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Final Report

MAY 1989

EVT 8-89

EVALUATION OF PREFABRICATED ALUMINUM DUNNAGE IN A RAIL AND ROAD TRANSPORTATION ENVIRONMENT

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A. C. McIntosh, Jr.

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The U.S. Army Defense Ammunition Center and School (USADACS), Evaluation Division (SMCAC-DEV), has been tasked by the U.S. Naval Weapons Station, Earle to evaluate a Navy suggestion to use aluminum dunnage which can be recycled as a replacement for wood. This suggestion was developed at an overseas command where dunnage lumber is expensive and difficult to obtain. Railroad impact and truck transportation tests of differing 500-pound bomb load configurations restrained by different configurations of prefabricated aluminum dunnage were conducted. These tests were accomplished using a flatcar and a flat bed trailer.

All test configurations passed the road transportation tests. Rail impact tests: The bulkhead restraint was able to keep six bomb units in place up to

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19. Abstract (CONT)

6 miles per hour (mph) but started to deform (100 percent nailing). With 50 percent nailing, the bulkhead restraint unit became separated from the flatcar. Testing of the 'E' frame was unsuccessful because the unit load configuration was not rigid enough. End bracing for this unit is required.

The use of aluminimum dunnage which can be recycled has the potential of saving the Army and Navy lumber dunnaging expenses. In the case of road transportation, aluminum dunnage satisfied the road transportation tests.

A query of the overseas commands (Europe and Asia) should be made to assess the feasibility of using aluminum dunnage as an alternative for wood. The cost of lumber in Europe is expensive and the humid conditions of Asia cause wood to deteriorate and require constant maintenance.

U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL
Evaluation Division
Savanna, IL 61074-9639

REPORT NO. EVT 8-89

EVALUATION OF PREFABRICATED ALUMINUM DUNNAGE IN A RAIL AND ROAD TRANSPORTATION ENVIRONMENT

TABLE OF CONTENTS

PART 1

INTRODUCTION

A. BACKGROUND

The U.S. Army Defense Ammunition Center and School (USADACS), Evaluation Division (SMCAC-DEV), was tasked by the U.S. Naval Weapons Station, Earle (Code 8021) to evaluate a Navy suggestion to use aluminum as an alternative to wood dunnage. This suggestion was developed at an overseas command where lumber dunnage is expensive and difficult to obtain. The original intent of this suggestion was for the replacement of wood for intra-installation movement of ammunition by truck or rail. To evaluate these conditions, inert 500-pound bomb pallets were used in differing load configurations for over the road and rail transportation. The test were accomplished using a standard flatcar and a flatbed semitrailer.

B. AUTHORITY

This test was conducted in accordance with mission responsibilities delegated by the U.S. Army Armament, Munitions and Chemical Command (AMCCOM), Rock Island, IL. Reference is made to Change 4, 4 October 1974, to AR-740-1, 23 April 1971, Storage and Supply Operations; AMCCOM-R 10-17, 13 January 1986, Mission and Major Functions of USADACS.

C. OBJECTIVE

The objective of these tests was to determine if the aluminum dunnage would be a suitable replacement for wood dunnage in a road and rail transportation environment. The tests performed on different 500-pound bomb load configurations were: Rail Impact Test, Hazard Course, Road Trip and Washboard Course.

D. CONCLUSIONS

All test configurations passed the road transportation tests (hazard, road, and washboard). Rail Impact Tests: The bulkhead restraint was able to keep six bomb units in place up to six mph but started to deform (100 percent nailing). With 50 percent nailing, the bulkhead restraint separated from the flatcar. Testing of the "E" frame was unsuccessful because the unit load configuration was not rigid enough. End bracing for this unit is required.

E. RECOMMENDATIONS

1. The use of aluminum dunnage which can be recycled has the potential of saving the Navy and Army lumber dunnaging expenses. In the case of road transportation, aluminum dunnage satisfied the road transportation tests. More investigation of aluminum dunnage techniques is required before it can be useful in a rail transportation environment.

2. A query of the overseas commands (Europe and Asia) should be made to assess the feasibility of using aluminum dunnage as an alternative to wood. The cost of lumber in Europe is expensive and the humid conditions of Asia cause wood to deteriorate and require constant maintenance.

F. APPROVAL

Approved for road transport upon U.S. Naval Weapons Station, Earle publication of Navy procedure.

PART 2

ATTENDEES

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PART 3

TEST PROCEDURES

A. RAIL IMPACT TEST.

The test load or vehicle should be positioned in/on a railcar. For containers, the loaded container shall be positioned on a container chassis and securely locked in place using the twist locks at each corner. The container chassis shall be secured to a railcar. Equipment needed to perform the test includes the specimen (hammer) car, five empty railroad cars connected together to serve as the anvil, and a railroad locomotive. These anvil cars are positioned on a level section of track with air and hand brakes set and with the draft gear compressed. The locomotive unit pulls the specimen car several hundred yards away from the anvil cars and, then, pushes the specimen car toward the anvil at a predetermined speed, disconnects from the specimen car about 50 yards away from the anvil cars and allows the specimen car to roll freely along the track until it strikes the anvil. This constitutes an impact. Impacting is accomplished at speeds of 4, 6, and 8 mph in one direction and at a speed of 8 mph in the opposite direction. The 4 and 6 mph impact speeds are approximate; the 8 mph speed is a minimum. Impact speeds are to be determined by using an electronic counter to measure the time required for the specimen car to traverse an 11 foot distance immediately prior to contact with the anvil cars.

B. HAZARD COURSE.

The specimen being tested will be subjected to the road hazard course. Using a suitable truck/tractor or tactical vehicle, the vehicle/specimen of test method No. A shall be towed/driven over a hazard course two times at a speed of approximately 5 mph. The speed may be increased or decreased, as appropriate, to produce the most violent load response.

C. ROAD TRIP.

Using a suitable truck/tractor and trailer, or tactical vehicle, the tactical vehicle/specimen load shall be towed/driven for a total distance of at least 30 miles over a combination of roads surfaced with gravel, concrete, and asphalt. Test route shall include curves, corners, railroad crossings, cattle guards, stops, and starts. The test vehicle shall travel at the maximum speed suitable for the particular road being traversed, except as limited by legal restrictions. This step provides for the tactical vehicle/specimen load to be subjected to three full airbrake stops while traveling in the forward direction and one in the reverse direction while traveling down a 7 percent grade. The first three stops are at 5, 10, and 15 mph, while the stop in the reverse direction is of approximately 5 mph.

D. WASHBOARD COURSE.

Using a suitable truck/tractor, and/or tactical vehicle, the specimen shall be towed/driven over the washboard course at a speed which produces the most violent response in the particular test load (as indicated by the resonant frequency of the suspension system beneath the load).

PART 4

TEST RESULTS

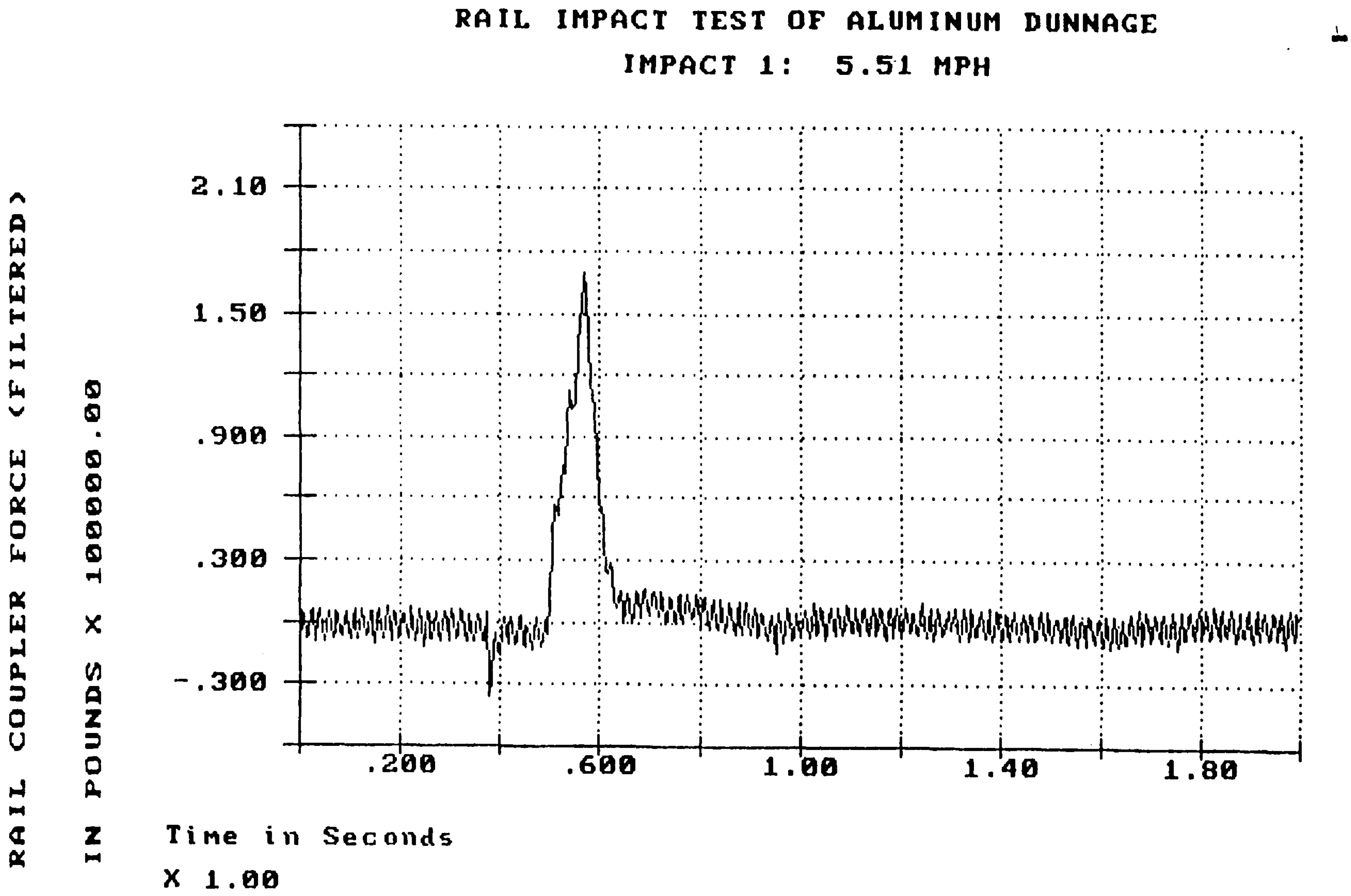
TEST RESULTS

TEST NO. 1 DATE: 22 FEBRUARY 1989

TEST SPECIMEN: Flatcar with Aluminum Bulkhead, Two Pallets of 500-pound Bombs and Aluminum "E" Frame. 50 percent Nailed.

