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ENHANCED WOOD PALLET EVALUATION

Prepared for:
U.S. Army Armament Research,
Development and Engineering Center
ATTN: SMCAR-AEP
Picatinny Arsenal, NJ 07806-5000

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The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SMCAC-DEV), was tasked by the U.S. Army Armament Research, Development and Engineering Center (ARDEC) to conduct MIL-STD-1660 and rail impact tests on prototype 40mm ammunition and 120mm ammunition enhanced wood pallets. The pallets met all requirements of MIL-STD-1660, Design Criteria for Ammunition Unit Loads, and rail impact tests; however, several changes are required to the pallet adapter assemblies prior to finalization of the unitization drawings. This report contains details of the tests conducted.

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VALIDATION ENGINEERING DIVISION
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PART 1

INTRODUCTION

A. BACKGROUND. The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SMCAC-DEV), was tasked by the U.S. Army Armament Research, Development and Engineering Center (ARDEC) to conduct MIL-STD-1660 and rail impact tests on prototype 40mm ammunition and 120mm ammunition enhanced wood pallets. The pallets met all requirements of MIL-STD-1660 and rail impact tests; however, several changes are required to the pallet adapter assemblies prior to finalization of the unitization drawings.

B. AUTHORITY. This test was conducted IAW mission responsibilities delegated by the U.S. Army Armament, Munitions and Chemical Command (AMCCOM), Rock Island, IL.

C. OBJECTIVE. The objective of this series of tests was to determine if the enhanced wood pallets could meet the design requirements for ammunition unitized loads and be transported by rail.

D. CONCLUSION. The pallets passed all tests conducted; however, the following concerns were raised:

1. The enhanced wood was prone to splitting in and around nail holes which could be detrimental to the transportation/storage cycles of ammunition as the wood ages.

2. The pallets were tested in like-new condition, with no data available on how these pallets will perform as they age. Due to the life cycle of ammunition, these pallets could be in service for a period of 10 to 30 years. As such, life-cycle testing is critical to ensure that this material is still serviceable over extended periods of time.

3. As tested, several design changes are required to the pallet adapters prior to finalization

of the ammunition unitized load drawings.

4. Various wood and plastic replacement materials have been tested which passed MIL-STD-1660 tests and more than likely would pass rail impact test. Several of these materials are very cost effective such as commercially-available exterior grades of plywood and recycled plastics; therefore, some consideration should be given to utilize these materials in the fabrication of pallets.

E. RECOMMENDATIONS:

1. Life-cycle tests should be conducted on enhanced wood and other replacement materials to ensure the serviceability of these materials over extended periods of time.

2. Change the pallet adapter design to resolve problems noted during testing.

3. Replace nails with an alternative wood fastening method such as wood screws or bolts.

PART 2

17 AUGUST 1994

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PART 3

TEST PROCEDURES

A. MIL-STD-1660. The test procedures outlined in this section were extracted from MIL-STD-1660, Design Criteria for Ammunition Unit Loads, 8 April 1977. This standard identifies nine steps that a unitized load must undergo if it is to be considered acceptable. The five tests that were conducted on the test pallets are summarized below.

1. STACKING TEST. The unit load was loaded to simulate a stack of identical unit loads stacked 16 feet high, for a period of 1 hour. This stacking load is simulated by subjecting the unit load to a compression weight equal to an equivalent 16-foot stacking height. The compression load was calculated in the following manner. The unit load weight is divided by the unit load height in inches and multiplied by 192. The resulting number is the equivalent compressive force of a 16-foot-high load.

2. REPETITIVE SHOCK TEST. The repetitive shock test was conducted IAW Method 5019, Federal Standard 101. The test procedure is as follows: the test specimen was placed on, but not fastened to, the platform. With the specimen in one position, the platform was vibrated at 1/2-inch amplitude (1-inch double amplitude) starting at a frequency of approximately 3 cycles per second. The frequency was steadily increased until the specimen left the platform. The resonant frequency is achieved when a 1/16-inch-thick feeler gage may be momentarily slid freely between every point on the specimen in contact with the platform at some instance during the cycle or a platform acceleration of 1 ± 0.1 G forces is achieved. Midway into the testing period, the specimen was rotated 90 degrees and the test continued for the duration. Unless failure occurs, the total time of vibration is two hours when the specimen is tested in one position. When the specimen is tested in more than one position, the total time is three hours.

3. EDGEWISE ROTATIONAL DROP TEST. This test was conducted using the procedures of Method 5008, Federal Standard 101. The procedure for the Edgewise Rotational Drop Test is as follows: The specimen was placed on its skids with one end of the pallet supported on a beam 4-1/2 inches high. The height of the beam was increased, when necessary, to ensure that there was no support for the skids between the ends of the pallet when dropping took place, but was not high enough to cause the pallet to slide on the supports when the dropped end was raised for the drops. The unsupported end of the pallet was then raised and allowed to fall freely to the concrete, pavement, or similar underlying surface from the prescribed height. Unless otherwise specified, the height of drop for level A protection shall conform to the following tabulation.

GROSS WEIGHT NOT EXCEEDING (Pounds)	DIMENSIONS ON ANY EDGE NOT EXCEEDING (Inches)	HEIGHT OF LEVEL DROP A PROTECTION (Inches)
600	72	36
3,000	no limit	24
no limit	no limit	12

4. INCLINE-IMPACT TEST. This test was conducted using the procedure of Method 5023, Incline-Impact Test of Federal Standard 101. The procedure for the Incline-Impact Test is as follows: The specimen was placed on the carriage with the surface or edge to be impacted projecting at least 2 inches beyond the front end of the carriage. The carriage was brought to a predetermined position on the incline and released. If it is desired to concentrate the impact on any particular position on the container, a 4- by 4-inch timber may be attached to the bumper in the desired position before the test. No part of the timber was struck by the carriage. The position of the container on the carriage and the sequence in which surfaces

and edges were subjected to impacts was at the option of the testing activity and depended upon the objective of the tests. When the test is to determine satisfactory requirements for a container or pack, and, unless otherwise specified, the specimen was subjected to one impact on each surface that has each dimension less than 9.5 feet. Unless otherwise specified, the velocity at time of impact was 7 feet-per-second.

5. HOT/COLD TEST. For hot and cold MIL-STD-1660 tests, samples were preconditioned to -40 degrees Fahrenheit and/or 145 degrees Fahrenheit for a period of 24 hours prior to tests being conducted. Following completion of one test, the samples were preconditioned again for a period of not less than two hours prior to the next test being conducted.

B. RAIL IMPACT TEST. The test procedures outlined herein were extracted from USADACS, Transportability Testing Procedures, TP-94-01, July 1994.

1. MILVAN LOAD PREPARATION. The railcar was loaded with 10 wooden pallets each of 120mm/40mm inert ammunition and blocked/braced in the same manner as authorized deviations to normal blocking and bracing procedures. The weight and physical characteristics of the load configuration were identical to the live (explosive) ammunition provided for in the outloading procedure; i.e., weights, physical dimensions, center of gravity (CG), materials, etc. The inert ammunition packages duplicated that of live ammunition. If failures occurred during any part of testing, modifications were made to the load and/or blocking and bracing procedures and the item retested in its entirety.

2. RAIL IMPACT TEST. Equipment needed to perform the test included the specimen (hammer) car, five empty railroad cars connected together to serve as the anvil, and a railroad locomotive. The anvil cars were positioned on a level section of track with air and hand brakes

set and with the draft gear compressed. The locomotive unit pulled the specimen car several hundred yards away from the anvil cars, pushed the specimen car toward the anvil at a predetermined speed, then disconnected from the specimen car approximately 50 yards away from the anvil cars which allowed the specimen car to roll freely along the track until it struck the anvil. This constituted an impact. Impacting is accomplished at speeds of 4, 6, and 8.1 mph in one direction and at a speed of 8.1 mph in the reverse direction. The 4 and 6 mph impact speeds are approximate; the 8.1 mph speed is a minimum. Impact speeds are 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.

3. DATA COLLECTION. The specimen car was instrumented with accelerometers on the sill of the railcar. At the end of each rail impact, the recorded accelerations were downloaded to determine stresses, movement forces, velocities, and accelerations during each impact. Data collected are suitable for use in investigating causes for failure and as a criteria for design when developing new procedures if required.

4. FAILURE CRITERIA. At the conclusion of each impact, the load was examined for excessive shifting of contents, loosening or breaking of load restraints or blocking and bracing, or any visible damage to the items in the load or their packaging. Normally, testing is stopped when it becomes apparent that the load will fail; however, the test may be continued until complete failure if the test engineer determines usable data will be developed and safety of personnel and equipment integrity is not violated.

PART 4

TEST EQUIPMENT

A. 120mm Palletized Ammunition (test samples).

1. Width:	41.75 inches
2. Length:	44.5 inches
3. Height:	53.5 inches
4. Weight:	1,730 pounds

B. 40mm Palletized Ammunition (test samples).

1. Width:	44.25 inches
2. Length:	47.75 inches
3. Height:	38.0 inches
4. Weight:	2,570 pounds

C. Railcar.

1. Car Type:	Boxcar
2. Length:	50 feet (approximately)
3. Width:	10 feet (approximately)
4. Draft Gear:	Friction

D. Data Acquisition Equipment.

1. Manufacturer:	Pacific Scientific
2. Number of Channels:	3

PART 5

TEST RESULTS

40MM AMMUNITION ENHANCED WOOD PALLET

MIL-STD-1660 TESTS

A. COMPRESSION TEST. Three compression tests were conducted on the 40mm ammunition pallet: one at ambient, one at -40 degrees Fahrenheit, and one at 145 degrees Fahrenheit. Compressive loads ranged from 12,500 to 13,000 pounds with no problems encountered during testing.

B. REPETITIVE SHOCK TEST. Four tests were conducted with vibration speeds ranging from 184 rpm to 252 rpm. Midway through the 3-hour test, each pallet was rotated 90 degrees so forces could be applied both longitudinally and laterally to the pallet skids. Although no problems were noted with the pallet during this series of tests, the following discrepancies/damage were noted on the pallet adapters after testing:

1. One nail on the bottom pallet adapter came loose.

2. Several nails on the corner of the top pallet adapter came loose (see photos in Part 6).

3. One crack was noted on the center board of the lower pallet adapter.

4. A forklift tine damaged a lower pallet adapter as well as breaking a horizontal unitization strap during handling.

5. During hot and cold testing, several containers became disengaged from the nested position with the containers below and shifted longitudinally and laterally. The reason for this disengagement is probably due to wear on the container lids from previous tests.

C. EDGEWISE ROTATIONAL DROP TEST. Four tests were conducted on the 40mm ammunition wooden pallet going clockwise until all four sides were dropped. No problems were noted with the pallet; however, the pallet adapters experienced the following damage:

1. Nails in the center board on the bottom adapter came loose.

2. Two nails in the 1- by 4-inch boards on the top pallet adapter came loose.

3. Small cracks were noted in the pallet skids.

4. During cold testing, the top adapter cross support member became loose at one end with all nails being pulled out.

D. INCLINE-IMPACT TEST. The incline plane was set to allow the pallets to travel 8 feet prior to impacting a stationary wall. The pallets were rotated clockwise after each impact, until all four sides had been tested. Following the four tests, the conditions listed below were noted:

1. The center layer of containers was no longer nested.

2. One end of the top pallet adapters had loose nails (see photos in Part 6).

3. Several containers during hot testing became disengaged and unnested.

4. During cold impact tests, one top pallet adapter board split and several nails came loose with several containers becoming disengaged from the container below (see photos in Part 6).

E. LIFTING TEST. During the 3-, 2-, and 1-sling lifting tests, the following damage occurred to the pallet adapters with no damage to the pallet itself:

1. One top pallet adapter board split; however, it continued to support the load during the three-ring lift.

2. The lifting rings had permanent deformation to a point where they were no longer self-nesting.

3. Nails on one of the sideboards on the bottom pallet adapter came loose (see photos in Part 6).

120MM AMMUNITION ENHANCED WOOD PALLET

MIL-STD-1660 TESTS

A. COMPRESSION TEST. Two compression tests were conducted at ambient temperature. The compressive loads ranged from 8,700 to 10,000 pounds with no damage occurring to the pallets.

B. VIBRATION TEST. Two tests were conducted at speeds ranging from 120 rpm to 175 rpm during lateral and longitudinal orientations. The following deviations were noted during testing:

1. The bell end of the PA116 containers shifted beyond the edge of the pallet.

2. One nut and washer fastening the lifting ring to the pallet adapter came loose.

3. The side 2- by 4-inch board on the bottom adapter came loose at the base end of the container.

4. Two nails came out of the bottom adapter after 70 minutes of testing.

C. EDGEWISE ROTATIONAL DROP TEST. Two tests were conducted on the 120mm ammunition wooden pallet going clockwise until all four sides were dropped. No problems were noted with the pallet; however, the pallet adapters experienced the following damage:

1. The top adapter shifted to the base end of the containers.

2. One metal strip attached to the bottom of the center skid came off.

3. Following two drops, the pallet was bowing, causing it to rest on only two skids.

4. The containers shifted 1-5/8-inches beyond the edge of the pallet.

5. One outside skid had a minor crack.

6. One wing on the pallet outside skid broke.

D. INCLINE- IMPACT TEST. The incline plane was set to allow the pallets to travel 8 feet prior to impacting a stationary wall. The pallets were rotated clockwise after each impact, until all four sides had been tested. Following the tests, the damage listed below was noted:

1. The top adapter shifted to the base end of the containers, due to improper placement of the bracing boards.

2. The nails in the sideboards on the bottom adapter came loose.

3. A pallet strap broke during testing, allowing the fourth row of containers to become disengaged.

E. LIFTING TEST. During the 3-, 2-, and 1-sling lifting tests, the following damage occurred to the pallet adapters with no damage to the pallet itself:

1. Catastrophic failure of one lifting ring, being pulled out of the top pallet adapter.

2. Following testing, the rings had permanent deformation and were no longer self-nesting.

40MM AMMUNITION AND 120MM AMMUNITION

ENHANCED WOOD PALLETS AND ADAPTERS

RAIL IMPACT TESTS

Rail impact tests were conducted on the 40mm ammunition and 120mm ammunition enhanced wood pallets with the test load being 2-layers high (see Part 8, Drawings). The 40mm ammunition pallets were on one side of the railcar and 120mm ammunition pallets on the other. The rail impact speeds were as follows:

Impact No.	MPH	Remarks
1	4.2	2-inch gap at rear of load
2	6.1	3-inch gap at rear of load
3	8.5	3-inch gap at rear of load
4	8.5	3-inch gap at rear of load

After testing, the following damage was noted.

a. The skids on the 120mm ammunition pallets rode up and under the forklift tine protector (2- by 4-inch timber) of the adjacent pallets.

b. The vertical center gate on the 40mm ammunition side of the railcar failed.

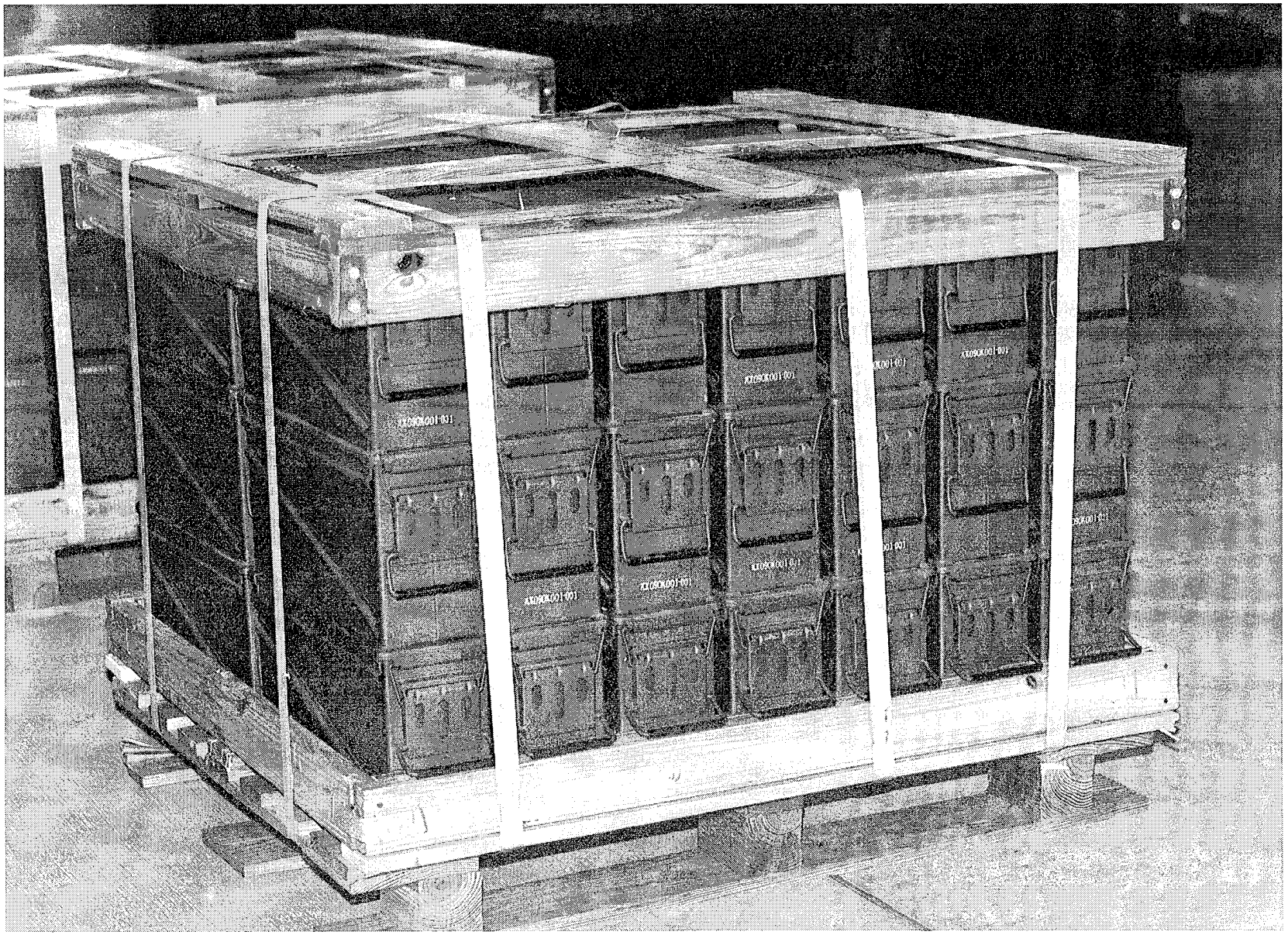
c. The 40mm ammunition side of the railcar top pallet adapter 2- by 4-inch timber failed due to misalignment of the adjacent pallet.

d. Many pallet adapter boards showed cracking in and around nail holes.

