6,900 gallons of water. It should be noted that the 6,900 gallon water load resulted in a load on the support legs somewhat in excess of the 32,500 lb load used in the AAR M-931 test specification.

Vertical displacement data are presented in Table 11. During the first three drop tests, while the trailer was empty, it appeared that the support legs were telescoping inside themselves during impacts. This was evident by the gear crank turning at impact. It was further indicated by the vertical displacement data. The support legs were initially a maximum distance of 3-1/2 in. above the ground, but the trailer dropped well over 4 in. The displacement data also show that the rear (tandem axles) end of the trailer lifted when the front end dropped. When the trailer was loaded with water the displacements increased. After the first three test runs damage to the landing feet was noticed as shown in Figure 34.

TABLE 11. DROP TEST DATA

Test Run No.	Load	Vertical displacement (in.) Pos. 1	Pos. 2	Pos. 3
1	Empty	-	-	1.00
2	Empty	-4.21	-2.30	1.00
3	Empty	-4.30	-2.25	1.20
4	3,450 Gal	-	-2.44	1.30
5	3,450 Gal	-5.00	-2.60	1.42
6	3,450 Gal	-4.65	-2.40	1.40
7	6,900 Gal	-	-2.80	1.80
8	6,900 Gal	-6.50	-2.90	1.80

Note: + Up; - Down
Displacement measurement locations, 1 at king pin, 2 at 20.35 ft from king pin; 3 at tandem axle