TEST CAR NO. SP&S 34085	LT.	WT.	47,100	pounds
LADING AND DUNNAGE		WT.	7,000	pounds
	TOTAL SPECIMEN	WT.	54,100	pounds
	BUFFER CAR (5 CARS)	WT.	220,000	pounds

IMPACT NO.	END STRUCK	VELOCITY (MPH)	IMPACT FORCE	REMARKS
1	forward	5.51	187,000	no damage
2	forward	6.94	306,000	no damage
3	forward	8.38	394,000	no damage
4	reverse	8.92	439,000	no damage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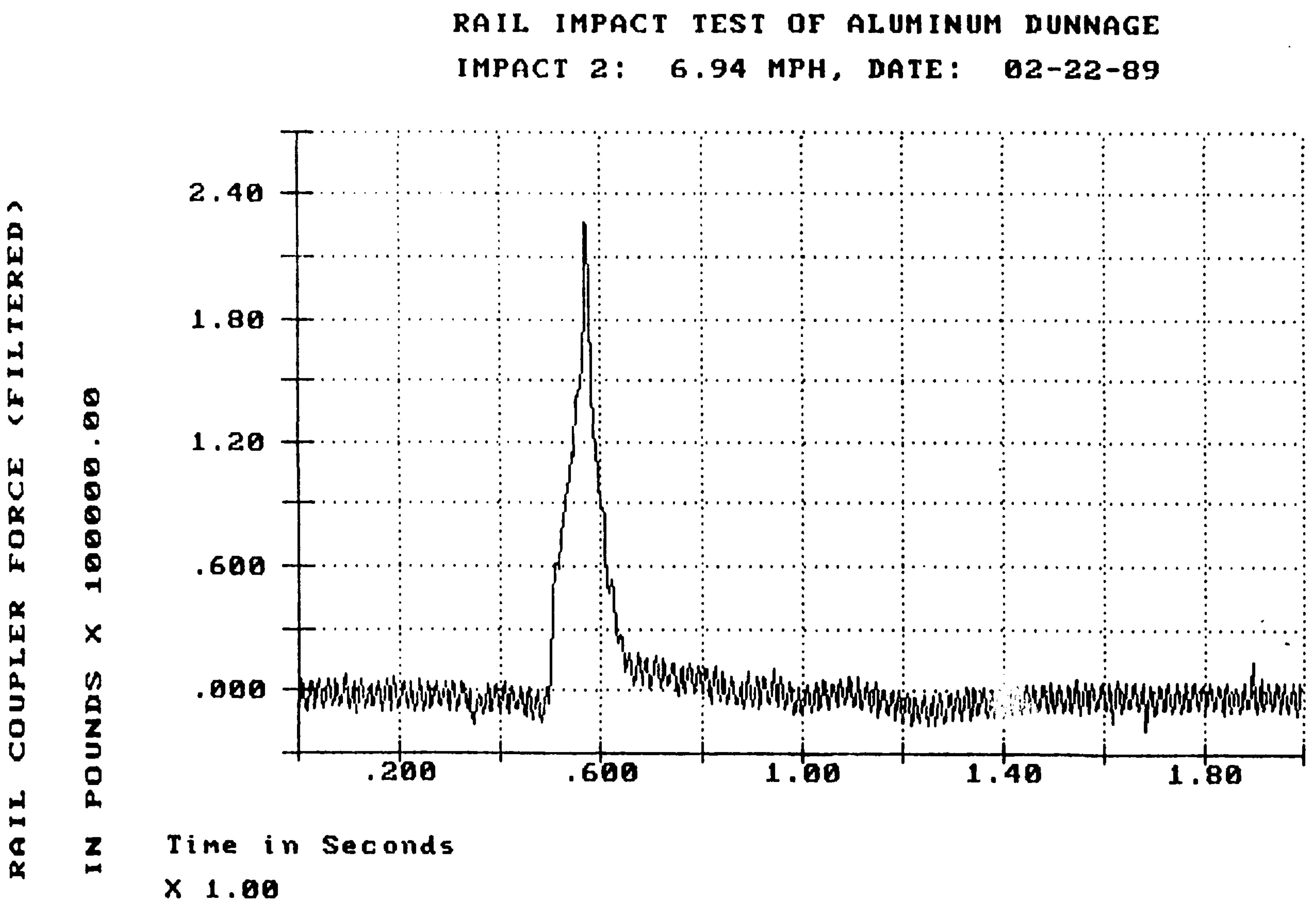
IMPACT 1: 5.51 MPH
2.10
1.50
.900
.300
-.300
.200
.600
1.00
1.40
1.80
Time in Seconds
X 1.00
RAIL COUPLER FORCE (FILTERED)
IN POUNDS X 100000.00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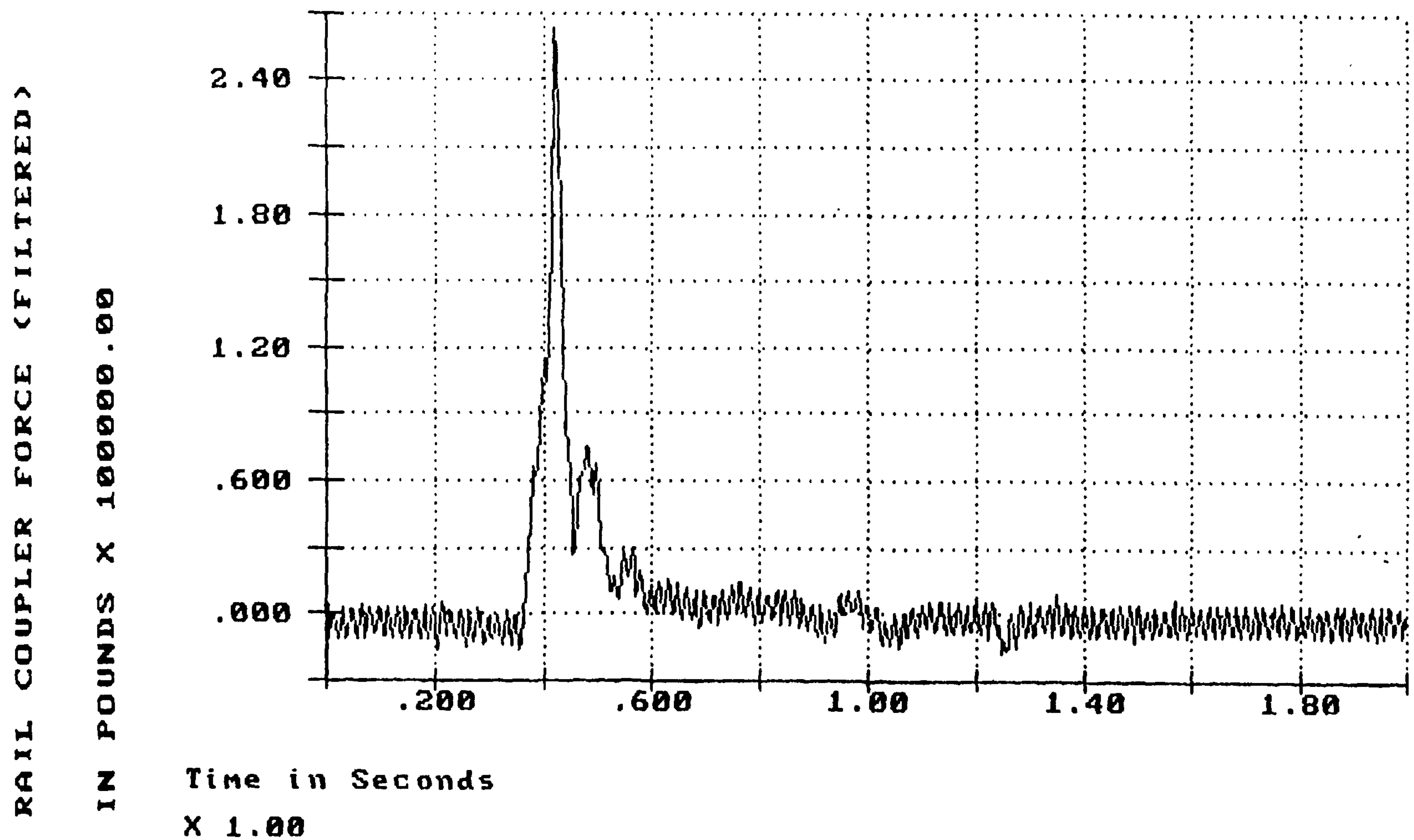
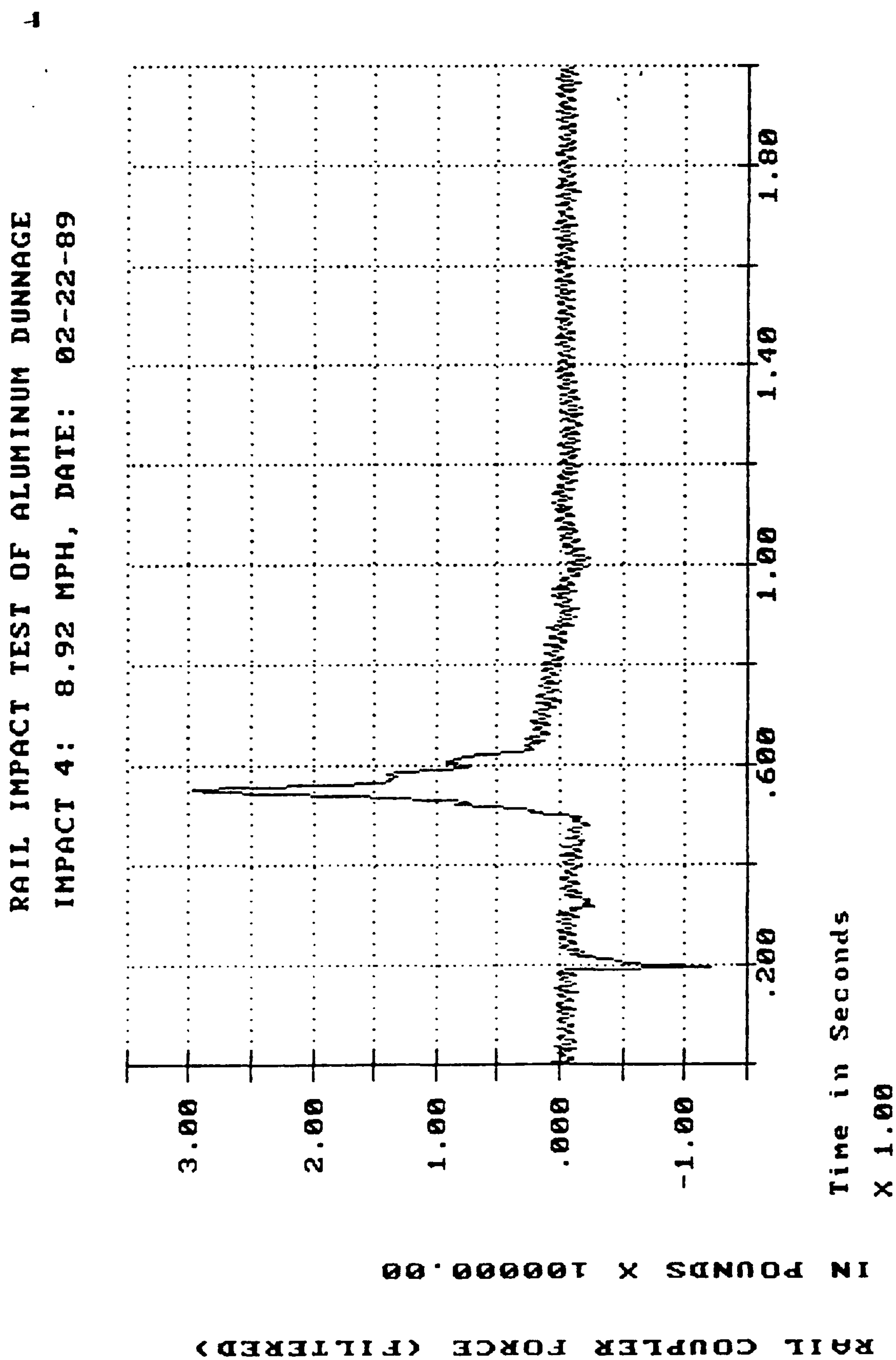
IMPACT 2: 6.94 MPH, DATE: 02-22-89
RAIL COUPLER FORCE (FILTERED)
IN POUNDS X 100000.00
2.40
1.80
1.20
.600
.000
.200
.600
1.00
1.40
1.80
Time in Seconds
X 1.00