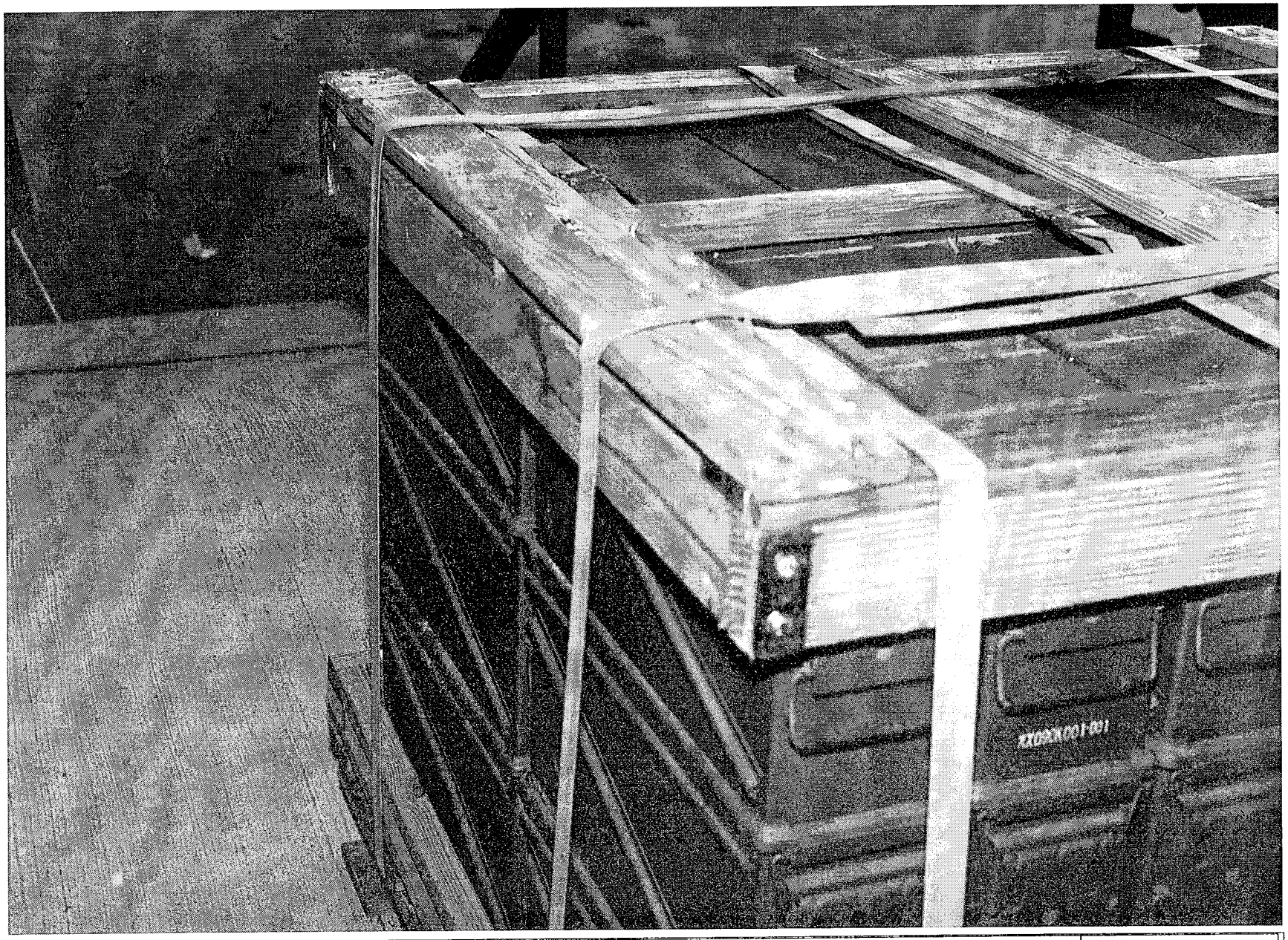
Generally speaking, except for wood splitting, all damage noted was due to pallet interfacing and misalignment of the inert load with the enhanced wood pallets.

PART 6

PHOTOGRAPHS

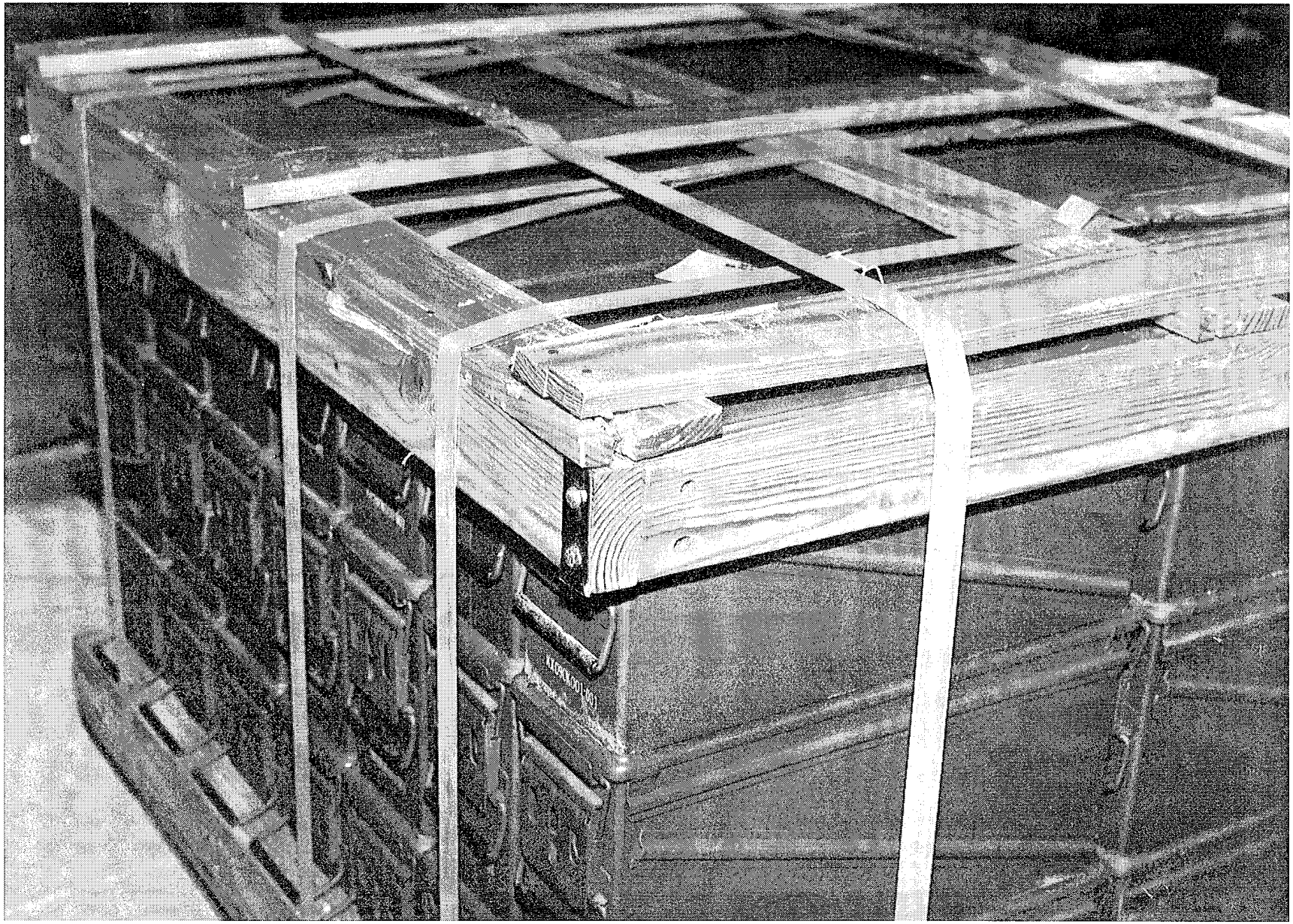


	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-222-4119. This photo shows the overall view of the 40MM ammunition enhanced wood pallet with enhanced wood pallet adapters.		



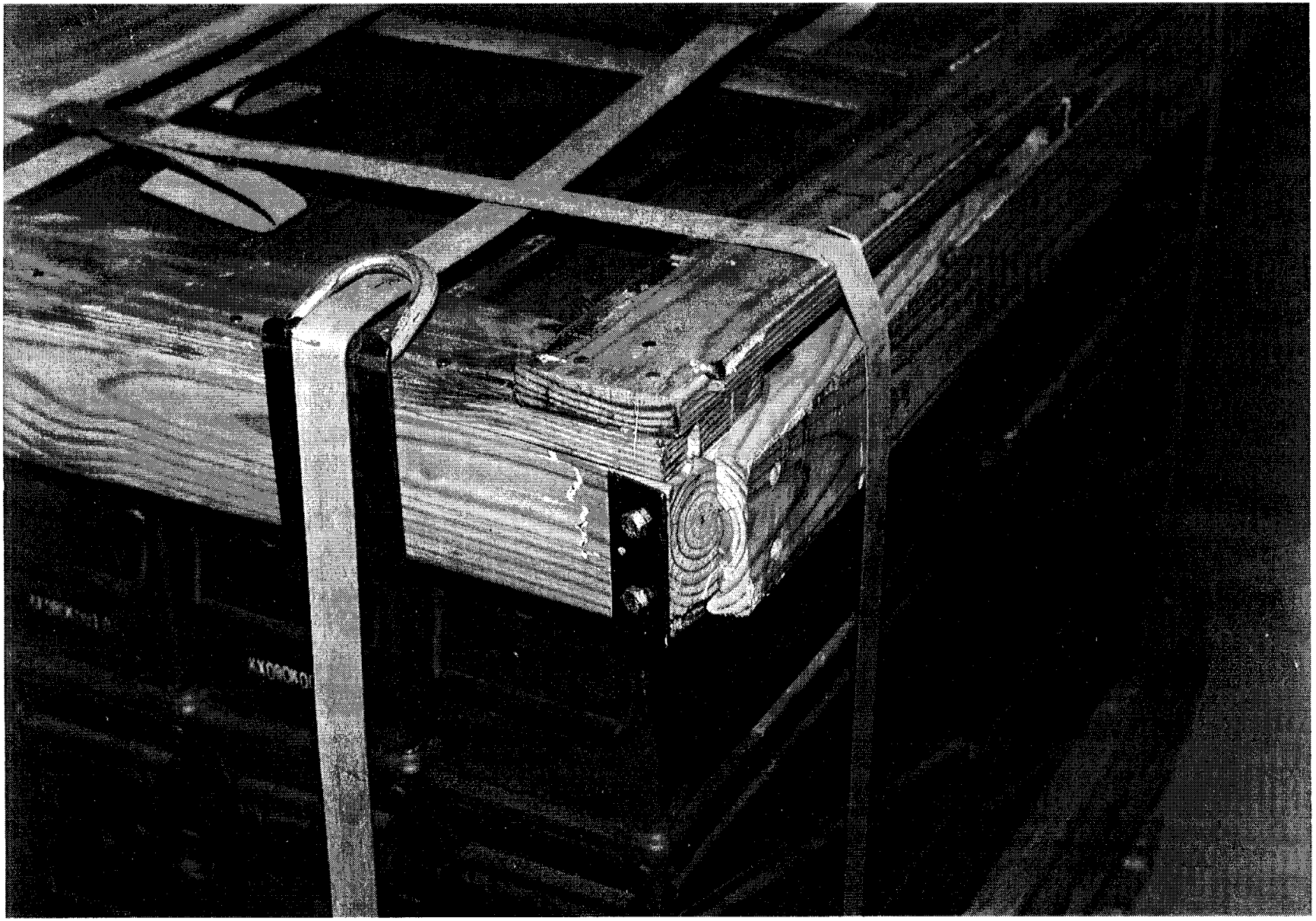
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

PHOTO NO. SCN94-223-4465. This photo shows a closeup view of a damaged 1- by 4-inch lumber on the top pallet adapter.



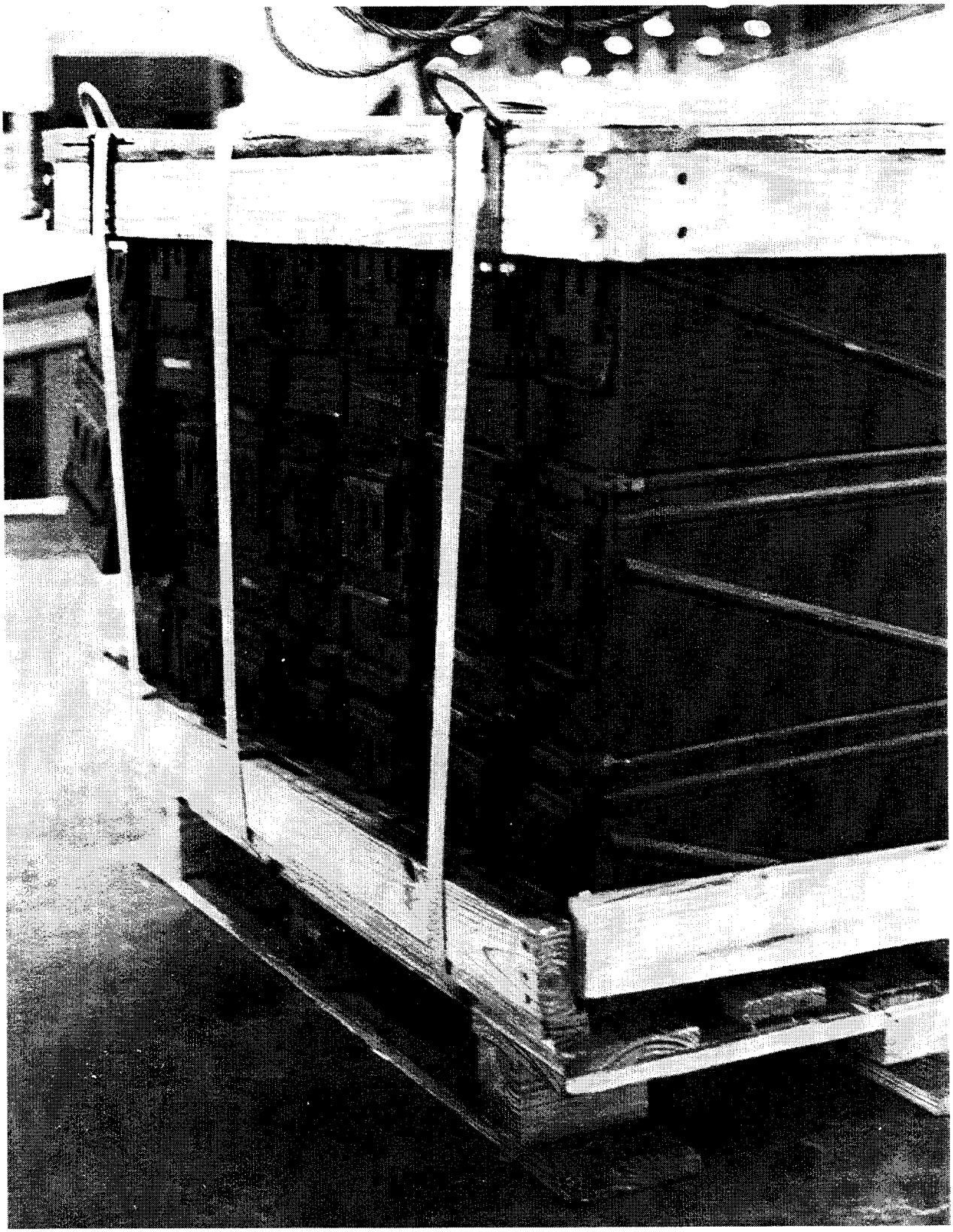
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-223-4463. This photo shows a closeup corner view of damage to the top pallet adapter.		

	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-223-4462. This photo shows a closeup view of the top pallet adapter with corner bolts being pulled from the top frame.		