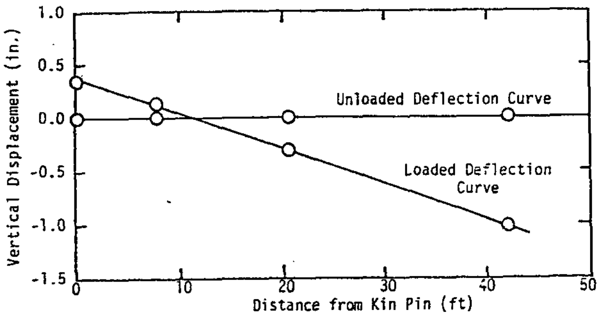


FIGURE 31. COMPARISON OF UNLOADED AND LOADED DEFLECTION CURVES, TRAILER SUPPORTED AT SUPPORT LEGS AND TANDEM AXLES

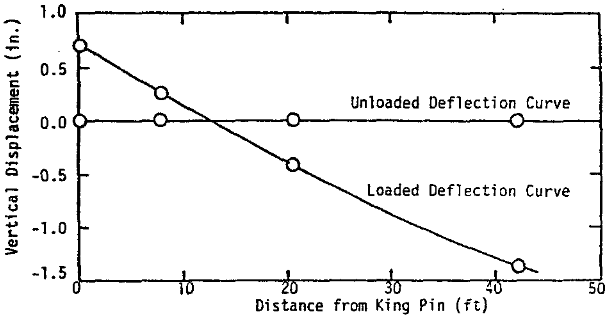


FIGURE 32. COMPARISON OF UNLOADED AND LOADED DEFLECTION CURVES, TRAILER SUPPORTED AT KING PIN AND TANDEM AXLES

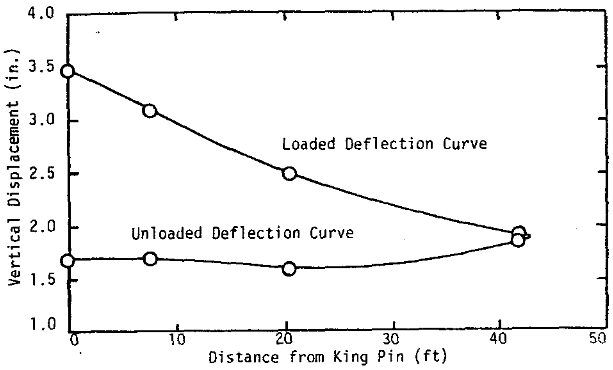


FIGURE 33. COMPARISON OF UNLOADED AND LOADED DEFLECTION CURVES, TRAILER SUPPORTED AT LIFTING PADS

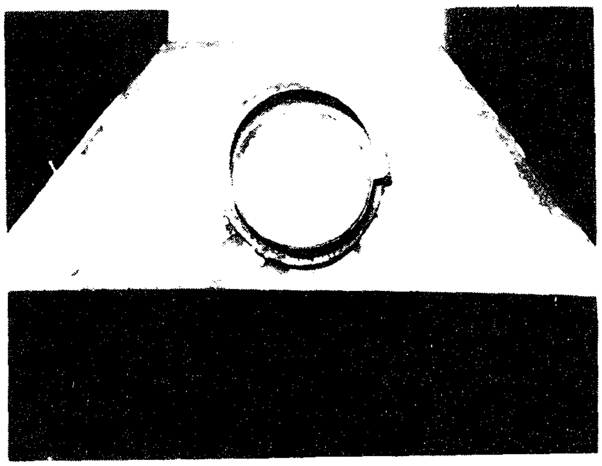


FIGURE 34. DAMAGE TO TRAILER SUPPORT FOOT AFTER THIRD TEST RUN

Test Runs Nos. 4, 5 and 6 were made with the trailer half full of water (3,450 gallons). During these drop tests the problems with the landing gear increased. Figure 35 shows the damage to the leg/foot connections. The entire support leg assembly bent so that it was no longer truly vertical. Internal damage within the support leg was also noticed.

On the last three drop tests, the trailer was fully loaded with 6,900 gallons of water. During these drop tests the first signs of damage to the trailer body appeared. Severe bending occurred at the top of the support legs where they connect to the trailer under carriage. The outer shell of the tank in the area was also damaged as shown in Figure 36. After the second fully loaded drop test, the support leg crank could not be turned in either high or low gear range. The leg framework was bent, the leg to foot connection was severely damaged and the up/down adjustment gear was left inoperable. The test was then terminated.

FIGURE 36. DAMAGE TO TRAILER TANK JACKET

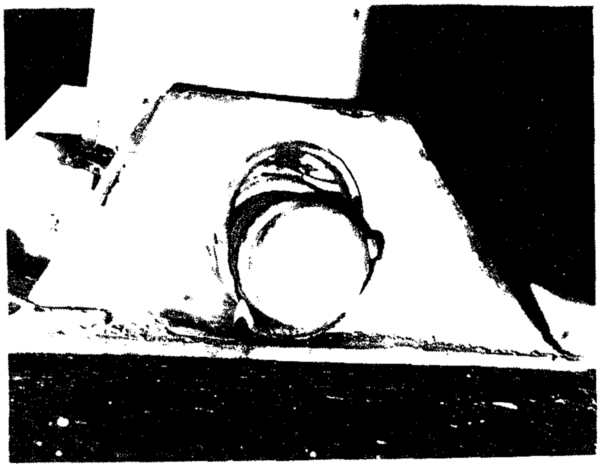


FIGURE 35. DAMAGE TO TRAILER SUPPORT FOOT AFTER SIXTH TEST RUN

6. CONCLUSIONS

6.1 SECUREMENT OF TRAILERS AND CONTAINERS TO FLAT CAR

One of the major objectives of the tests was to determine if there would be a tendency for the trailers and containers to become dislodged from the flat car during car coupling impacts. The force and displacement measurements as well as the visual observations indicated that the trailers and containers were secure at all impact speeds. It should be noted, however, that the 157 kip design load on the container pedestal supports given in AAR.600-19b was exceeded on some of the higher speed impacts, the forces being larger for A end impacts of the flat car. This was due to the poor performance of the end-of-car cushion unit on the A end of the car. It is presumed that there is an ample factor of safety in the design of the pedestal supports so that they can carry the extra load associated with this condition. There was no visible evidence of damage to the pedestal supports from these high loads developed during the tests.

6.2 TRAILER, CONTAINER AND CHASSIS DAMAGE

The car coupling impact tests produced only minor apparent damage on the trailers and containers used on the tests. The primary damage to the trailers was separation of the jacket sheets at one of the seams in the jacketing. One of the intermodal tank containers received minor damage to the gusset plates connecting the partitions which support the tank to structural members of the framework. Also, several small tabs which connect vertical framework members to the tank were damaged.

A potentially more serious problem with both the tank trailers and containers is the prevention of damage to the vents and valves under impact conditions. The fusible link vents on both the tank trailers (which open under high temperature) failed during the tests and released water. The bottom outlet valve on one of the containers was damaged which allowed slight leakage to take place. The safety relief valve on another container also allowed liquid to come out during the liquid surge associated with the impact.

There was minor damage to one of the bogie chassis. A crack developed in a weld on a front diagonal member which reinforces the framework connecting the front part of the container support to the member which extends forward to the hitch connection.

6.3 CONDITION OF END-OF-CAR CUSHIONING UNITS ON TTX CAR

The results of the tests revealed that an important factor which should be considered in the TOFC/COFC shipment of hazardous materials is the condition of the car on which the intermodal equipment is placed. The trailer and container securement forces were significantly larger for impacts on the A end of the car than on the B end. This showed that the properties of end-of-car cushioning devices were considerably different at each end of the car.