RAIL IMPACT TEST OF ALUMINUM DUNNAGE

IMPACT 3: 8.38 MPH, DATE: 02-22-89




RAIL IMPACT TEST OF ALUMINUM DUNNAGE
IMPACT 4: 8.92 MPH, DATE: 02-22-89
3.00
2.00
1.00
.000
-1.00
.200
.600
1.00
1.40
1.80
Time in Seconds
X 1.00
RAIL COUPLER FORCE (FILTERED)
IN POUNDS X 100000.00

TEST RESULTS

TEST NO. 2 DATE: 22 FEBRUARY 1989

TEST SPECIMEN: Flatcar with Aluminum Bulkhead, Four Pallets of 500-pound Bombs and Aluminum "E" Frame. 50 percent Nailed.

TEST CAR NO. SP&S 34085	LT.	WT.	47,100	pounds
LADING AND DUNNAGE		WT.	13,000	pounds
	TOTAL SPECIMEN	WT.	60,100	pounds
	BUFFER CAR (5 CARS)	WT.	220,000	pounds

IMPACT NO.	END STRUCK	VELOCITY (MPH)	IMPACT FORCE	REMARKS
1	forward	4.28	n.r.*	no damage
2	forward	7.02	n.r.	bulkhead separated from flatcar. All nails pulled out of flatcar deck.

* impact force was not recorded.

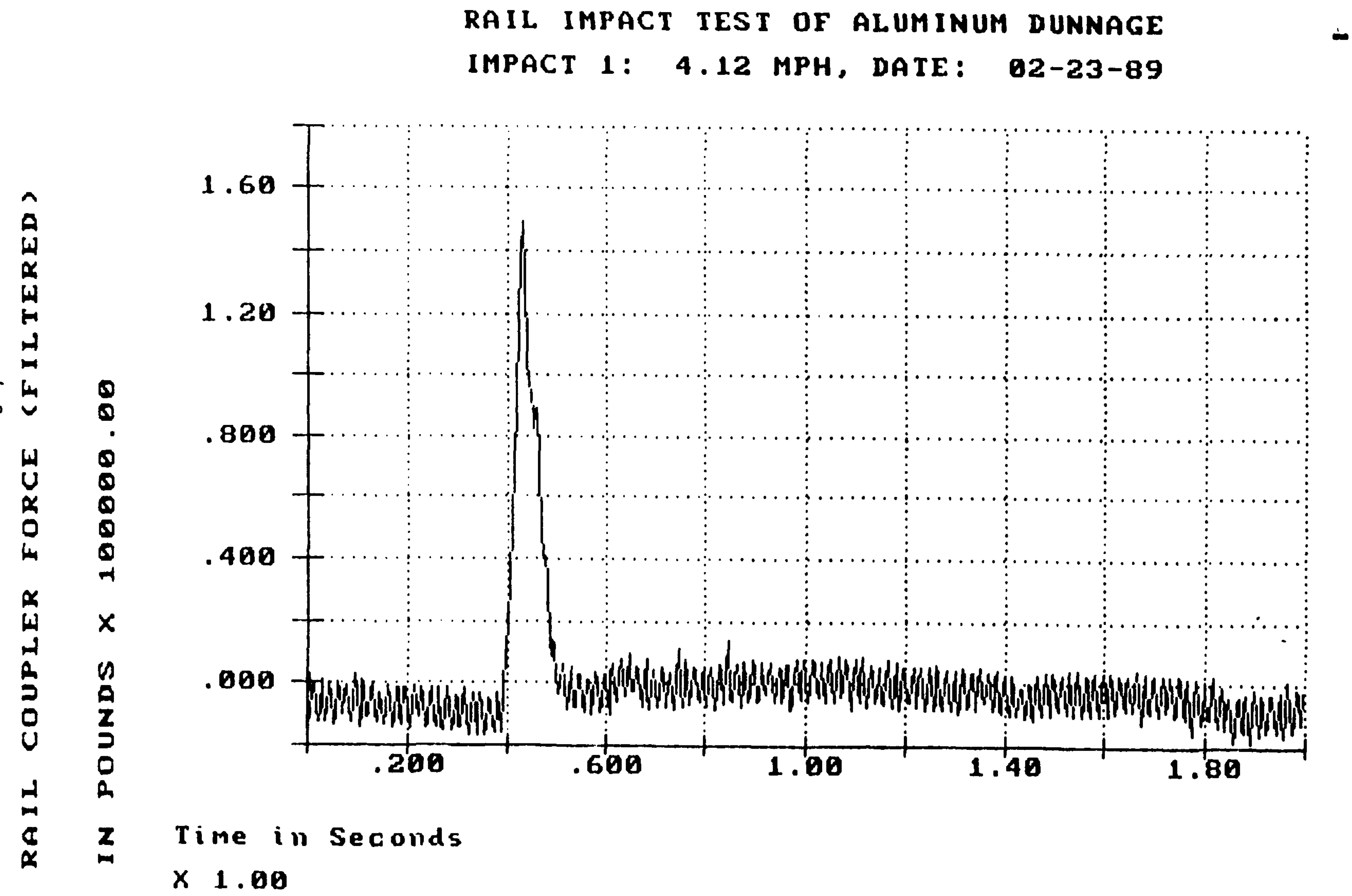
TEST RESULTS

TEST NO. 3 DATE: 23 FEBRUARY 1989

TEST SPECIMEN: Flatcar with Aluminum Bulkhead, Four Pallets of 500-pound Bombs and Aluminum "E" Frame. 100 percent Nailed.

TEST CAR NO. SP&S 34085	LT. WT.	47,100 pounds
LADING AND DUNNAGE	WT.	13,000 pounds
TOTAL SPECIMEN	WT.	60,100 pounds
BUFFER CAR (5 CARS)	WT.	220,000 pounds