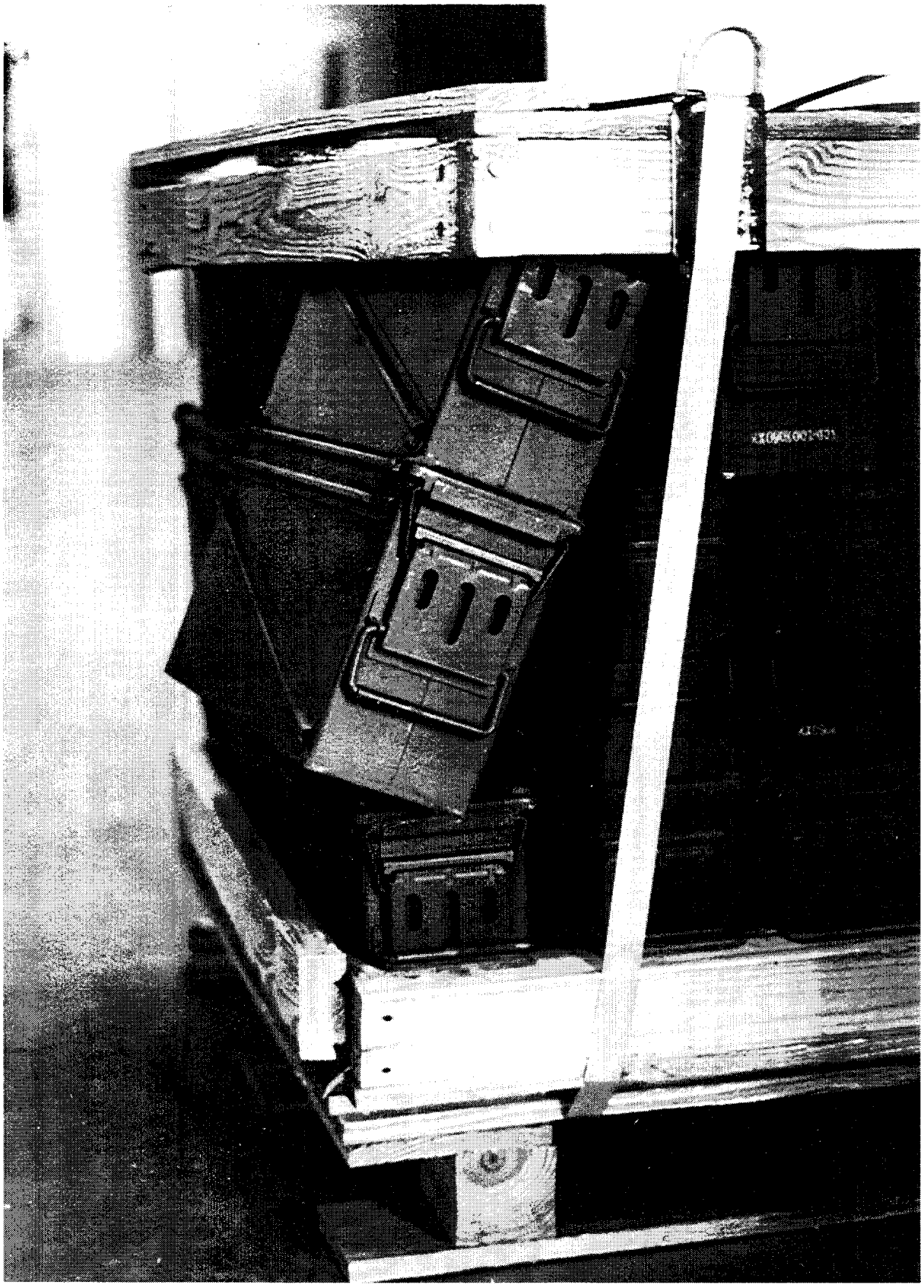


	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

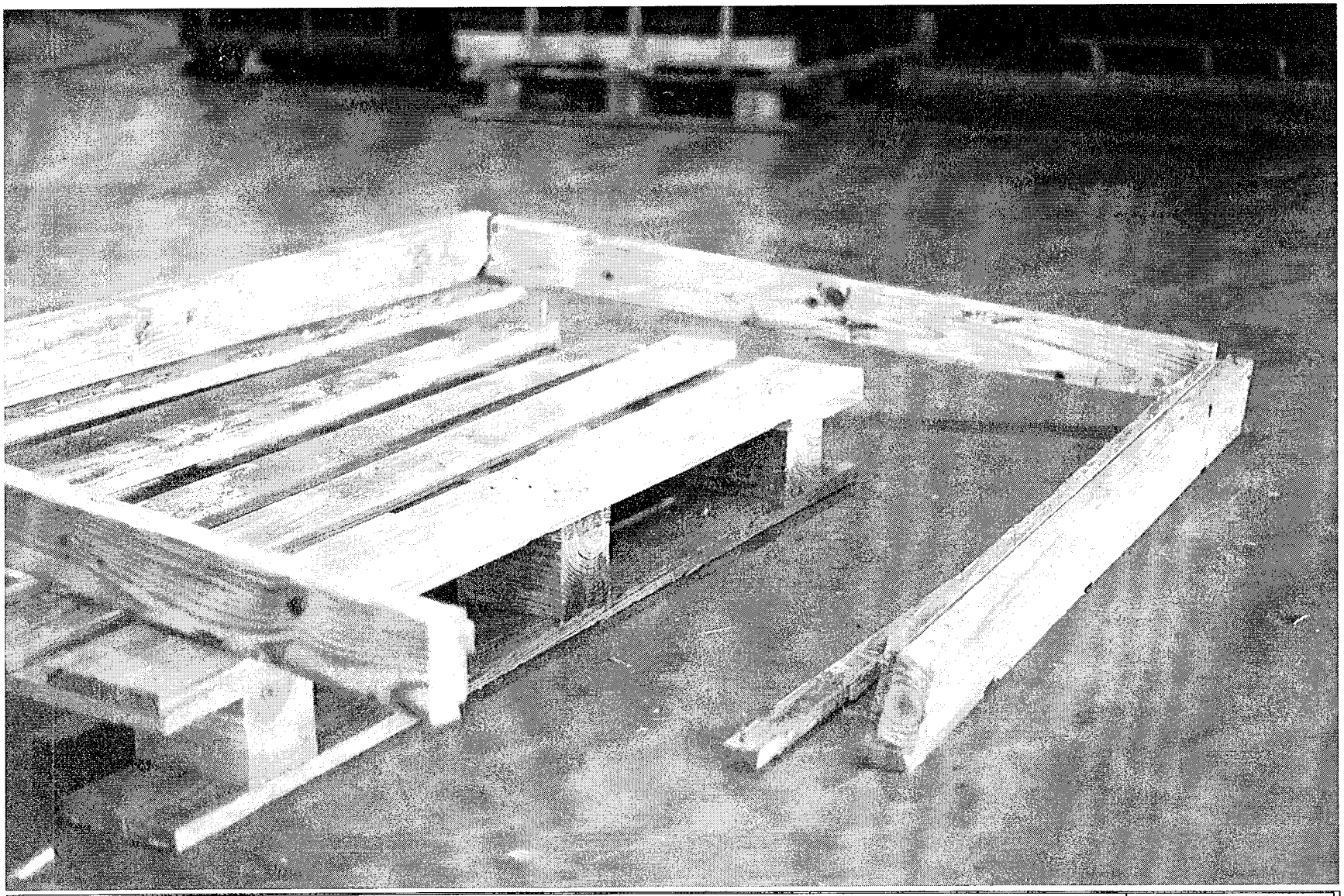
PHOTO NO. SCN94-223-4455. This photo shows a closeup view of additional damage which occurred during rail testing.



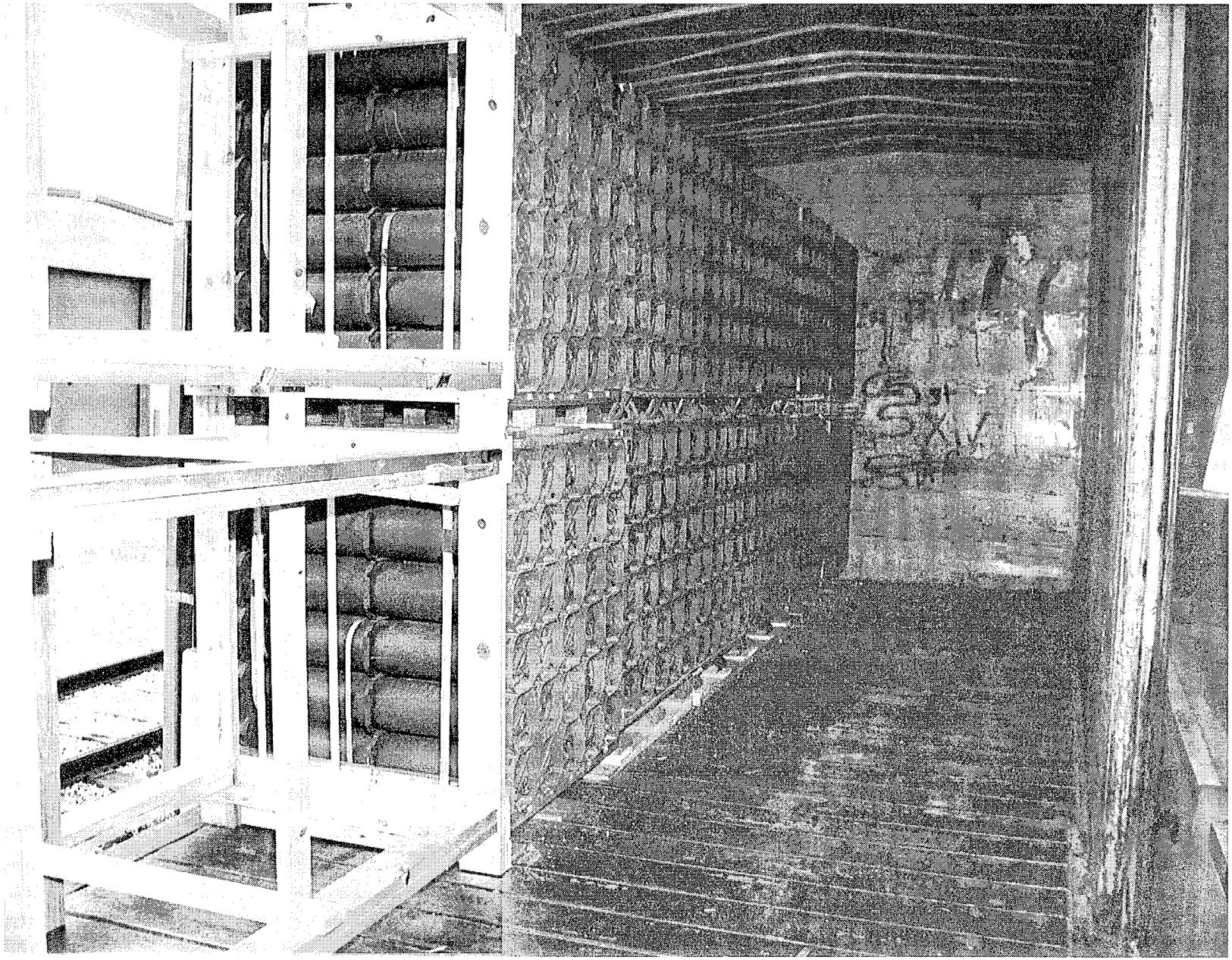
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL
PHOTO NO. SIOAC-DEV 001. This photo shows damage to the lower pallet adapter following MIL-STD-1660 tests.	



	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL
PHOTO NO. SIOAC-DEV 002. This photo shows damage to the lower pallet adapter following MIL-STD-1660 tests.	



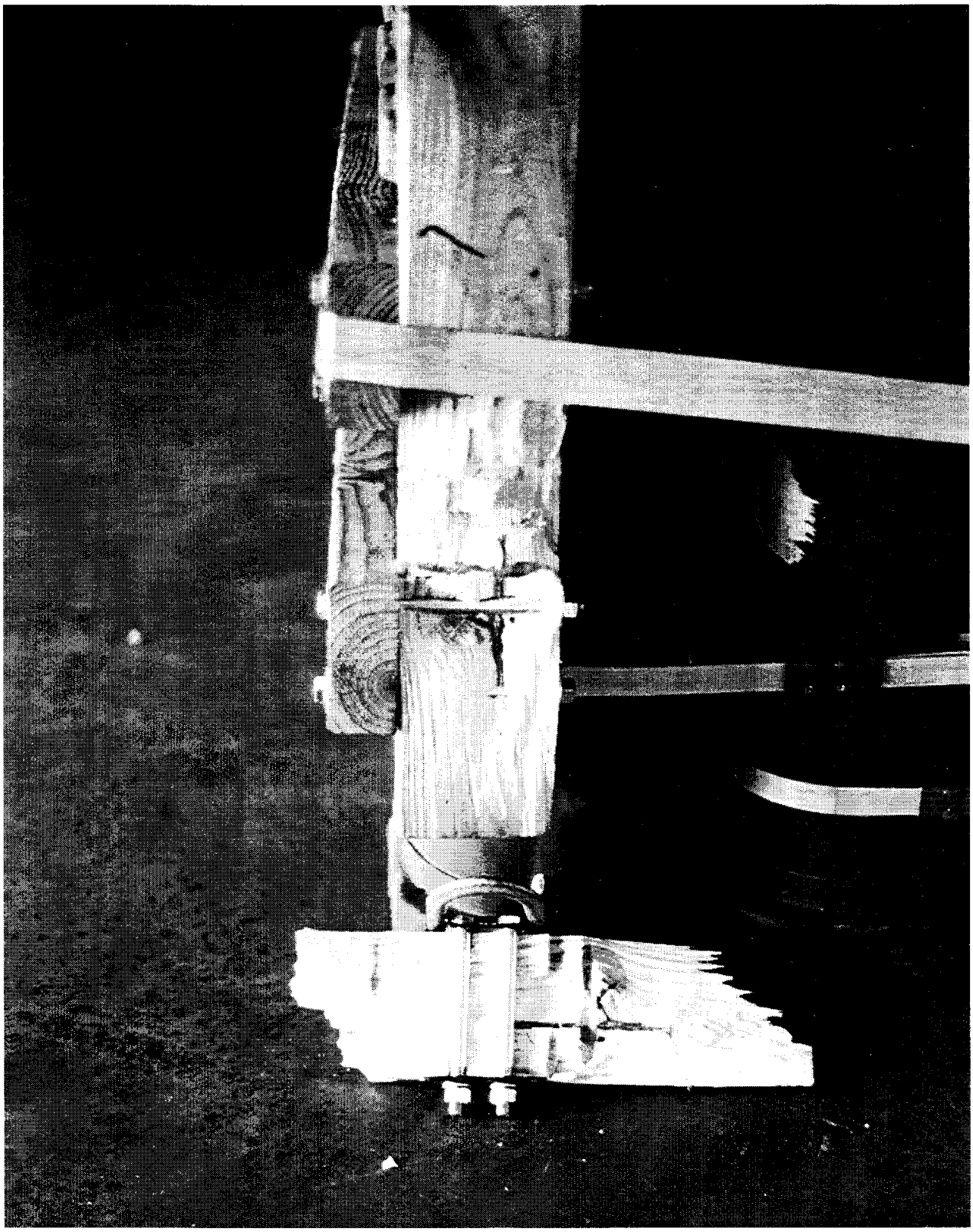
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SIOAC-DEV 003. This photo shows the total damage of the lower pallet adapter after disassembly, following MIL-STD-1660 testing.		



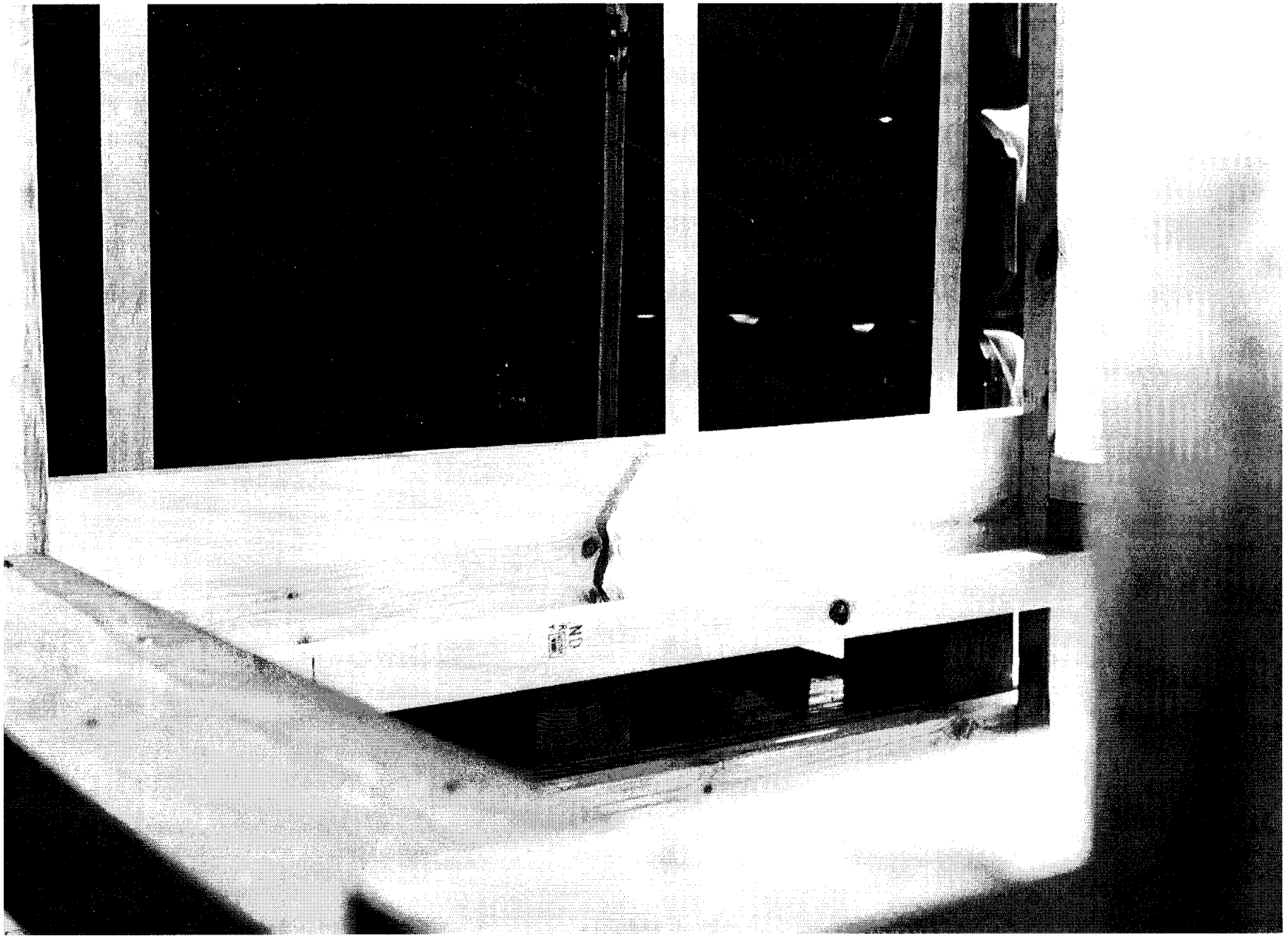
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-222-4168. This photo shows an overall view of the 120MM ammunition pallet loaded in the boxcar prior to testing.		