The differences in the performance of end-of-car cushioning devices raises a potential problem with securing trailers and containers on flat cars. The design criteria for the securement system is based on a properly functioning end-of-car cushioning device. If it is not working properly, the loads may be considerably higher under impact conditions and could cause failures in the securement system. End-of-car cushioning devices can have degraded properties even though there is no visible indication of damage. They are removed for repair only if there is visible indication of damage. They are not routinely checked to determine their performance characteristics.

A result of the poor performance of the end-of-car cushioning devices was that the container securement forces exceeded the criteria given in Specifications M-952 (135 kips) and AAR.600-19b (157 kips) for container pedestal design. The 157 kip load was exceeded on several of the 10 mph impact tests. It should be noted that there is an inconsistency between the load given in this specification and the requirements for tank integrity given in AAR.600-15. AAR.600-15 specifies that the tank container should withstand a longitudinal 4g load. In the case of Container US 2272, this would amount to a total longitudinal load of 197,000 lbs.

6.4 LIQUID SLOSHING EFFECTS

There was no increase in trailer or container longitudinal securement forces from liquid sloshing effects. The opposite result was found. There was alleviation of longitudinal forces when the outage in the tank was increased. The gross movement of the liquid takes place at a slower rate than the dynamic phenomena associated with the development of the maximum longitudinal forces. It therefore does not contribute to the magnitude of peak longitudinal force. The outage in the tank inhibits the coupling of the inertial load from the liquid into the container during the initial stages of the impact. This results in a considerable alleviation of the maximum load when the liquid level is decreased.

6.5 AAR.600 CONTAINER TESTS

The tests conducted in accordance with Specification AAR.600-15 were unable to develop the 4g longitudinal load specified in this test. Impact speeds up to 11 mph were used. Impact speeds above 11 mph were not attempted because of the danger of derailment.

This test involves impacting a heavy loaded car into a standing car loaded with a container. In this test the container was placed on a TTX car. The container was placed on the end of the car opposite the struck end. This had the potential of causing a derailment from the impact of the lightly loaded end of the car. Also, on the secondary impact, when the TTX car and the striking car coupled into the standing cars, which stopped the motion of the consist, there was danger of derailment. The lightly loaded TTX car was then squeezed between the two heavy cars.

The procedure described in AAR.600 did not produce the 4g longitudinal load that was required. It would be easier to develop this load if the container were placed on the striking car rather than on the anvil car. The type of draft gear or end-of-car cushioning device to be used on the standard car is left open in the specification. It may be desirable to specify that the car on which container is placed can be equipped with a standard draft gear. It would be easier to develop the required load under these conditions, although this would not be an acceptable configuration for the movement of the container in service since it would not be consistent with AAR Specification M-952.

The major reason for not developing the 4g load was the sloshing of the liquid in the tank. If the tank were shell full it may have been possible to develop the desired load, but the container would have been at a gross weight larger than the maximum allowable gross weight.

6.6 DROP TEST

The trailer drop test caused significant damage to the support legs of the trailer. It would appear that the test is more severe than required for this component of the trailer. While the test imposes severe loads on the support legs it does not impose correspondingly severe loads on the region of the trailer near the tandem axles. It would be desirable to develop a test procedure that would subject the entire trailer to shock motions.

6.7 RECOMMENDATIONS FOR QUALIFICATION TESTS

Based on the results of the test program a preliminary recommendation is made that a car coupling qualification test be considered for demonstrating the structural integrity of trailer and container tanks used to transport regulated commodities in TOFC/COFC service. This test could be conducted as follows. The tank trailer or container would be mounted on a flat car using standard positioning and securement techniques. This car would then be impacted into standing anvil cars, first at a speed of 4 mph, and then at increasing speeds, in 2 mph increments, until a longitudinal load on the trailer or container equal to 4 times its gross weight is developed and the impact speed is at least 8 mph. On tests with a tank trailer the longitudinal load would be measured at the trailer hitch. On tests with a IM tank container the longitudinal load would be measured at the pedestal supports. Two test series would be required with the orientation of the trailer or container on the flat car reversed from one test series to the next. The tank trailer or IM tank container should be filled so that there is at least 2, but no more than 5, percent outage in the tank. The test car would be impacted into three standing anvil cars each loaded to a minimum rail load of 220,000 lbs. The criteria for the successful completion of the test would be that no liquid is released from the tank and that there is no apparent structural damage which would preclude the use of the tank, the container support pedestal or trailer hitch, as applicable.

It is recognized that another major environmental factor which could lead to structural damage is the shock motions which occur during loading and unloading of the trailer or container on the railroad flat car. The only AAR tests that relate to this problem at the present time are the trailer lift/drop tests. The drop test subjects trailer support legs to severe loads and possible damage, but does not subject the rest of the structure to shock loads. Therefore, it would appear that more research is required before a suitable test can be recommended which would be used for qualifying both trailers and containers to withstand this environmental factor.