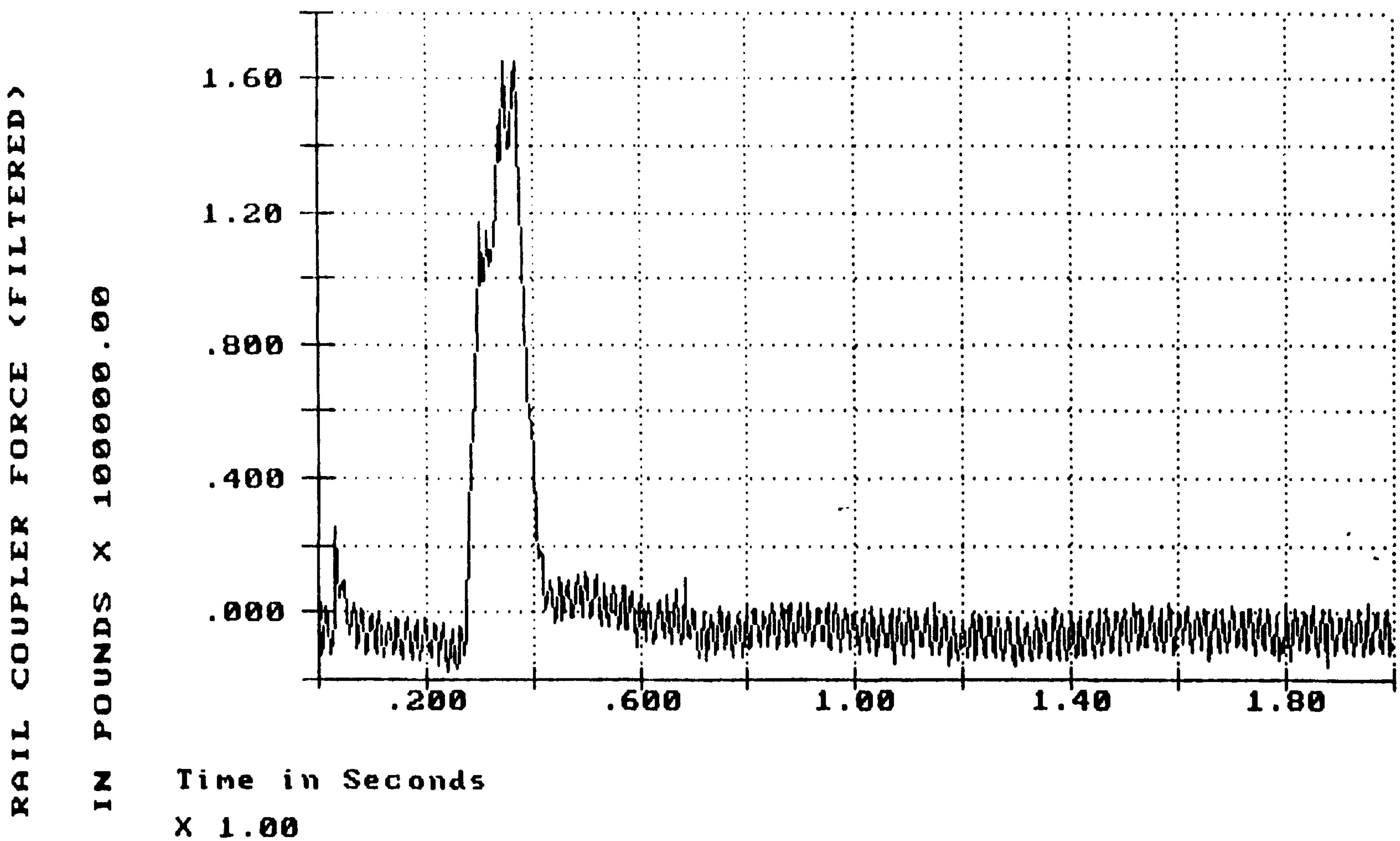
IMPACT NO.	END STRUCK	VELOCITY (MPH)	IMPACT FORCE	REMARKS
1	forward	4.12	194,000	no damage
2	forward	6.52	165,000	no damage
3	forward	8.31	379,000	Exceeded structural limit of end gate. Aluminum angle deformed and corner weld broken.



RAIL IMPACT TEST OF ALUMINUM DUNNAGE
IMPACT 1: 4.12 MPH, DATE: 02-23-89
RAIL COUPLER FORCE (FILTERED)
IN POUNDS X 100000.00
1.60
1.20
.800
.400
.000
.200
.600
1.00
1.40
1.80
Time in Seconds
X 1.00

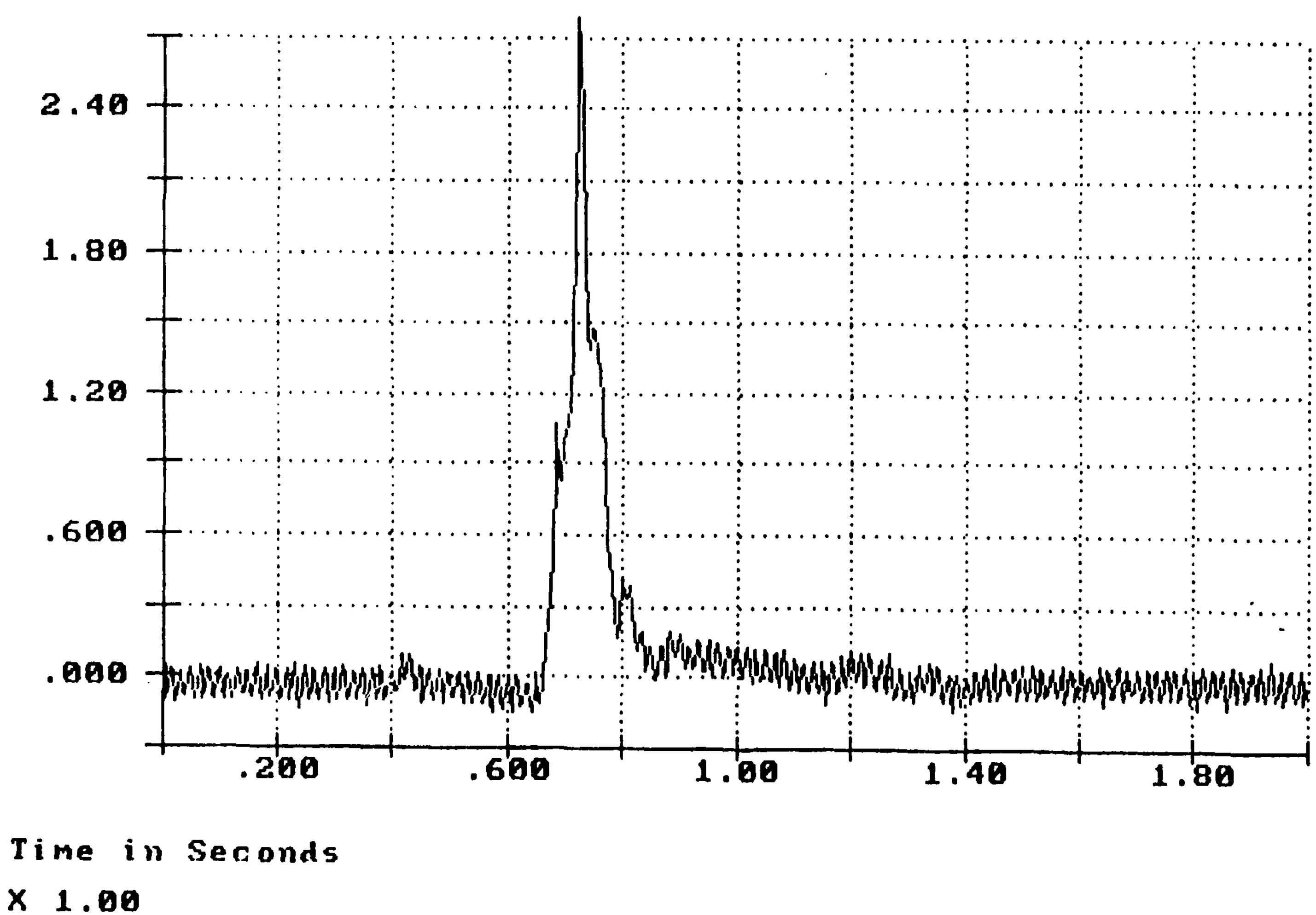
RAIL IMPACT TEST OF ALUMINUM DUNNAGE

IMPACT 2: 6.52 MPH, DATE: 02-23-89



RAIL IMPACT TEST OF ALUMINUM DUNNAGE

IMPACT 3: 8.31 MPH, DATE: 02-23-89 (FAILURE OCCURED)



TEST NO. 4 DATE: 23 FEBRUARY 1989

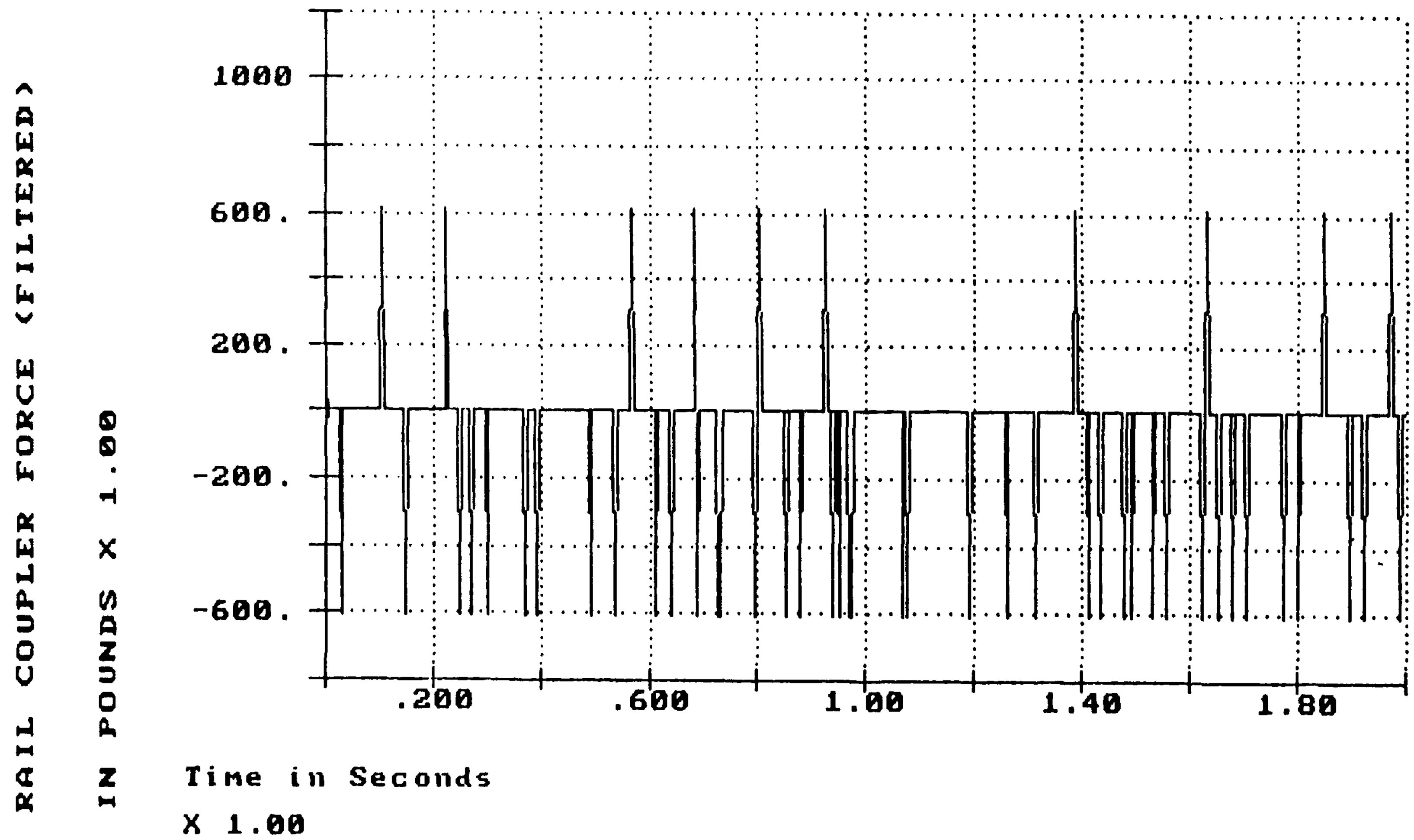
TEST SPECIMEN: Flatcar with Aluminum Bulkhead, 10 Pallets of 500-pound Bombs and Aluminum "E" Frame. 100 percent Nailed. Web Strap unit restraint.