	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-223-4452. This photo shows the lower pallet adapter damage following rail impact testing.		

	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-223-4456. This photo shows the damage received to the top pallet adapter following rail impact testing. Note the bolt being pulled out of the 2- by 4-inch dimensional lumber.		



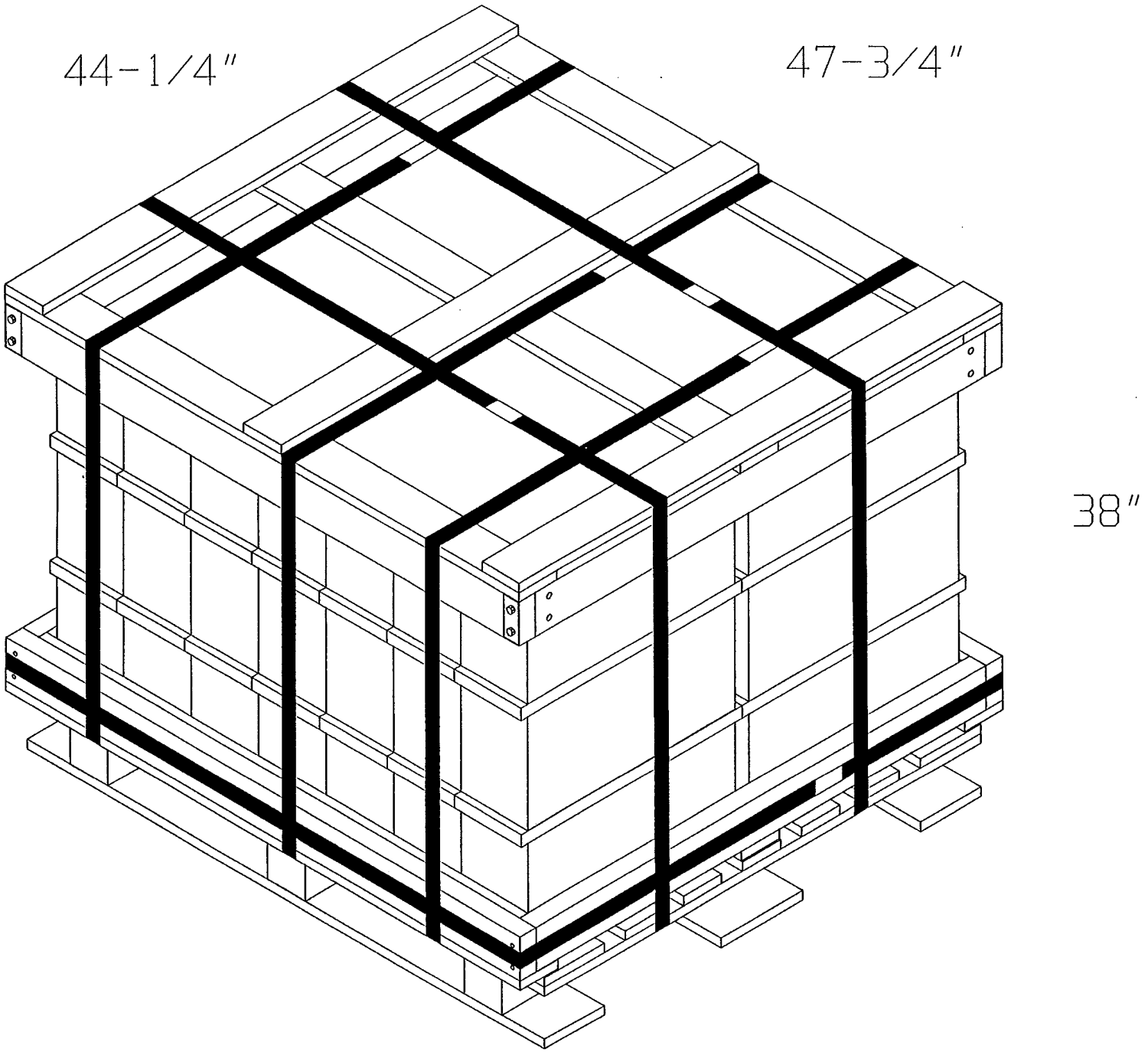
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SIOAC-DEV-004. This photo shows the damage received to the top pallet adapter following the single-sling lifting test. Note the lifting ring being separated from the top pallet adapter.		

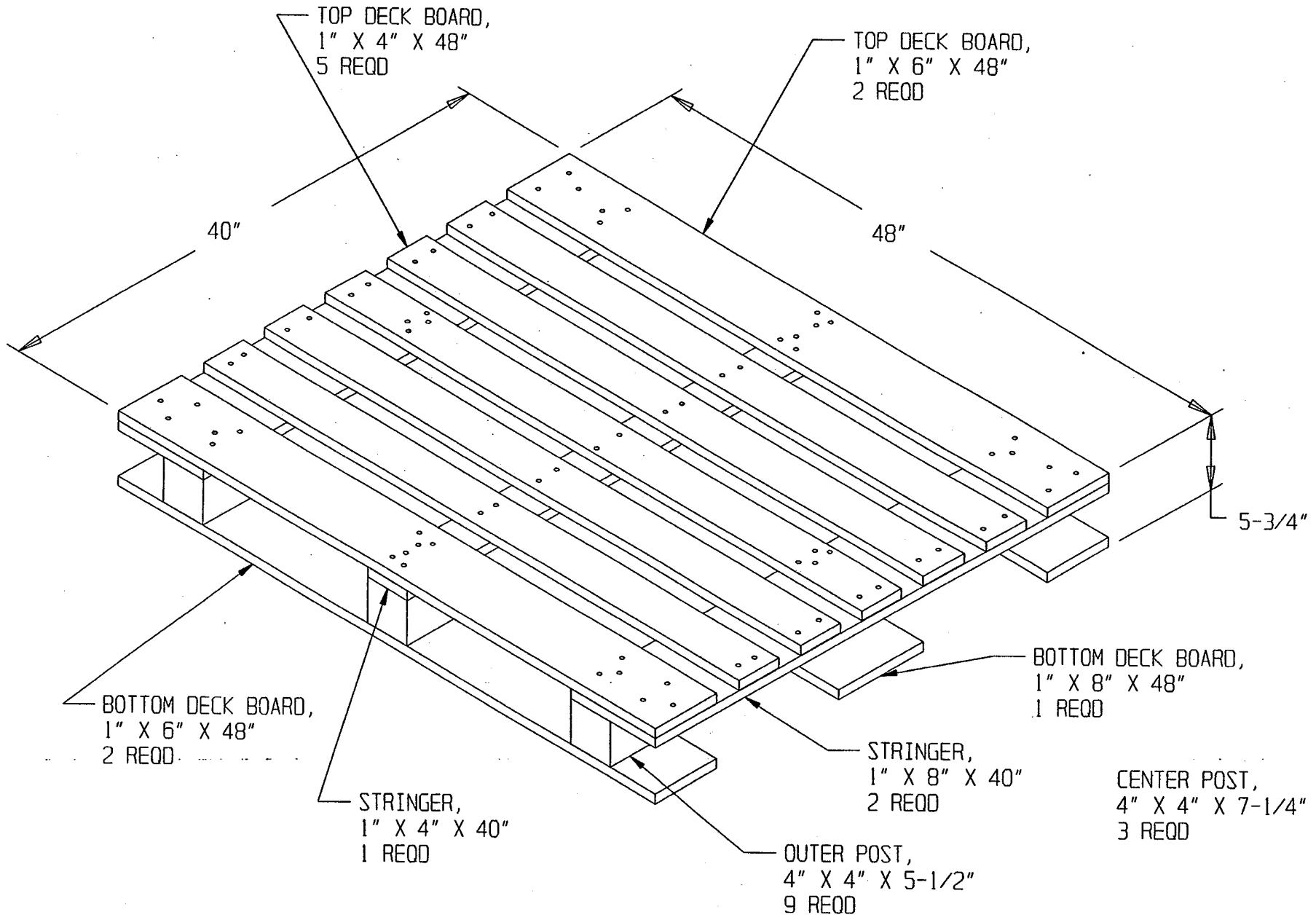


	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
PHOTO NO. SCN94-222-4116. This photo shows the damage received to the center gate in the railcar following rail impact testing.		

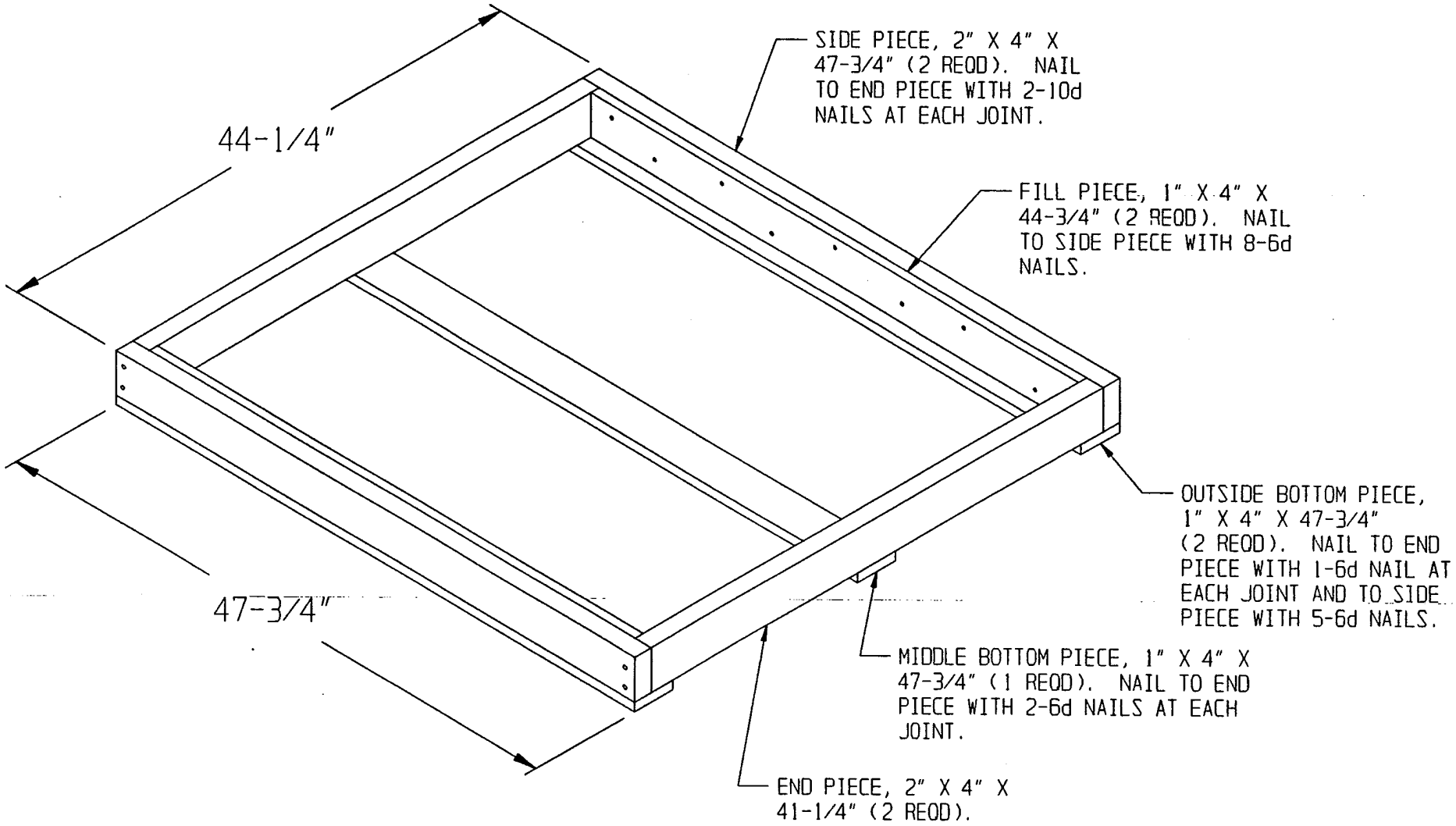
PART 7

DRAWINGS

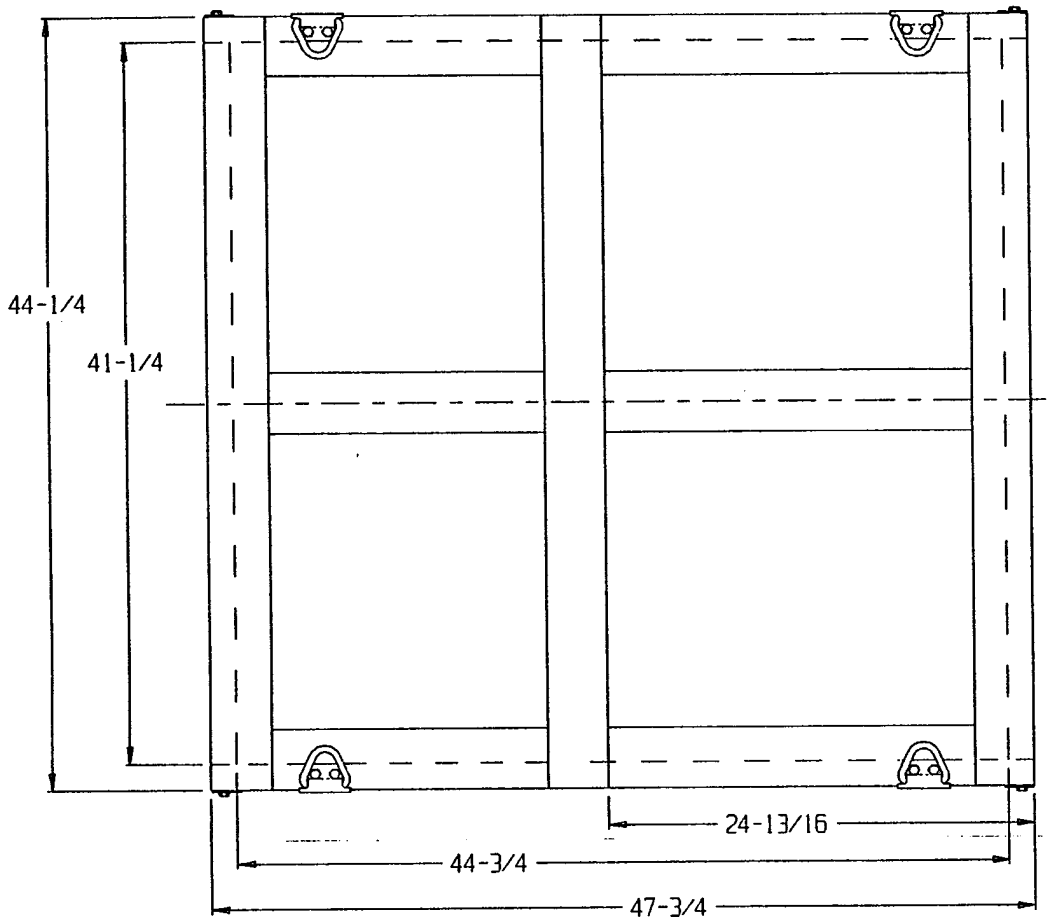

44-1/4"
47-3/4"
38"

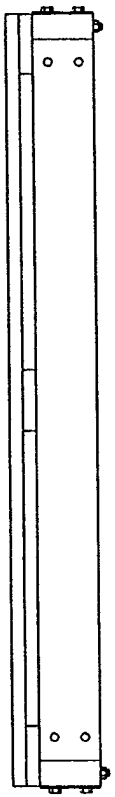


40" X 48" PALLET FOR PA120 CONTAINER

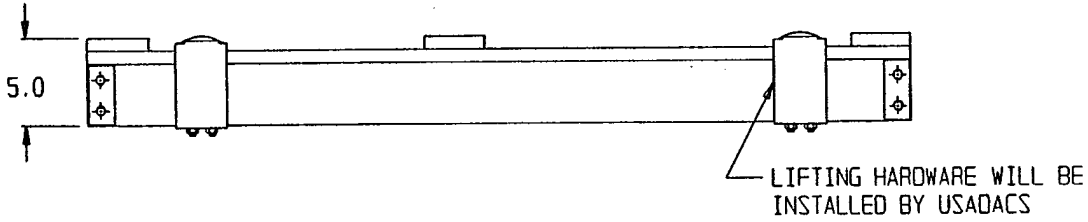


BOTTOM ADAPTER FOR PA120 CONTAINER



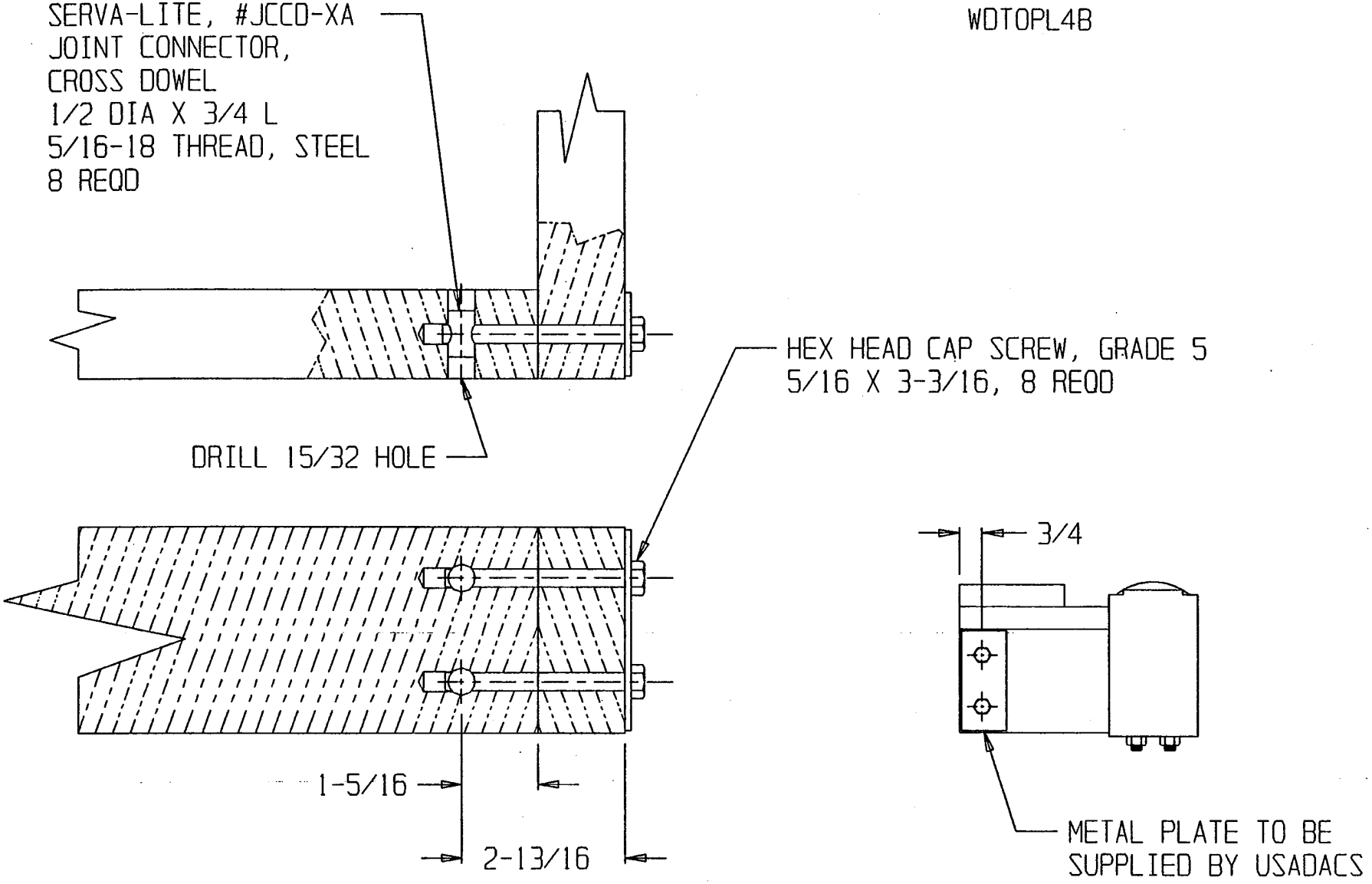


LIFTING HARDWARE OMITTED FOR CLARITY

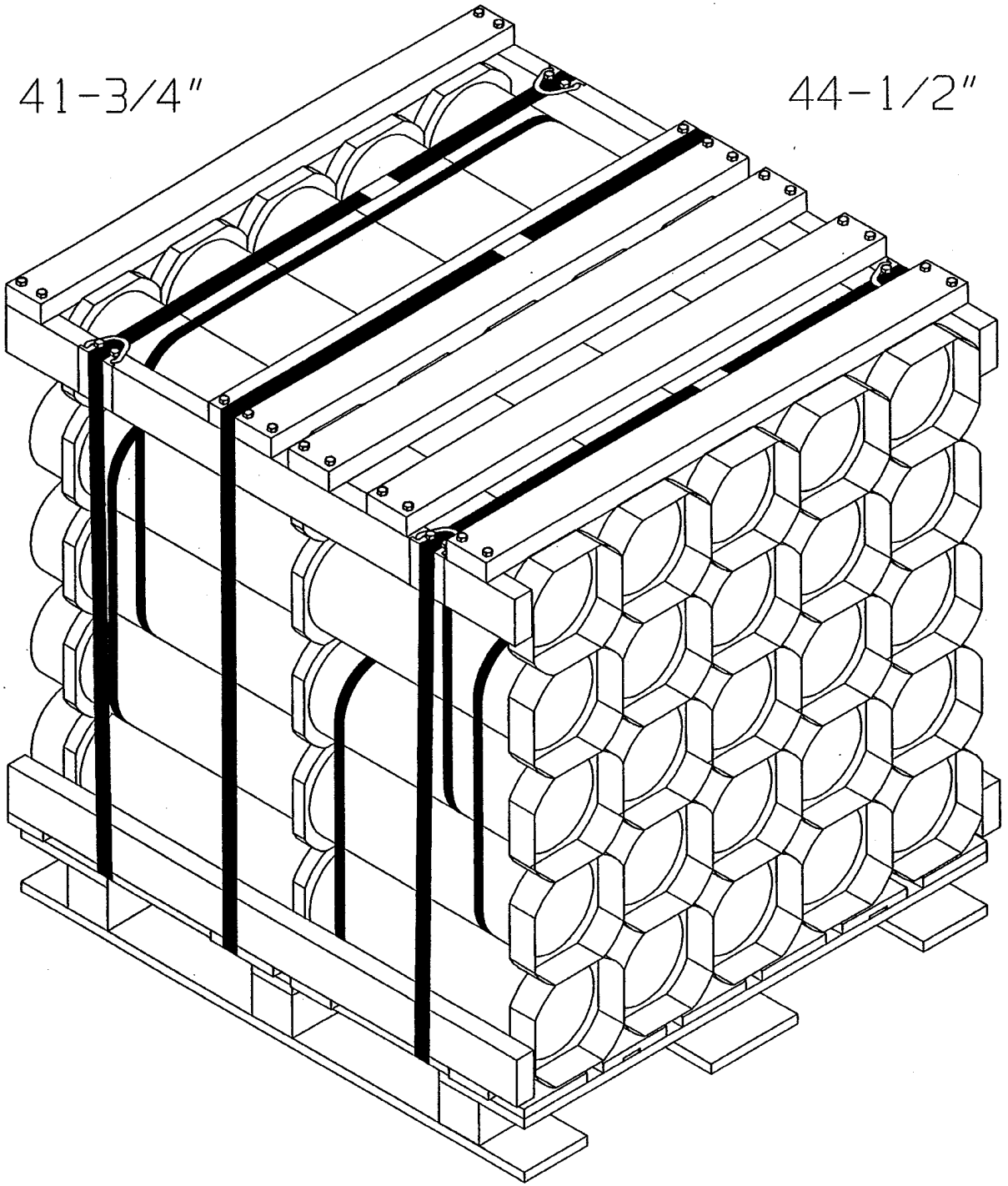


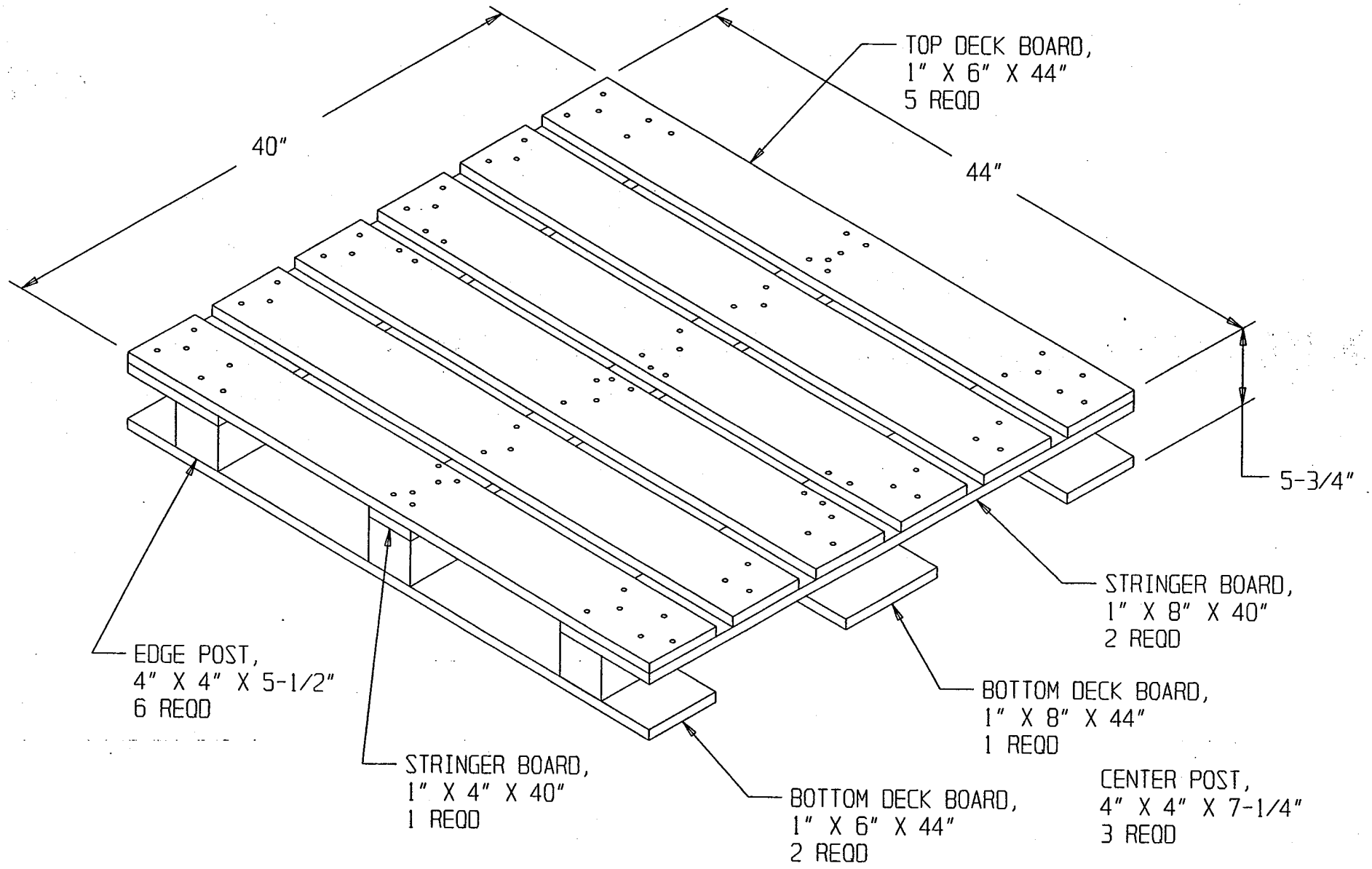
TOP LIFT FOR PA120 CONTAINER

CAD FILE
WDTOPL4B

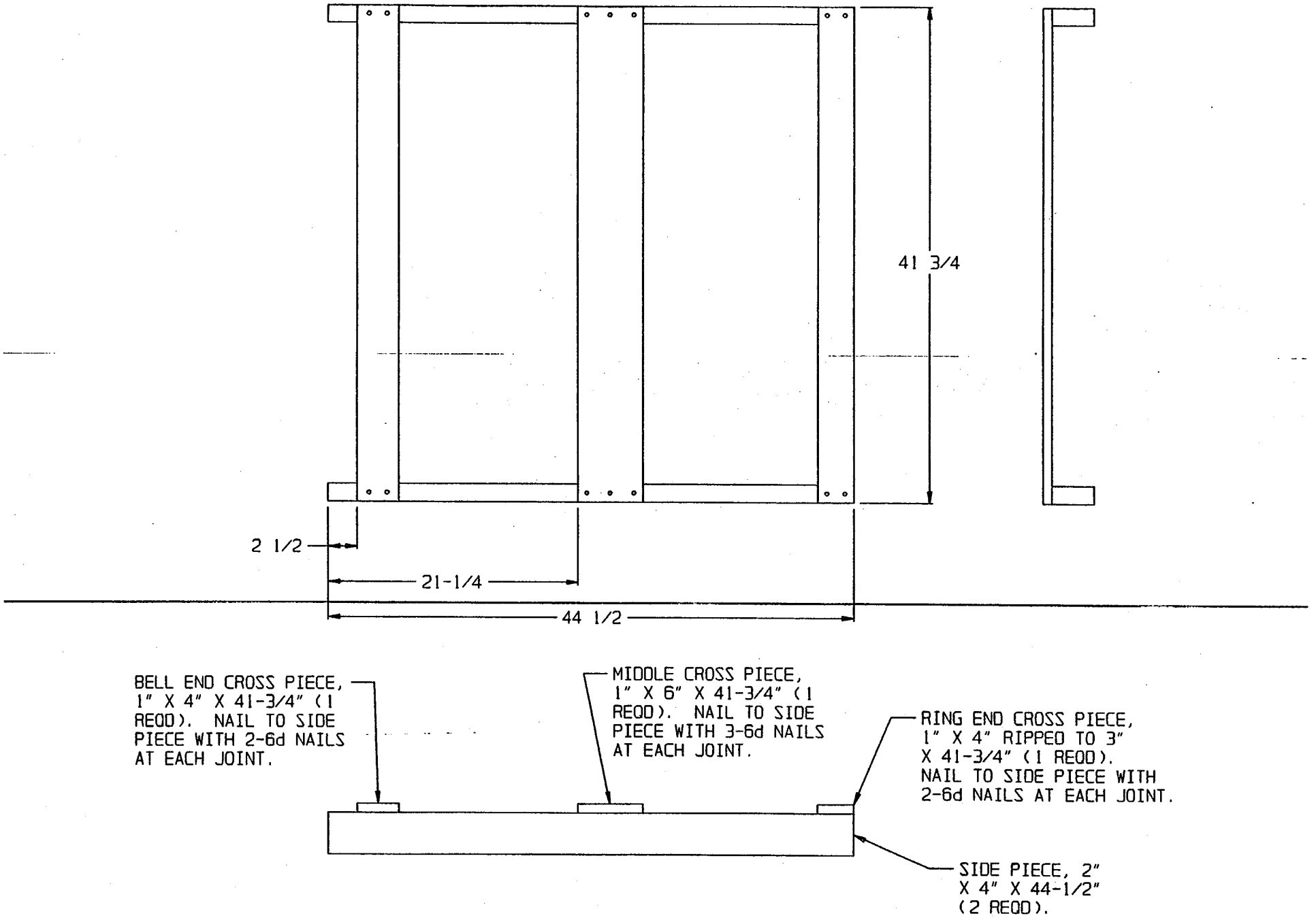


DETAIL FOR PA120 CONTAINER TOP LIFT

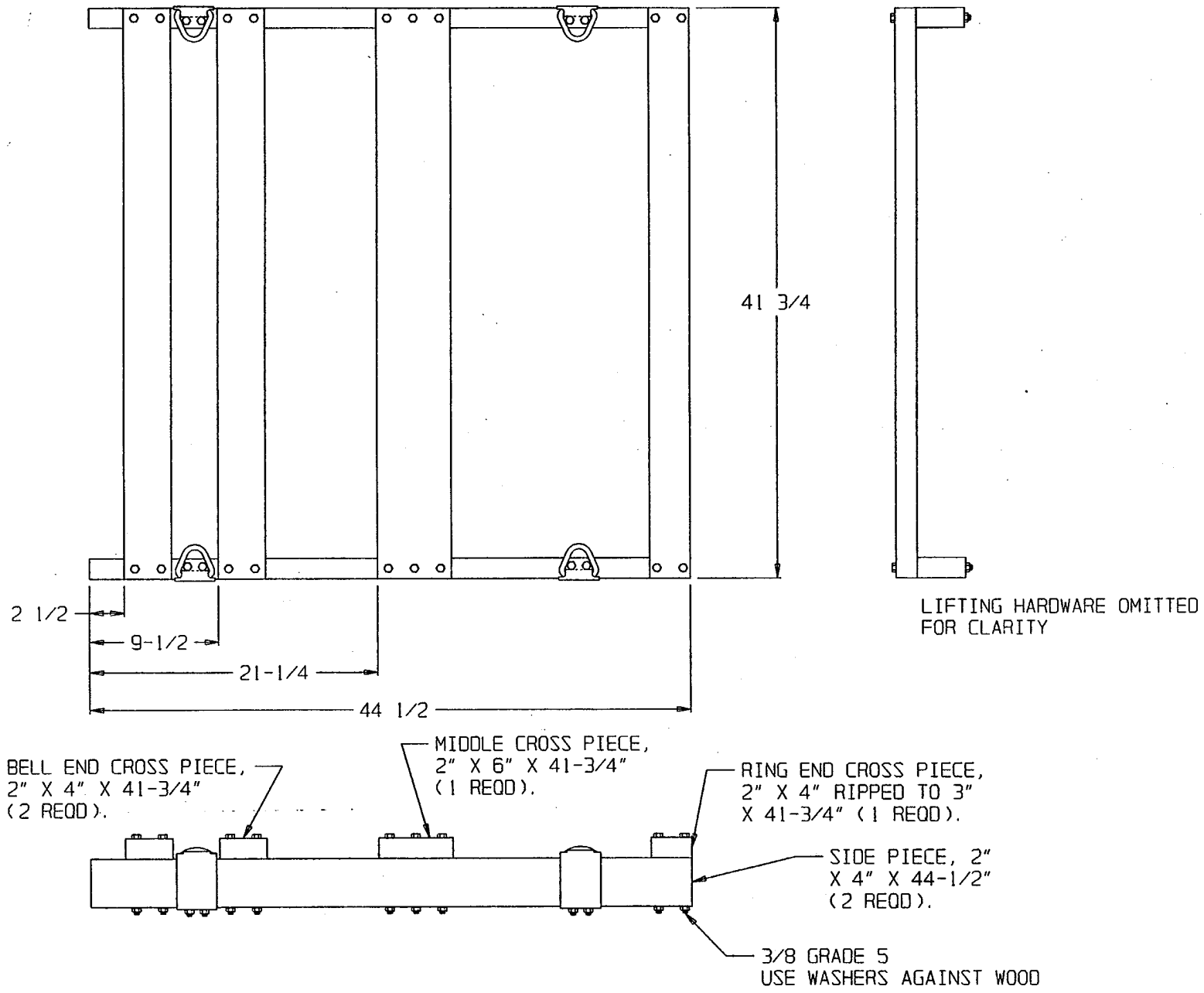

41-3/4"
44-1/2"
45-3/4"