TEST CAR NO. SP&S 34085	LT.	WT.	47,100 pounds
LADING AND DUNNAGE		WT.	32,000 pounds
	TOTAL SPECIMEN	WT.	79,100 pounds
	BUFFER CAR (5 CARS)	WT.	220,000 pounds

IMPACT NO.	END STRUCK	VELOCITY (MPH)	IMPACT FORCE	REMAKRS
1	forward	3.91	215,000	no damage
2	forward	6.46	264,000	Unit at position 2 and 3 racked. Broken Web Straps. Forward shift in pallets.

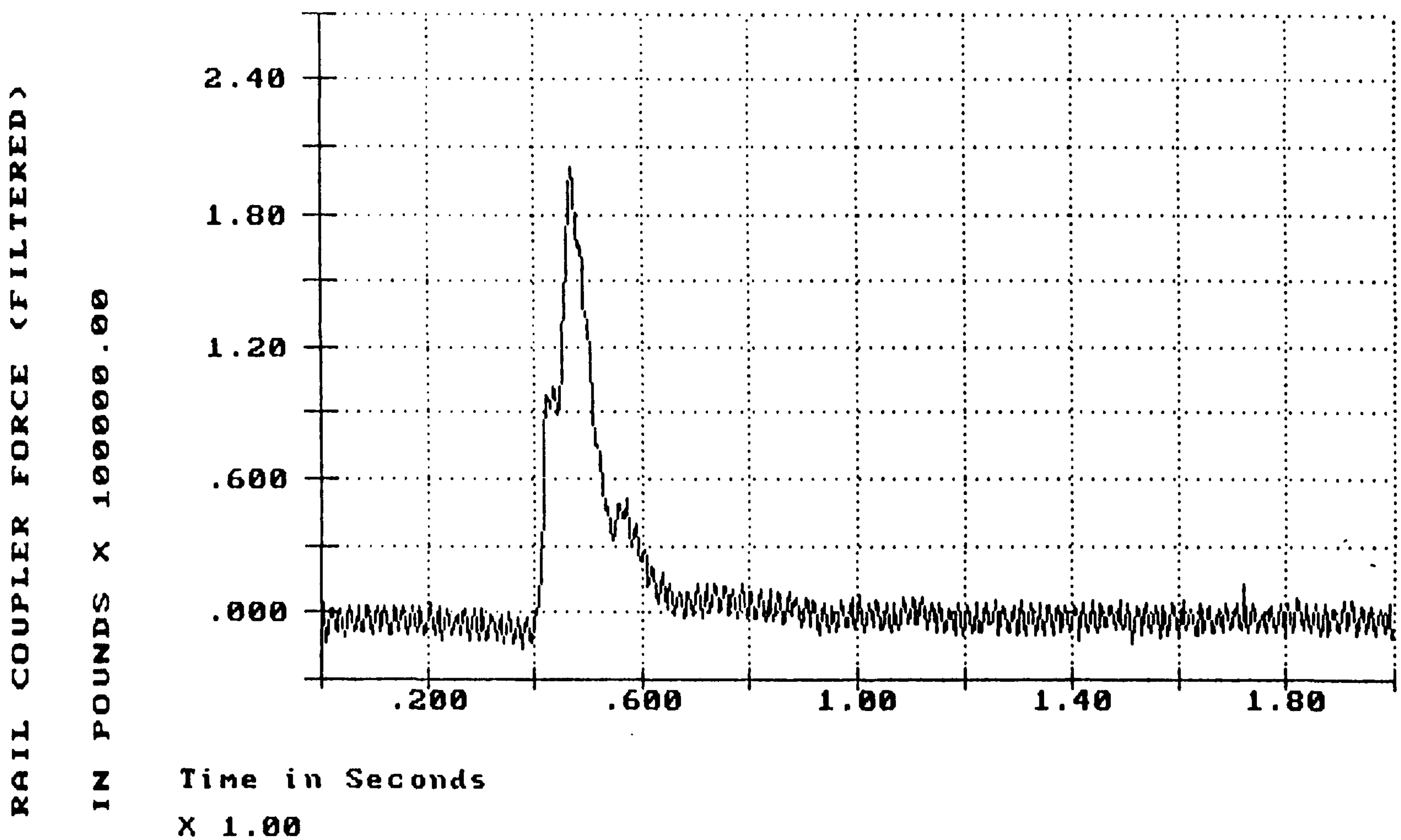
RAIL IMPACT TEST OF ALUMINUM DUNNAGE

IMPACT 1: 3.91 MPH, DATE: 02-23-89, 1200 HRS



RAIL IMPACT TEST OF ALUMINUM DUNNAGE

IMPACT 2: 6.46 MPH, DATE: 02-23-89, 1200 HRS

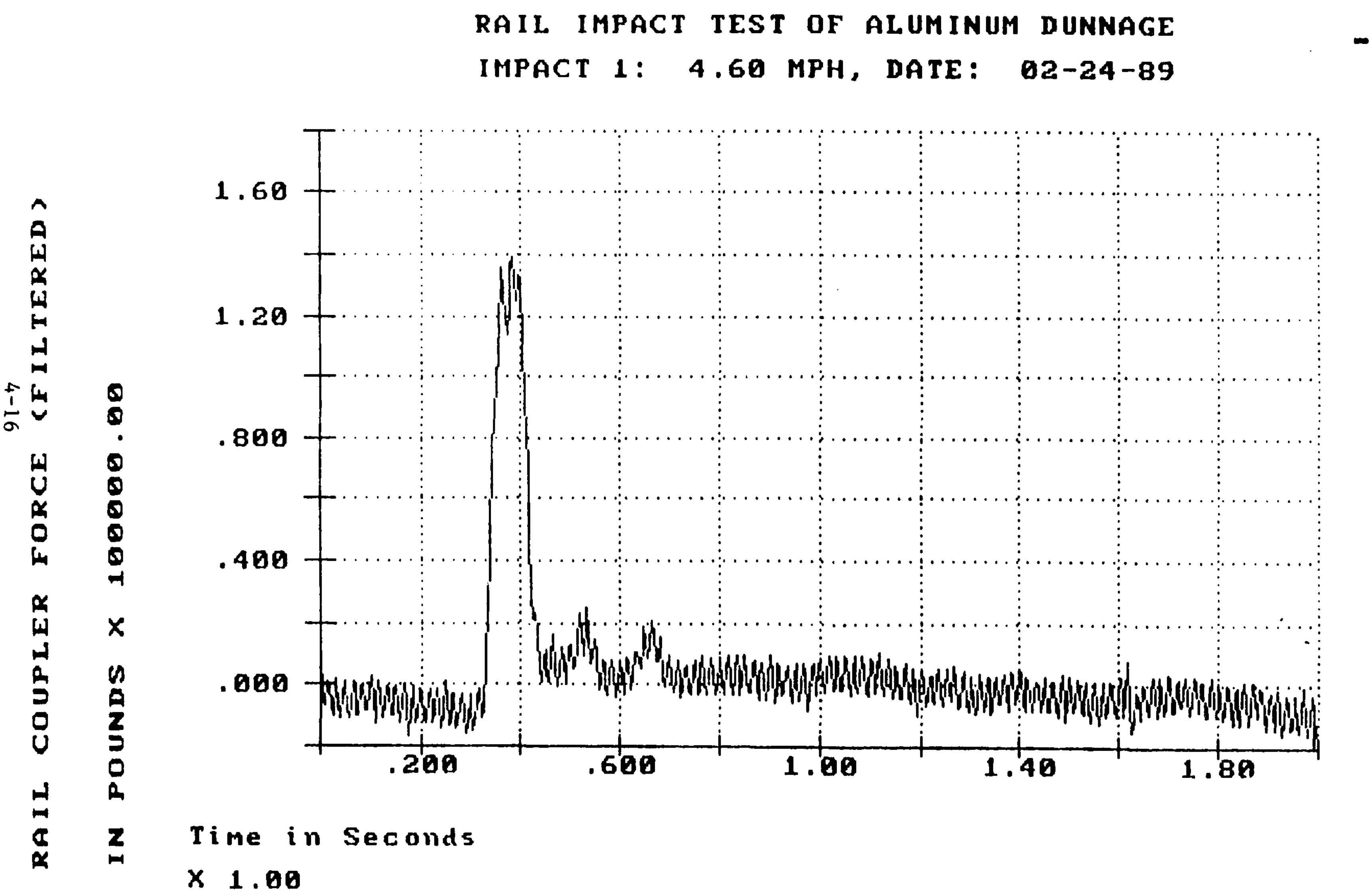


TEST NO. 5 DATE: 24 FEBRUARY 1989

TEST SPECIMEN: Flatcar with Aluminum Bulkhead, 10 Pallets of 500-pound Bombs and Aluminum 'E' Frame. 100 percent Nailed. (1-1/4-inch Banding Restraint.)