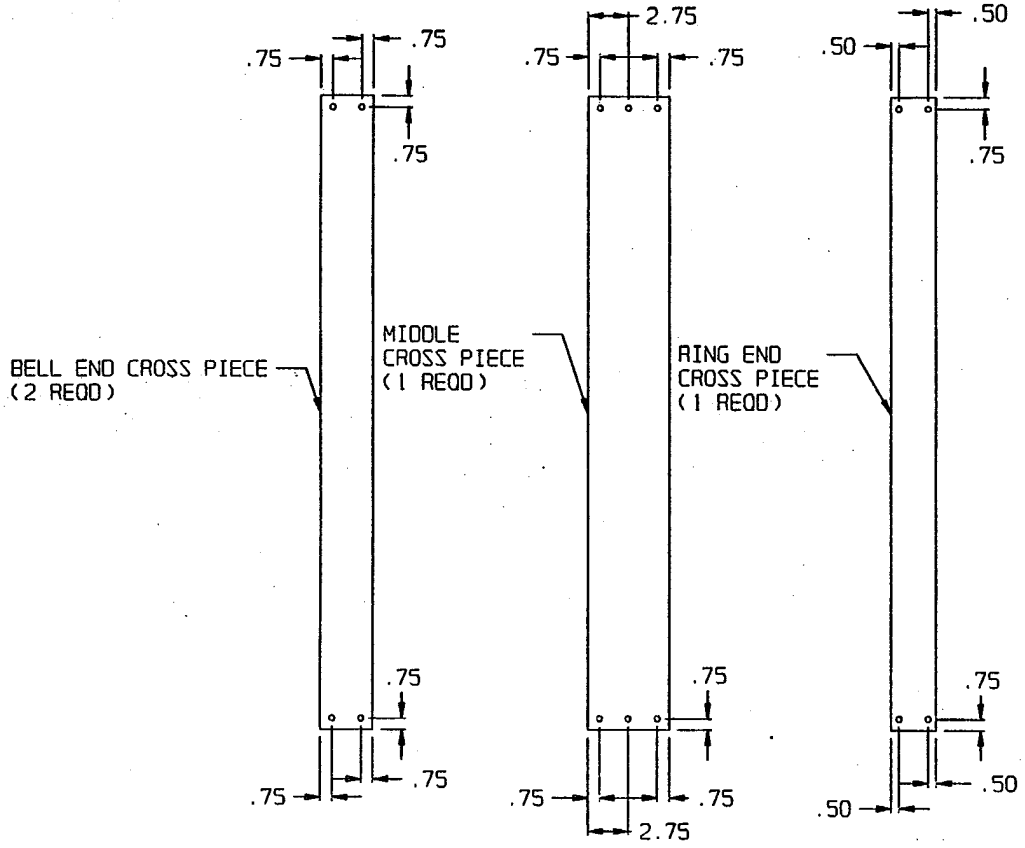
40" X 44" PALLET FOR PA116 CONTAINER

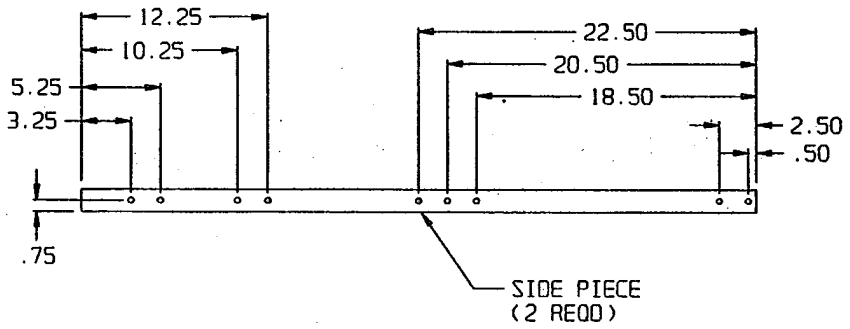


BOTTOM ADAPTER FOR PA116 CONTAINER



TOP ADAPTER FOR PA116 CONTAINER





ALL HOLES 3/8" + 1/32"

ALL DIMENSIONS ARE TO CENTER OF HOLES

TOP ADAPTER FOR PA116 CONTAINER

LOADING AND BRACING IN BOXCAR OF 40MM CARTRIDGES PACKED IN METAL CANS, AND 120MM COMPLETE ROUNDS PACKED IN PA116 CYLINDRICAL METAL CONTAINERS, EACH UNITIZED ON ENHANCED WOODEN PALLETS

THIS 6-PAGE DOCUMENT DEPICTS PROCEDURES FOR A LOAD CONSISTING OF TWO ROWS OF PALLET UNITS EACH TWO LAYERS IN HEIGHT. ONE ROW CONSISTS OF 14 PALLET UNITS OF 40MM CARTRIDGES PACKED IN METAL CANS AND UNITIZED ON ENHANCED WOODEN PALLETS, AND FOR BALLAST PURPOSES, 12 PALLET UNITS OF 40MM UNITIZED ON METAL PALLETS. THE OTHER ROW CONSISTS OF 14 PALLET UNITS OF 120MM COMPLETE ROUNDS IN CYLINDRICAL METAL CONTAINERS UNITIZED ON ENHANCED WOODEN PALLETS, AND FOR BALLAST PURPOSES, 12 PALLET UNITS OF 120MM COMPLETE ROUNDS ON METAL PALLETS.

THE ACCOMPLISHMENT OF THIS TEST WILL DETERMINE IF THE ENHANCED WOODEN PALLETS ARE CAPABLE OF WITHSTANDING THE FORCES INCURRED DURING RAIL SHIPMENTS.

Prepared during August 1994 by:
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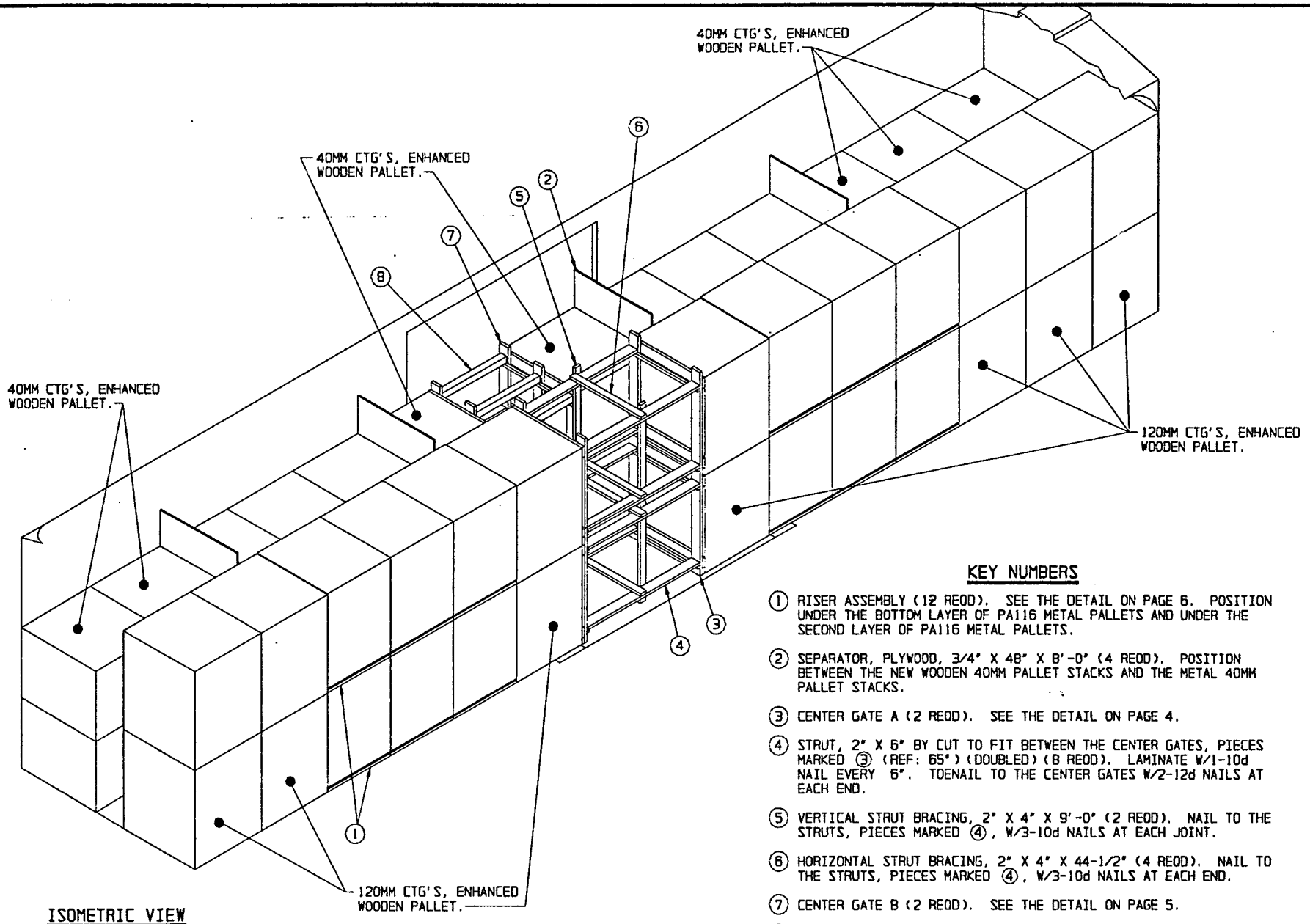
WILLIAM R. FRERICHS
Chief, Transportation Engineering Division



ISOMETRIC VIEW

KEY NUMBERS

(1) RISER ASSEMBLY (12 REQD). SEE THE DETAIL ON PAGE 6. POSITION UNDER THE BOTTOM LAYER OF PA116 METAL PALLETS AND UNDER THE SECOND LAYER OF PA116 METAL PALLETS.

(2) SEPARATOR, PLYWOOD, 3/4" X 48" X 8'-0" (4 REQD). POSITION BETWEEN THE NEW WOODEN 40MM PALLET STACKS AND THE METAL 40MM PALLET STACKS.

(3) CENTER GATE A (2 REQD). SEE THE DETAIL ON PAGE 4.

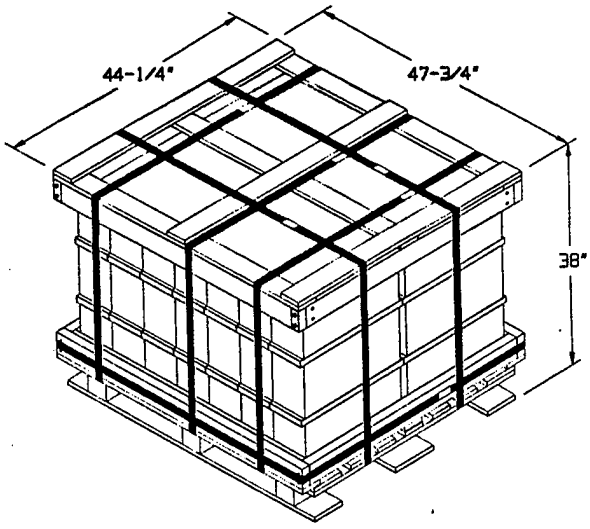
(4) STRUT, 2" X 6" BY CUT TO FIT BETWEEN THE CENTER GATES, PIECES MARKED (3) (REF: 65") (DOUBLED) (8 REQD). LAMINATE W/1-10d NAIL EVERY 6". TOENAIL TO THE CENTER GATES W/2-12d NAILS AT EACH END.

(5) VERTICAL STRUT BRACING, 2" X 4" X 9'-0" (2 REQD). NAIL TO THE STRUTS, PIECES MARKED (4), W/3-10d NAILS AT EACH JOINT.

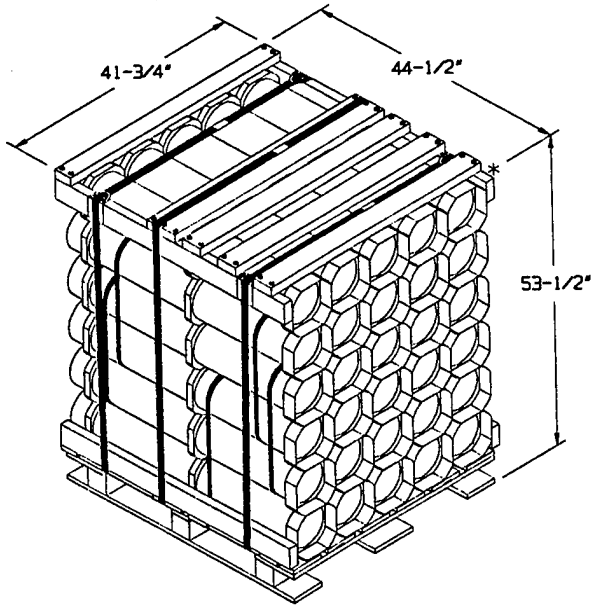
(6) HORIZONTAL STRUT BRACING, 2" X 4" X 44-1/2" (4 REQD). NAIL TO THE STRUTS, PIECES MARKED (4), W/3-10d NAILS AT EACH END.

(7) CENTER GATE B (2 REQD). SEE THE DETAIL ON PAGE 5.

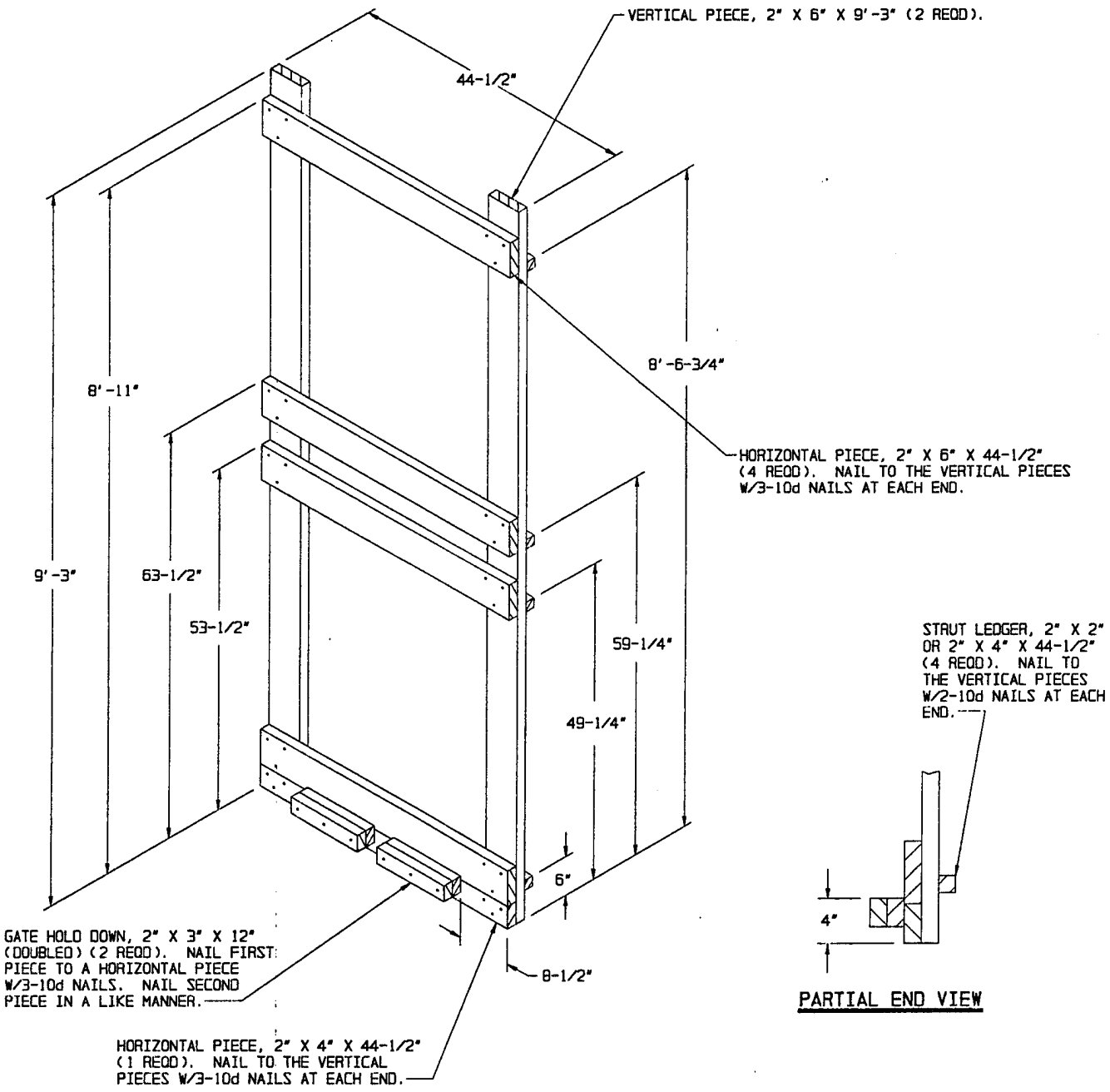
(8) STRUT, 4" X 4" BY CUT TO FIT BETWEEN THE CENTER GATES, PIECES MARKED (7) (REF: 42") (12 REQD). TOENAIL TO THE CENTER GATES W/2-16d NAILS AT EACH END.