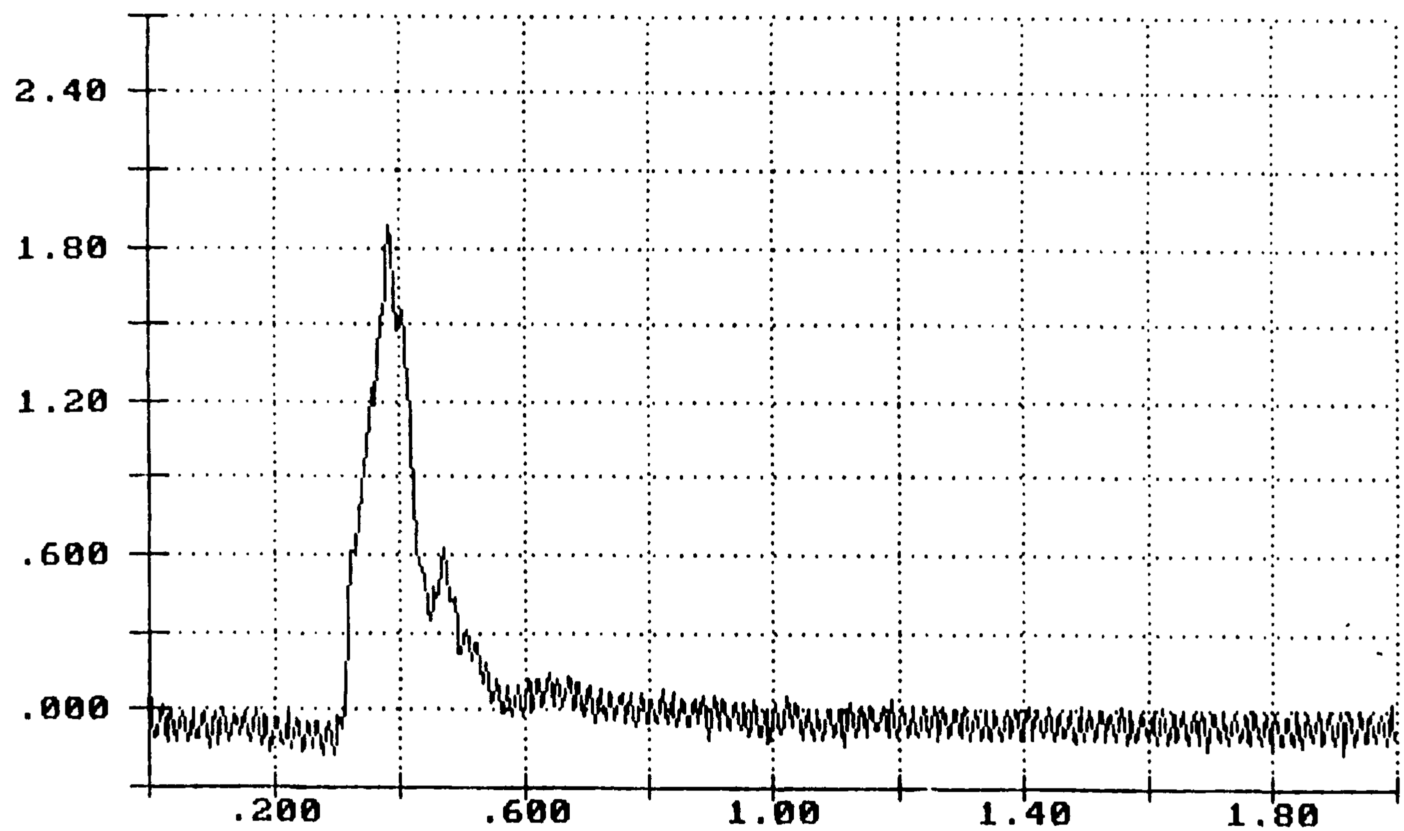
TEST CAR NO. SP&S 34085	LT. WT.	47,100	pounds
LADING AND DUNNAGE	WT.	32,000	pounds
TOTAL SPECIMEN	WT.	79,100	pounds
BUFFER CAR (5 CARS)	WT.	220,000	pounds

IMPACT NO.	END STRUCK	VELOCITY (MPH)	IMPACT FORCE	REMARKS
1	forward	4.60	178,000	no damage
2	forward	6.71	245,000	Units at position 2 and 3 racked. Banding straps broke. The 500-pound bomb pallets canted forward after impact. Further rail testing was stopped due to the instability of this test configuration.


RAIL IMPACT TEST OF ALUMINUM DUNNAGE
IMPACT 1: 4.60 MPH, DATE: 02-24-89
1.60
1.20
.800
.400
.000
.200
.600
1.00
1.40
1.80
Time in Seconds
X 1.00
RAIL COUPLER FORCE (FILTERED)
IN POUNDS X 100000.00

RAIL IMPACT TEST OF ALUMINUM DUNNAGE

IMPACT 2: 6.71 MPH, DATE: 02-24-89



Time in Seconds
X 1.00

RAIL COUPLER FORCE (FILTERED)
IN POUNDS X 100000.00

ROAD TEST DATA

TEST NO. 6 DATE: 22 FEBRUARY 1989

TEST SPECIMEN: 500-pound Bombs, Aluminum Bulkhead and "E" Restraint, M871 Semitrailer, Two Pallets One-layer High, Web Strap Restraint.

PASS 1-A OVER FIRST SERIES OF TIES:	0.09 MIN	6.3 MPH
PASS 1-B OVR SECOND SERIES OF TIES:	0.09 MIN	6.3 MPH

REMARKS: No damage or load movement.

PASS 2-A OVER FIRST SERIES OF TIES:	0.09 MIN	6.3 MPH
PASS 2-B OVER SECOND SERIES OF TIES:	0.09 MIN	6.3 MPH

REMARKS: No damage to load or load movement.

30 MILE ROAD TEST: No damage or load movement.

PANIC STOP TEST: No load movement or damage.

PASS 3-A OVER FIRST SERIES OF TIES:	0.10 MIN	5.7 MPH
PASS 3-B OVER SECOND SERIES OF TIES:	0.10 MIN	5.7 MPH

REMARKS: No movement.

PASS 4-A OVER FIRST SERIES OF TIES:	0.10 MIN	5.7 MPH
PASS 4-B OVER FIRST SERIES OF TIES:	0.10 MIN	5.7 MPH

REMARKS: No load movement or damage.

WASHBOARD COURSE: No movement or damage.

ROAD TEST DATA

TEST NO. 7 DATE: 22 FEBRUARY 1989

TEST SPECIMEN: 500-pound Bombs, Aluminum Bulkhead and "E" Frame, M871 Semitrailer, Six Pallets (two-high by three-long) Web Strap Restraints, Units Banded Together Two-high with 2 by 6 Vertical Supports.

PASS 1-A OVER FIRST SERIES OF TIES:	0.09 MIN	6.3 MPH
PASS 1-B OVER SECOND SERIES OF TIES:	0.09 MIN	6.3 MPH

REMARKS: Lateral unit load movement in upper layer. Tore off lateral cleat. Replaced.

PASS 2-A OVER FIRST SERIES OF TIES:	0.10 MIN	5.7 MPH
PASS 2-B OVER SECOND SERIES OF TIES:	0.10 MIN	5.7 MPH

REMARKS: Bombs moving out of unitization.

30 MILE ROAD TEST: No additional movement.

PANIC STOP TEST: No movement or damage.

PASS 3-A OVER FIRST SERIES OF TIES:	0.10 MIN	5.7 MPH
PASS 3-B OVER SECOND SERIES OF TIES:	0.09 MIN	6.3 MPH

REMARKS: Lateral shifting of bombs in unit.

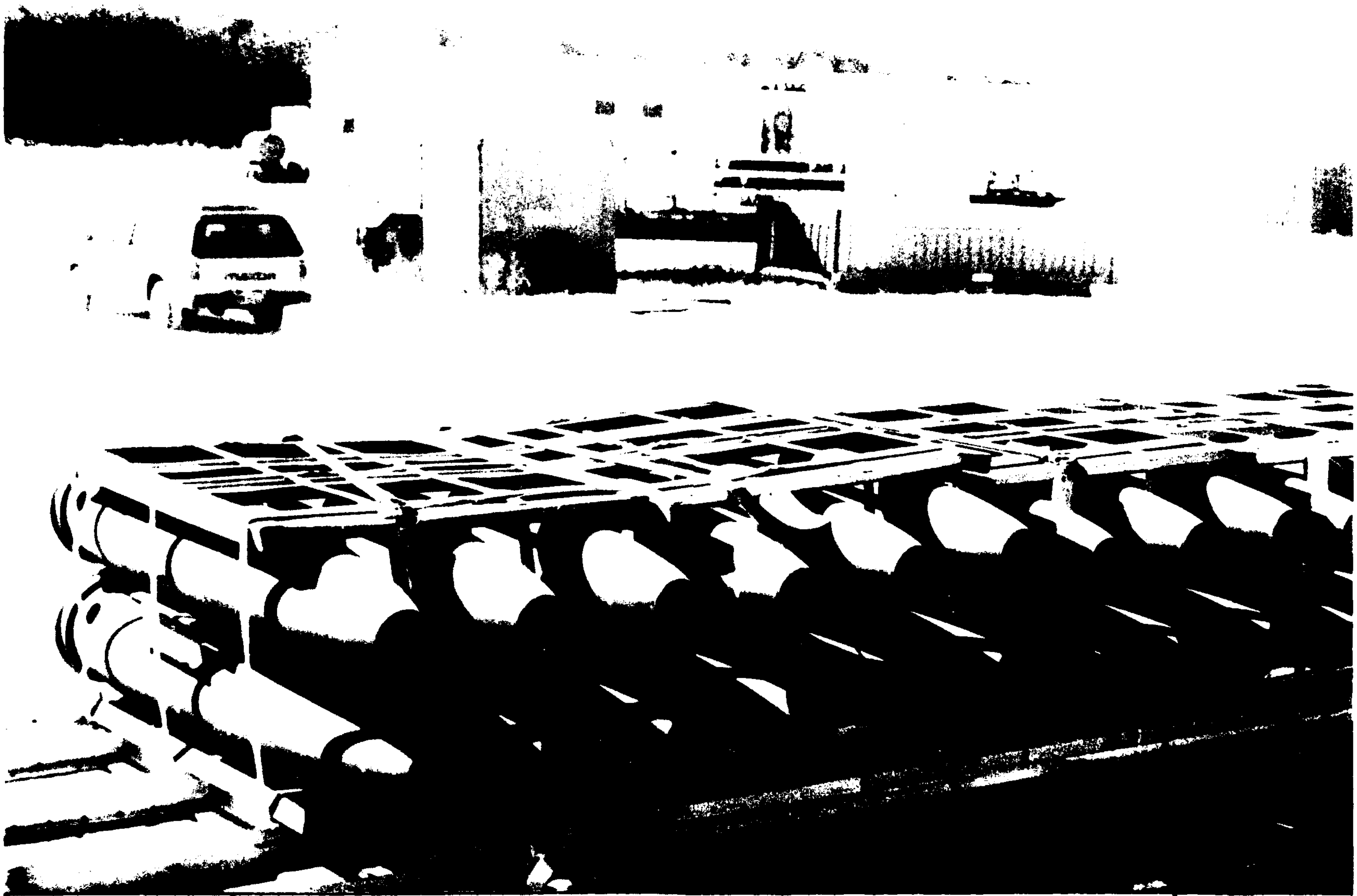
PASS 4-A OVER FIRST SERIES OF TIES:	0.09 MIN	6.3 MPH
PASS 4-B OVER SECOND SERIES OF TIES:	0.09 MIN	6.3 MPH

REMARKS: Lateral movement of bombs in unitization.