40MM PALLET



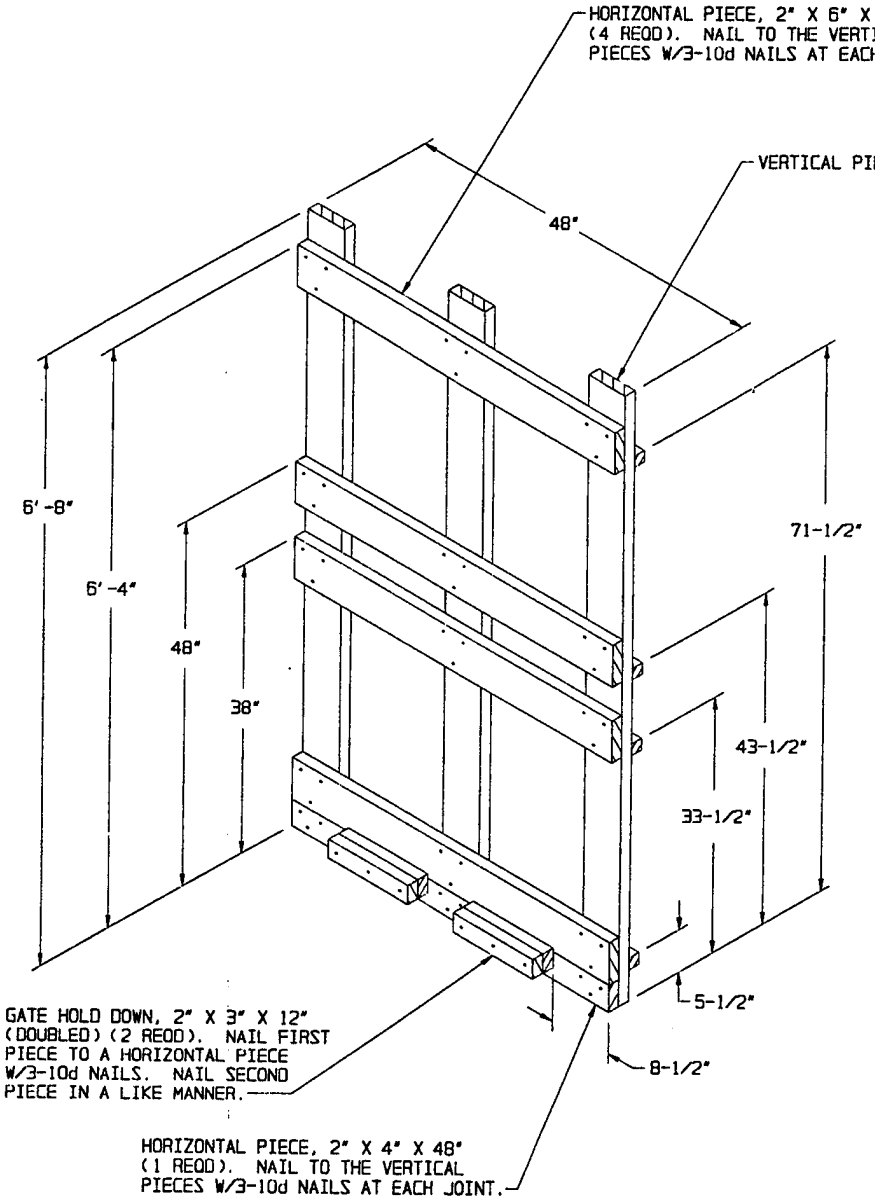
120MM PALLET



PARTIAL END VIEW

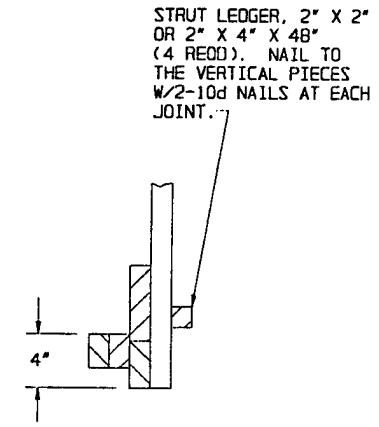
CENTER GATE A

FOR 120MM CONTAINER

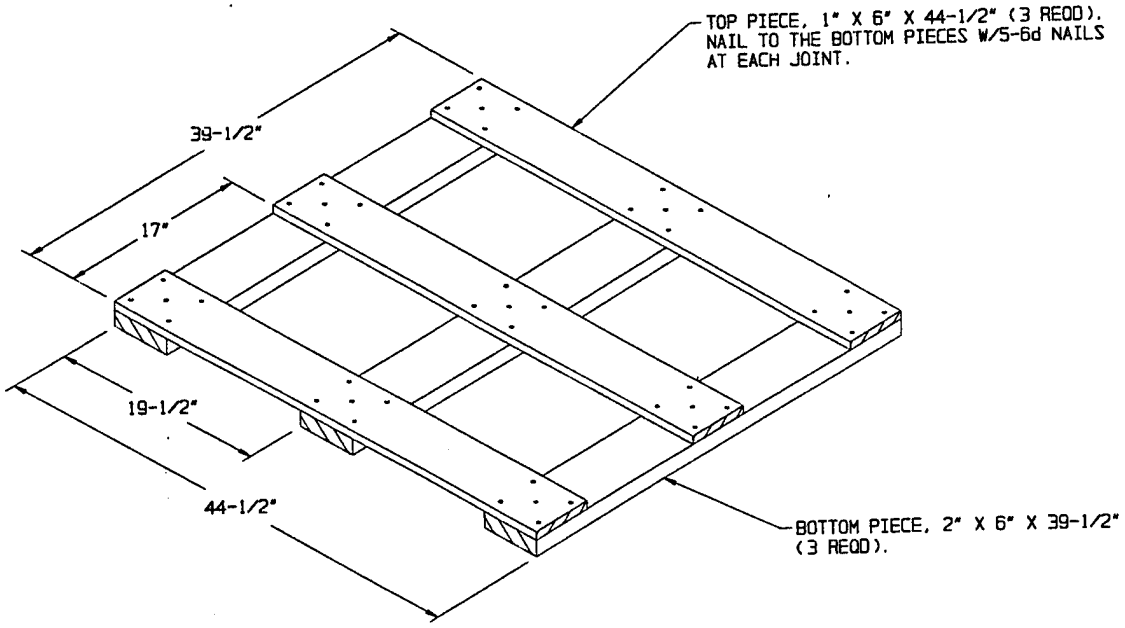


CENTER GATE B

FOR 40MM METAL BOX



PARTIAL END VIEW



RISER ASSEMBLY

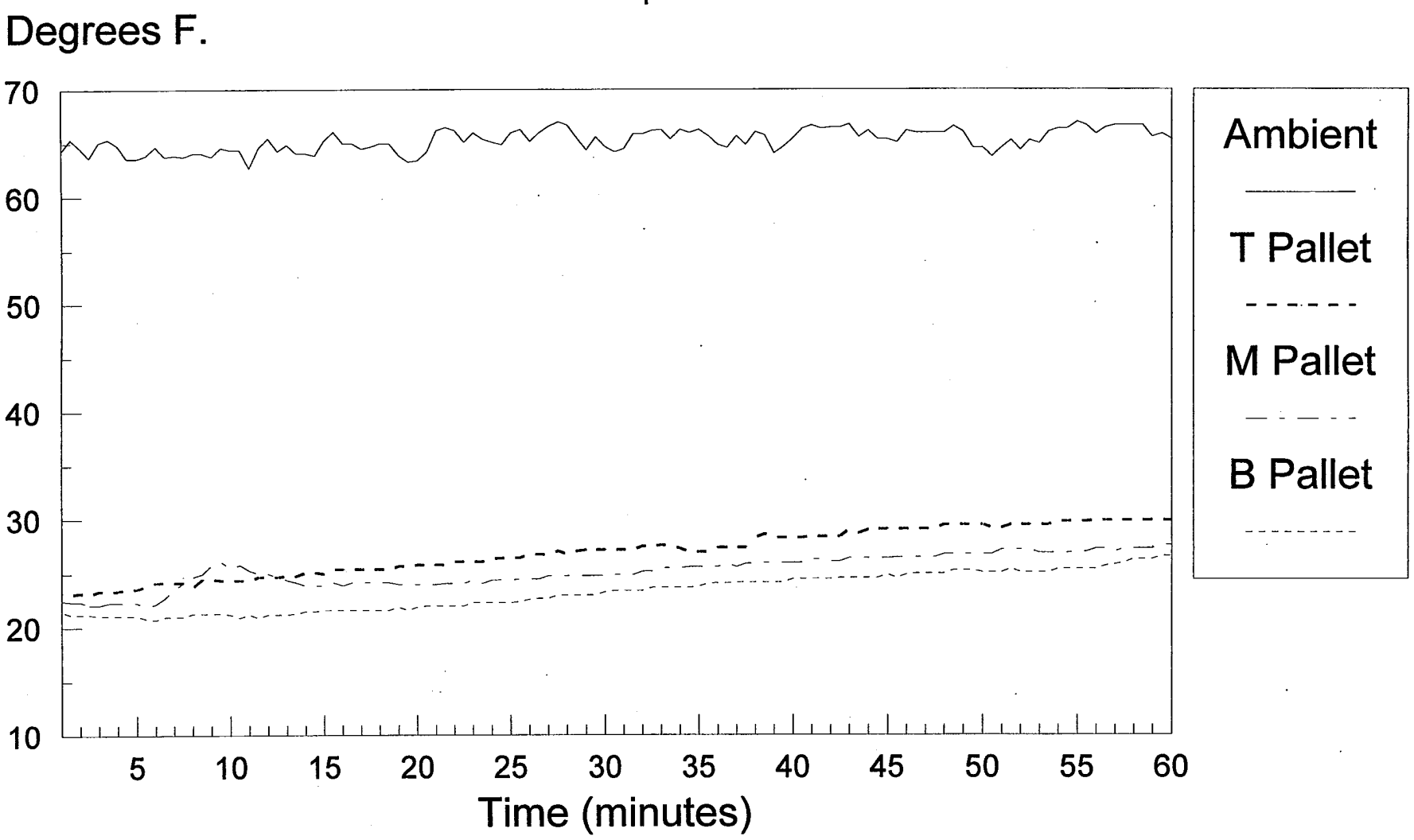
PART 8

GRAPHS

40mm Enhanced Wood Pallet

Mil Std 1660 Cold Test

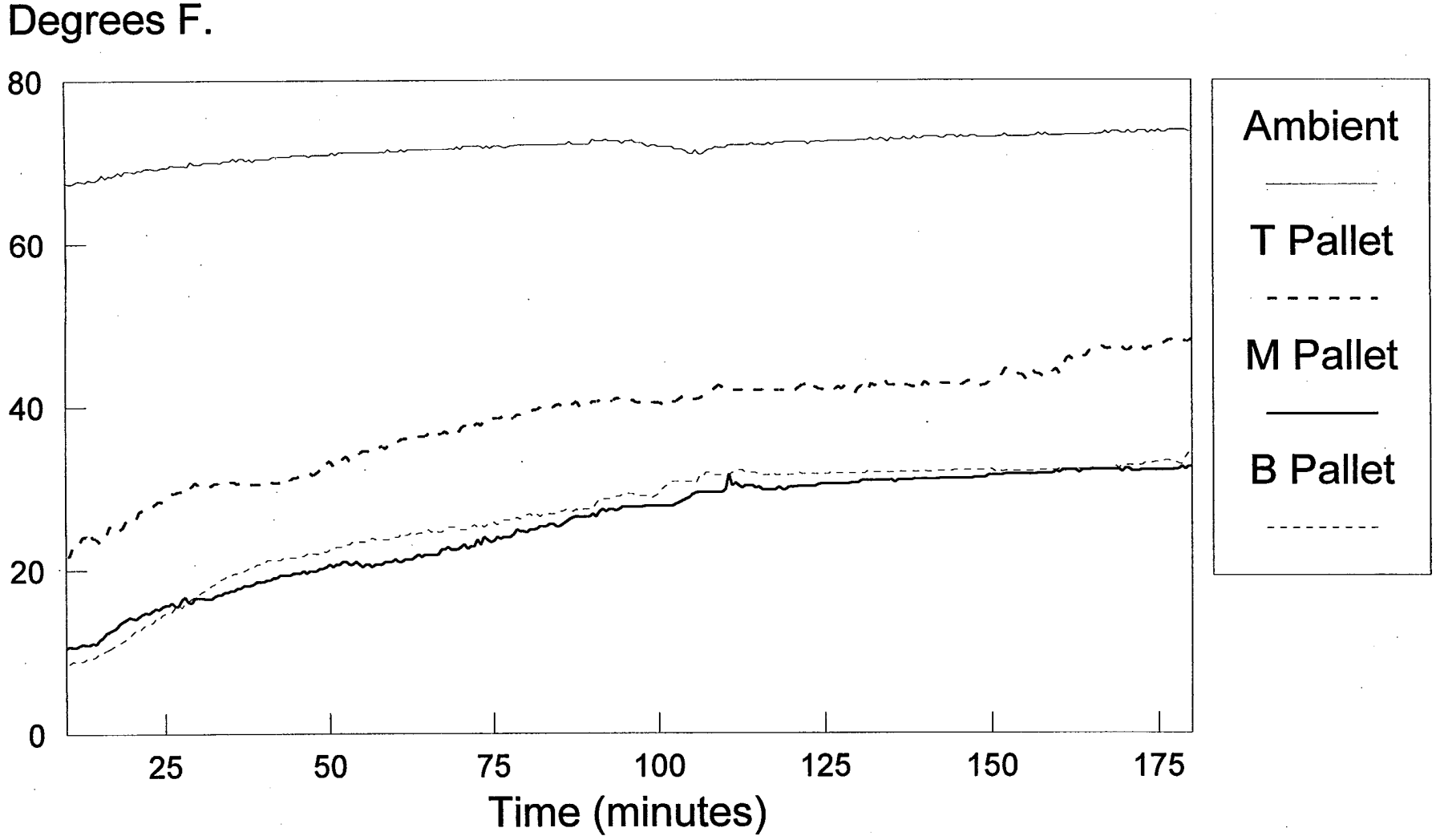
Compression Test



40mm Enhanced Wood Pallet

Mil Std 1660 Cold Test

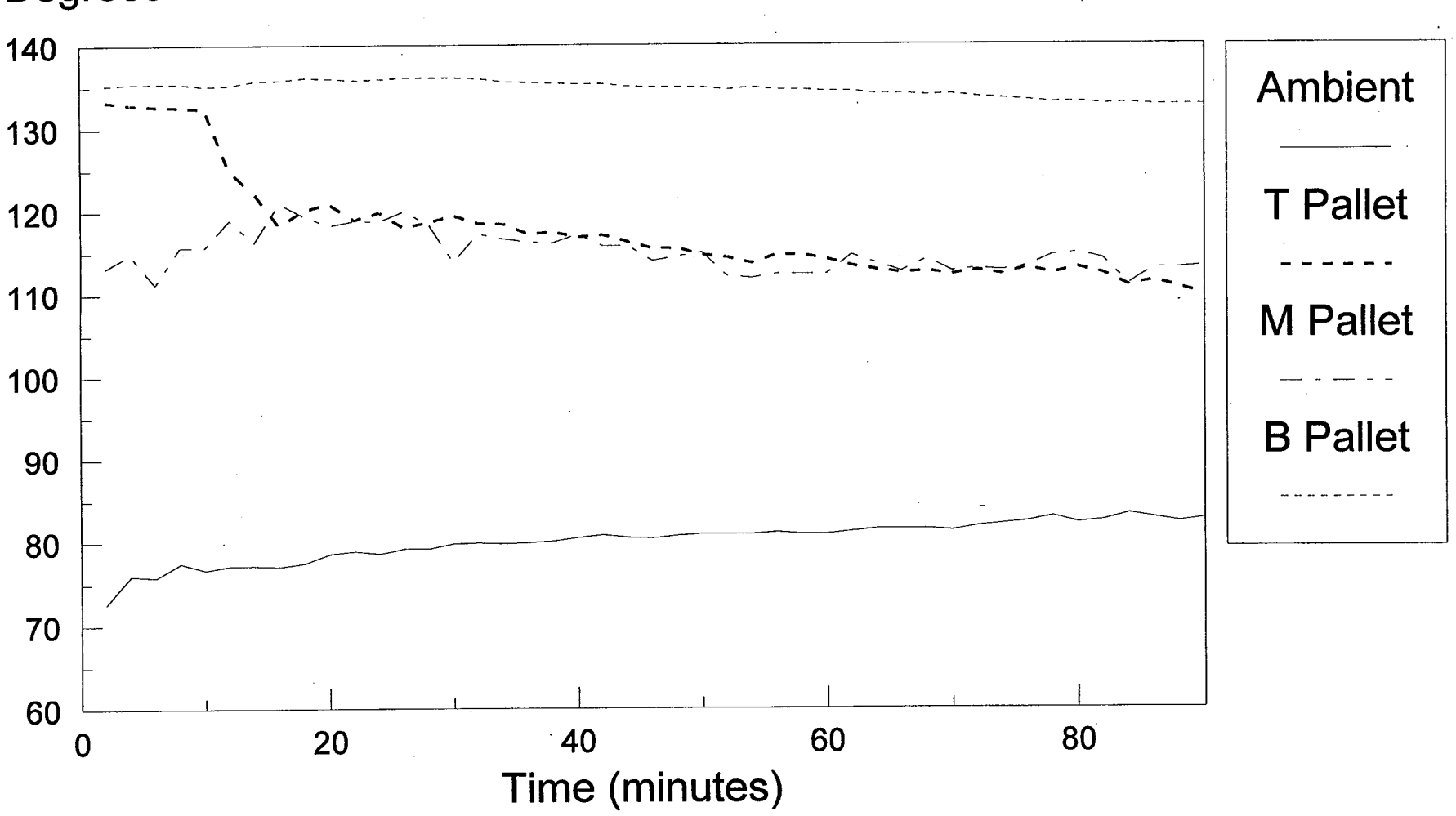