WASHBOARD COURSE: No additional lateral movement.

PART 5

PHOTOGRAPHS



DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

__Photo No. 1__ (89-2623) This photo shows unitized 500-pound bombs on a railcar restrained by the aluminum prefabricated dunnage "E" frame. Bomb pallets were restrained to the railcar by the use of nuclear web straps. Note racking of the unit loads on the railcar. Also note the in-line dunnage required to restrain the unit loads being made up of one run of 2 by 4s with 2 by 6s recessed to hold the bottom skid of the bomb pallet in place.

DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. 2 (89-2620) This photo shows the aluminum 'E' frame with 100 percent nailing to the flatcar deck. Note unitization restrain at the right-hand side of the pallet for in-line blocking of a single aluminum angle.

DEFENSE AMMUNITION CENTER AND SCHOOL- SAVANNA, IL

<u>Photo No. 3</u> (89-2619) This photo shows damage to the prefabricated aluminum dunnage 'E' frame after impacting in rail transportation.

DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

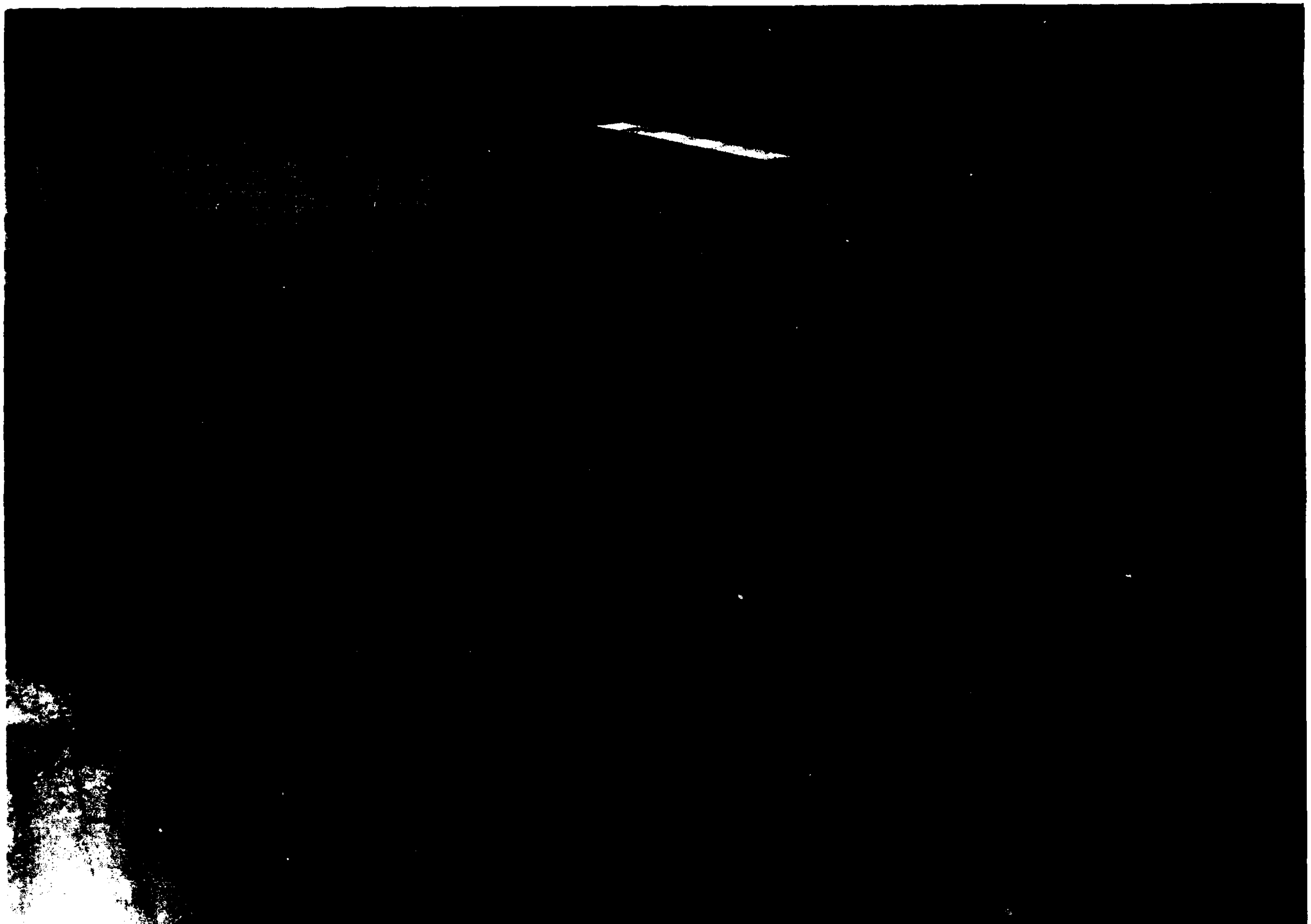
<u>Photo No. 4</u> (89-2610) This photo shows a close up of a 3 x 3 aluminum angle used for in-line dunnage on the railcar. Note deformation of the angle from lateral movement of the 500-pound bomb pallet and also note damage to the bottom skid of the pallet.

DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

<u>Photo No. 5</u> (89-2588) This photo shows a fully loaded flatcar with a prefabricated aluminum dunnage 'E' frame restraint after impact and also note these pallets were restrained with a 1-1/4-inch steel banding. Note the broken bands on the 4th and 5th pallets. No damage was sustained by the aluminum 'E' frame; however, severe racking of the ammunition pallets due to columnar loading and insufficient strength in the unitization.

DEFENSE AMMUNITION CENTER AND SCHOOL- SAVANNA, IL

Photo No. 6 (89-2616) This photo shows a truss and blocking arrangement made out of aluminum restraining a 500-pound bomb pallet on a flatcar. Web straps are used to hold a pallet onto the flatcar. Fifty percent nailing was used to attach the 'A' frame to the flatcar deck.



DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

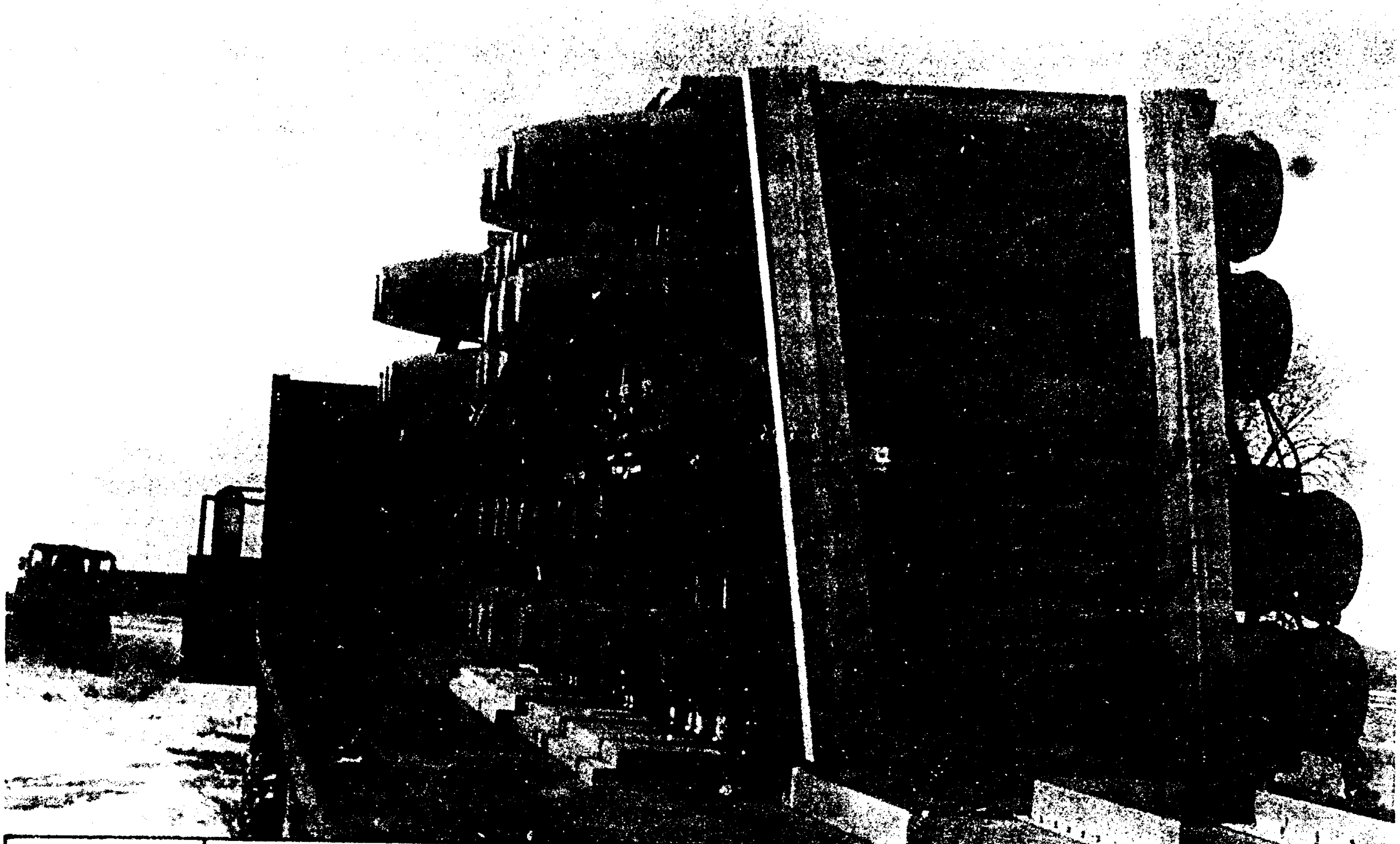
<u>Photo No. 7</u> (89-2618) This photo shows the aluminum 'A' frame, with 50 percent nailing, after impact. On impact the 'A' frame separated from the flatcar deck pulling all nails out.

DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. 8 (89-2613) This photo shows cracking in the lower corner of the prefabricated aluminum end truss. Cracking was due to insufficient weld penetration.

DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

<u>Photo No. 9</u> **(89-2122) This photo shows the aluminum 'A' frame** with additional weld breakage after impact. **This weld breakage was caused by insufficient weld penetration in fabrication of the end truss.**

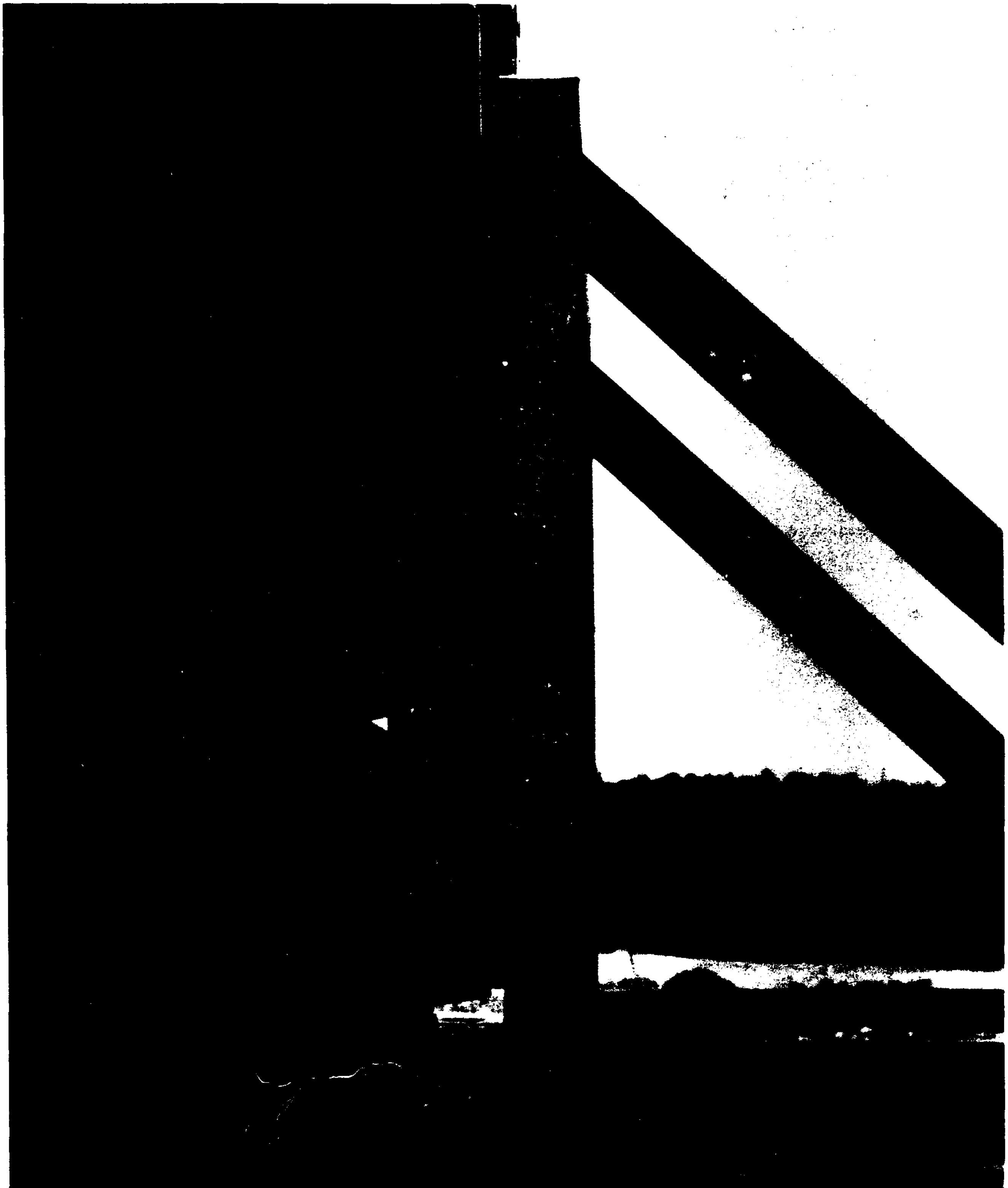


DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. 10 (89-2598) This photo shows a truckload of 500-pound bombs restrained by prefabricated aluminum dunnage 'E' frame at the rear and an 'A' frame at the forward end with overlapped in-line blocking. Additional restraint over each unit was accomplished using two nuclear web straps per stack of 500-pound bombs. This photo shows the transportation load on a semitrailer after going over the road hazard course at approximately 5 mph.

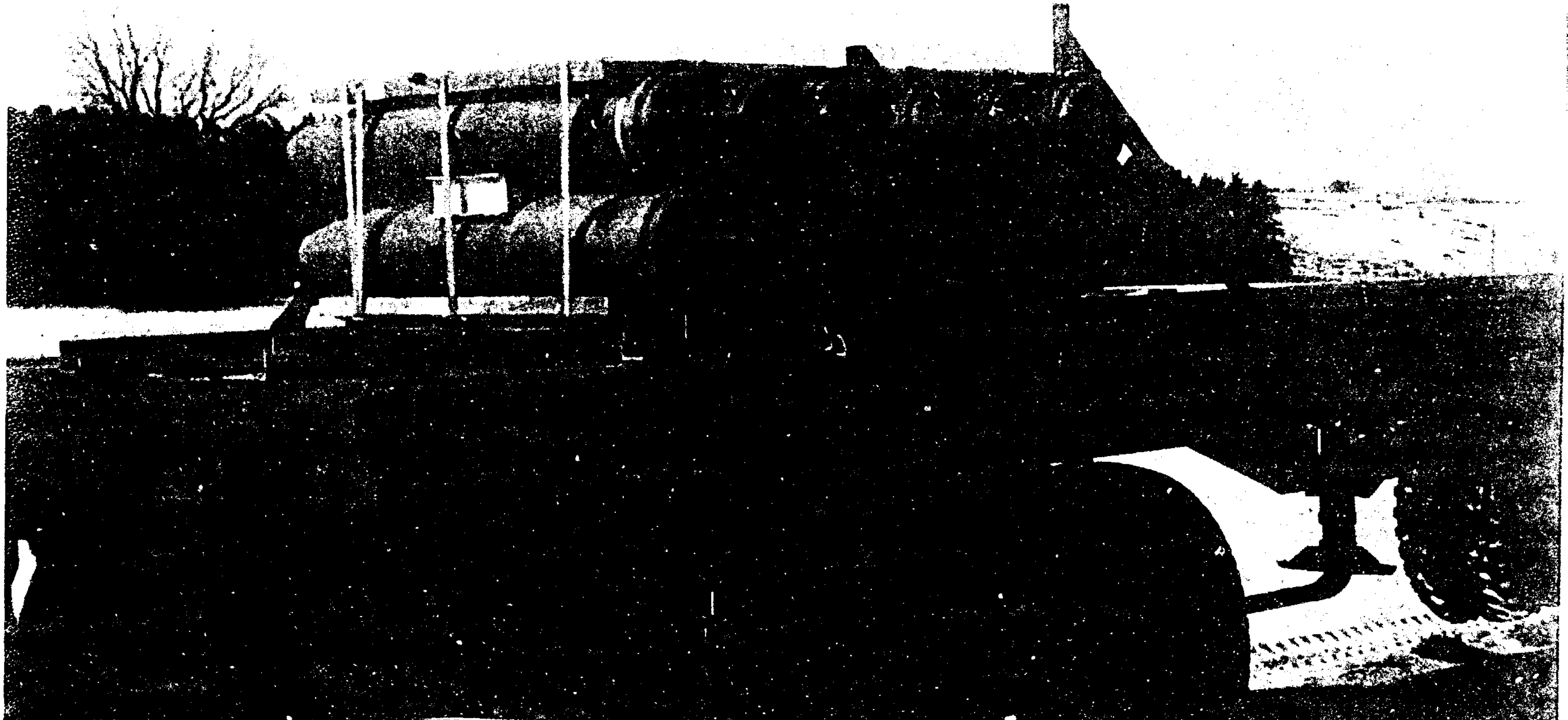
DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

<u>Photo No. 11</u> (89-2591) This photo shows a semitrailer load of 500-pound bombs with an aluminum prefabricated dunnage 'A' frame at the forward end. This load has passed over the road hazard course at a speed of approximately 5 mph.



DEFENSE AMMUNITION CENTER AND SCHOOL- SAVANNA, IL

Photo No. 12 (89-2596) This photo shows the forward end of a two-high 500-pound bomb unit load on a M871 trailer after going over the road hazard course. The load shifted towards the rear approximately 1/2 inch.



DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

<u>Photo No. 13</u> (89-2609) This photo shows two pallets of 500-pound bombs restrained forward and aft by a prefabricated aluminum dunnage 'E' frame at the rear and an 'A' frame at the forward end. Inline blocking is accomplished with a 3-inch aluminum angle. Each pallet is restrained with one nuclear strap over the top.