Vibration Test



40mm Enhanced Wood Pallet

Mil Std 1660 Hot Testing

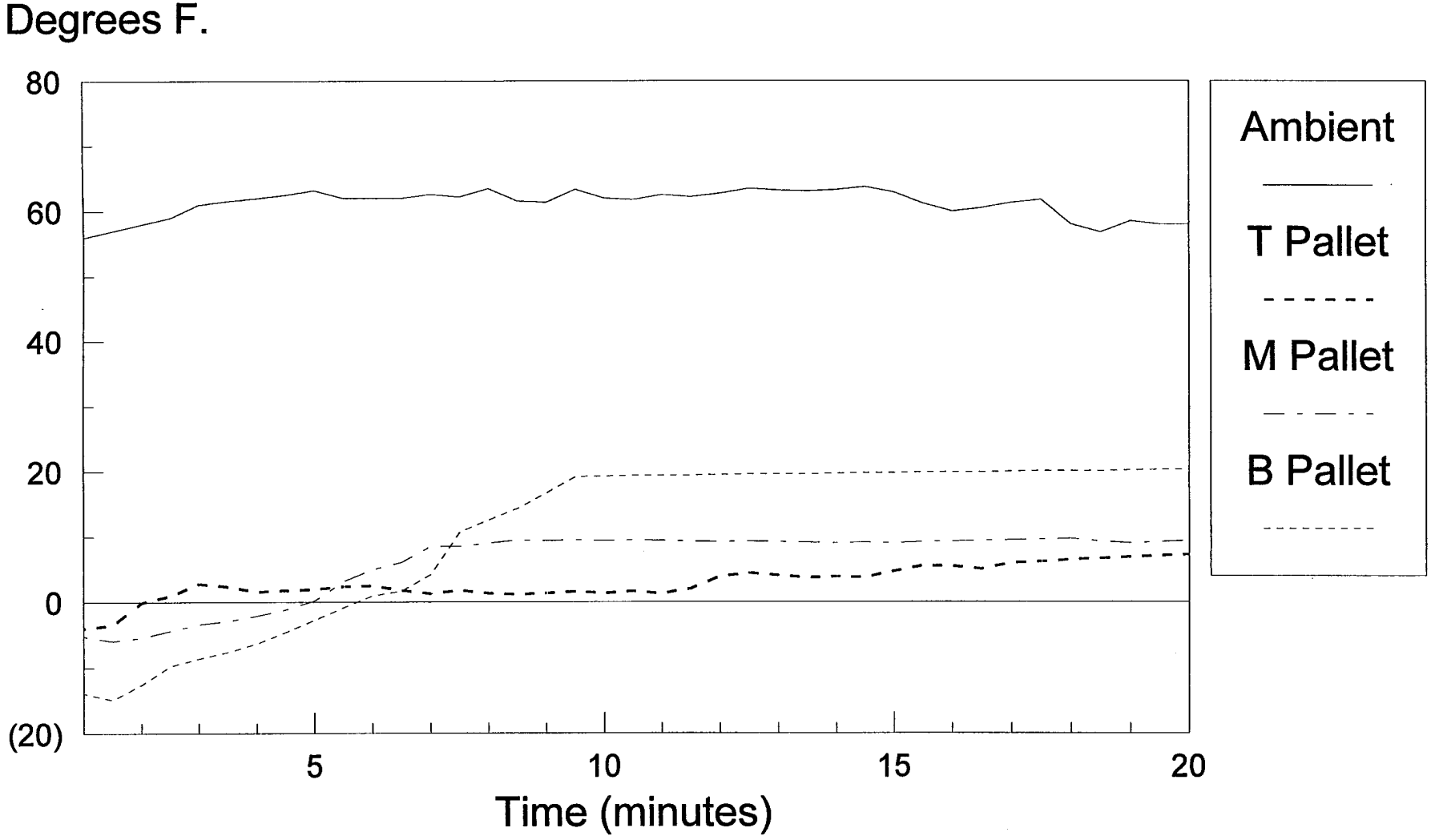
Vibration Test



40mm Enhanced Wood Pallet

Mil Std 1660 Cold Test

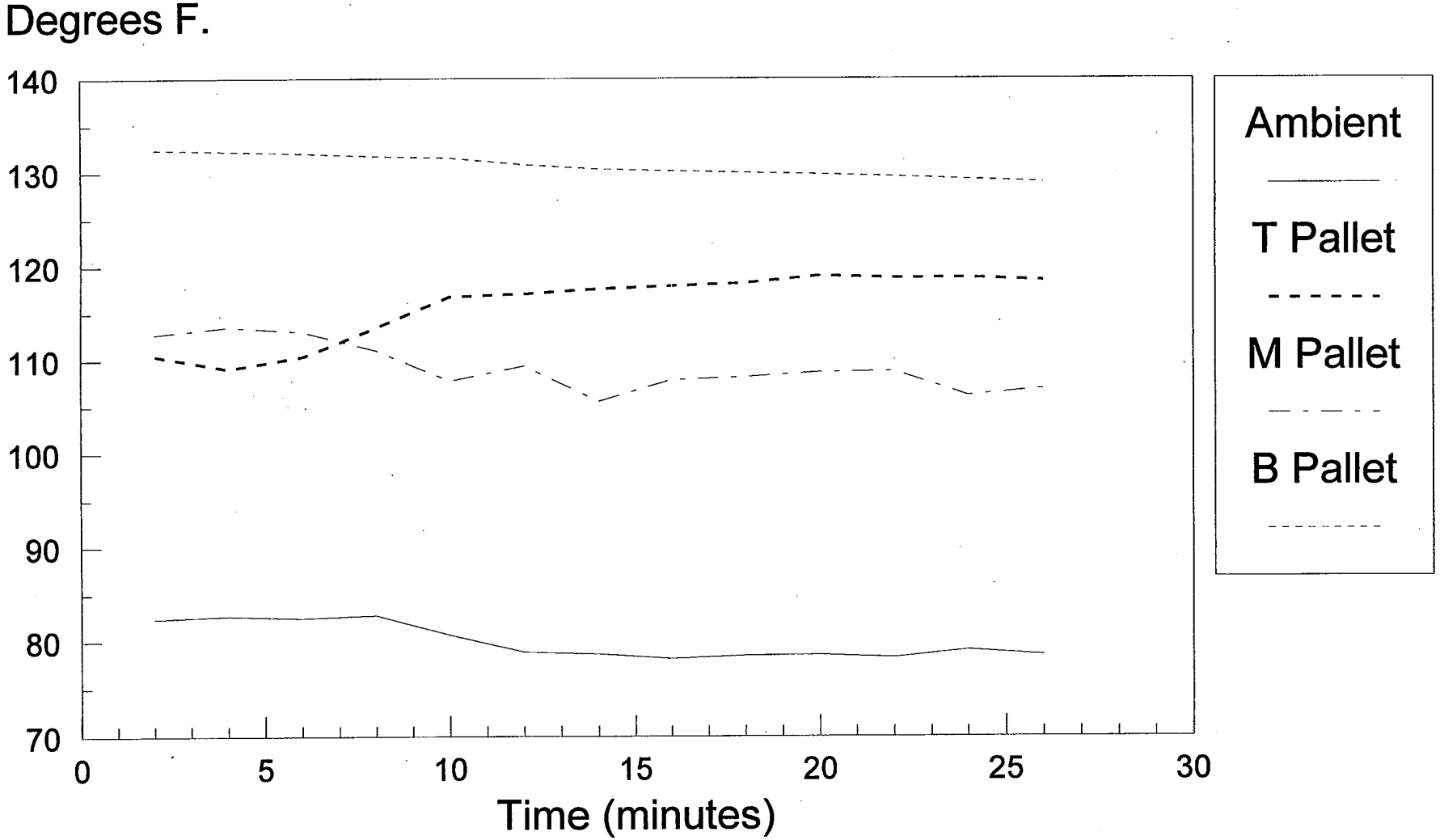
Drop Test



40mm Enhanced Wood Pallet

Mil Std 1660 Hot Testing

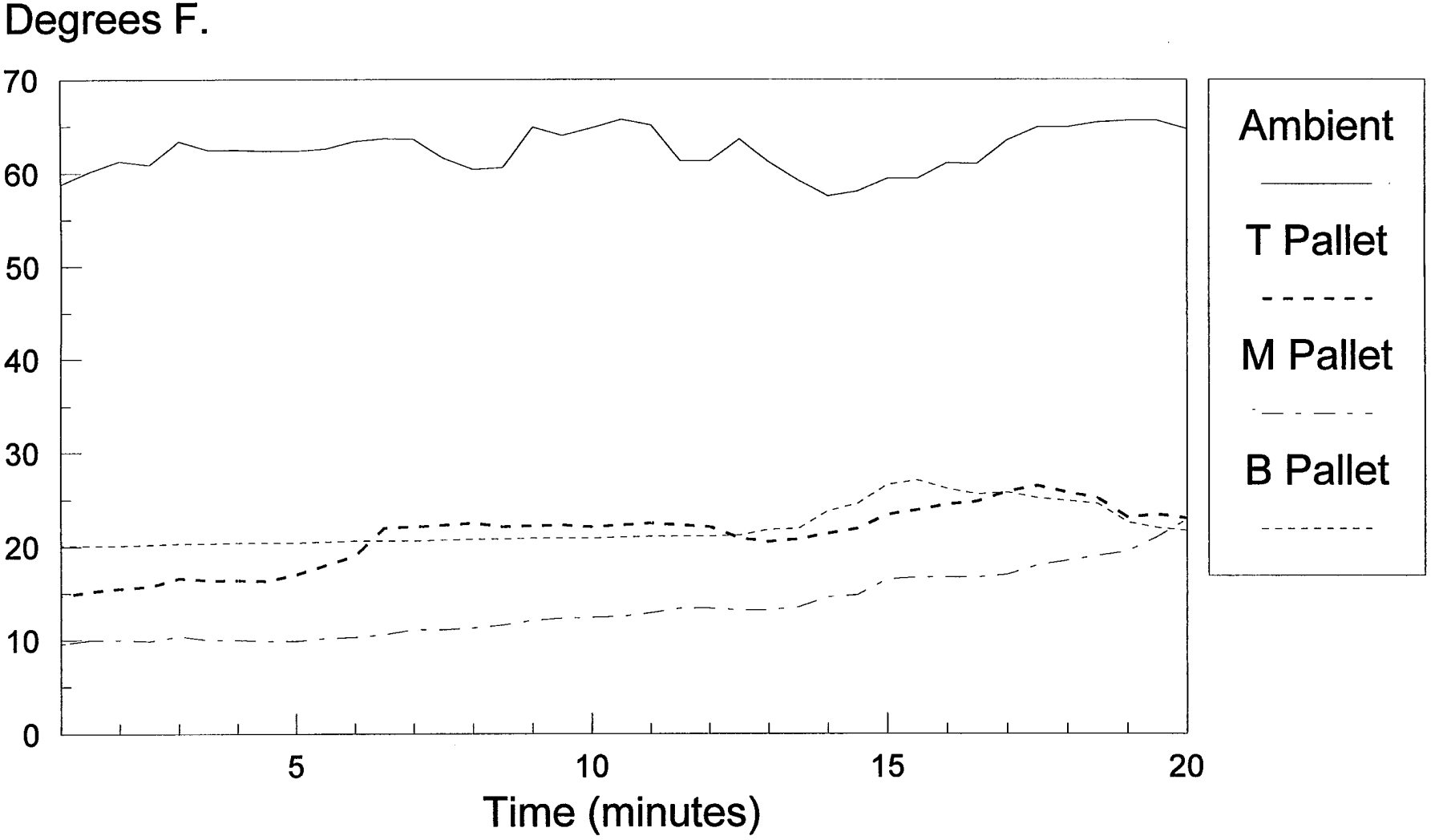
Drop Test



40mm Enhanced Wood Pallet

Mil Std 1660 Cold Test

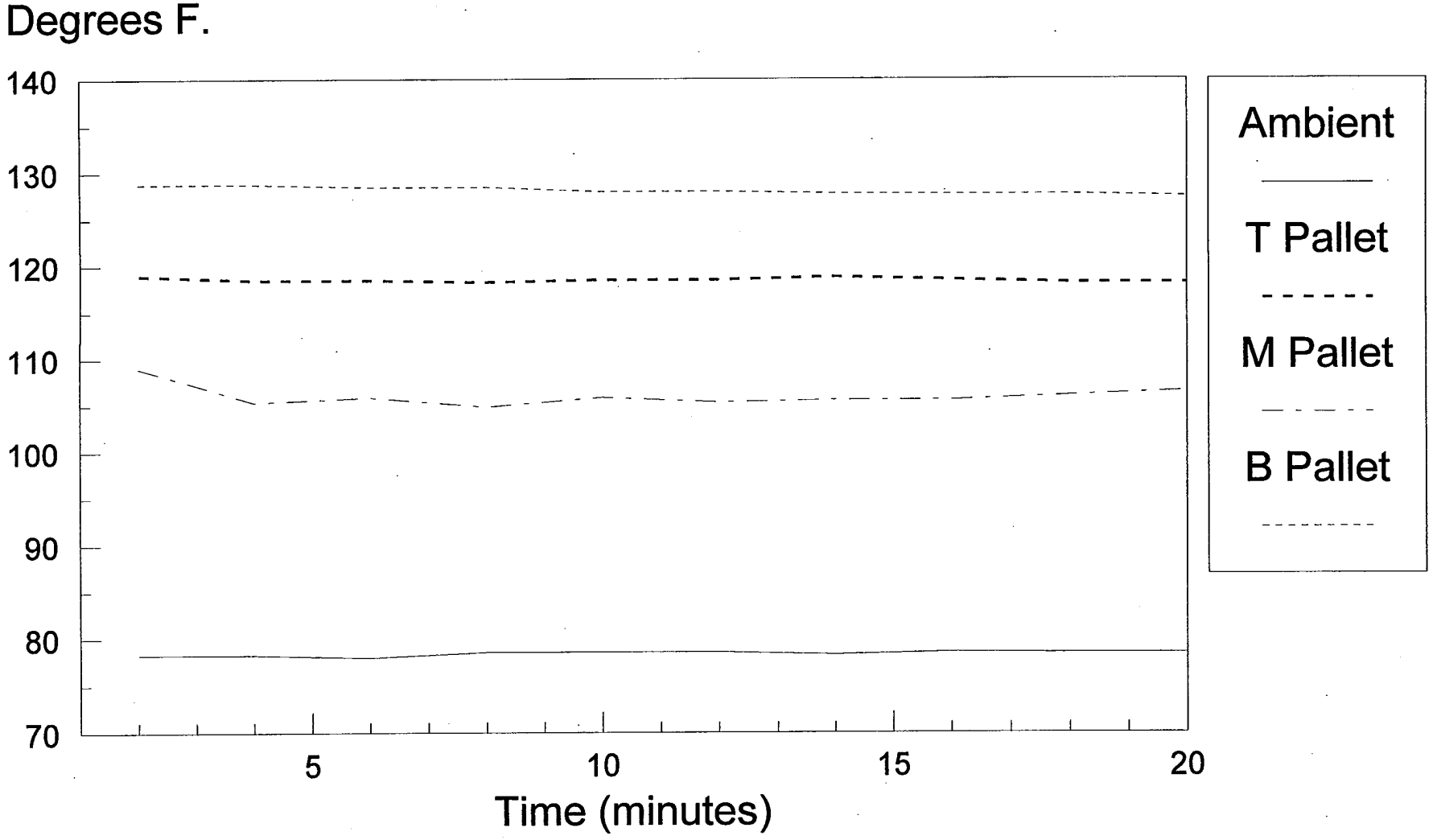
Incline Plane Test



40mm Enhanced Wood Pallet

Mil Std 1660 Hot Testing

Incline Plane Test



PART 9

APPENDIX

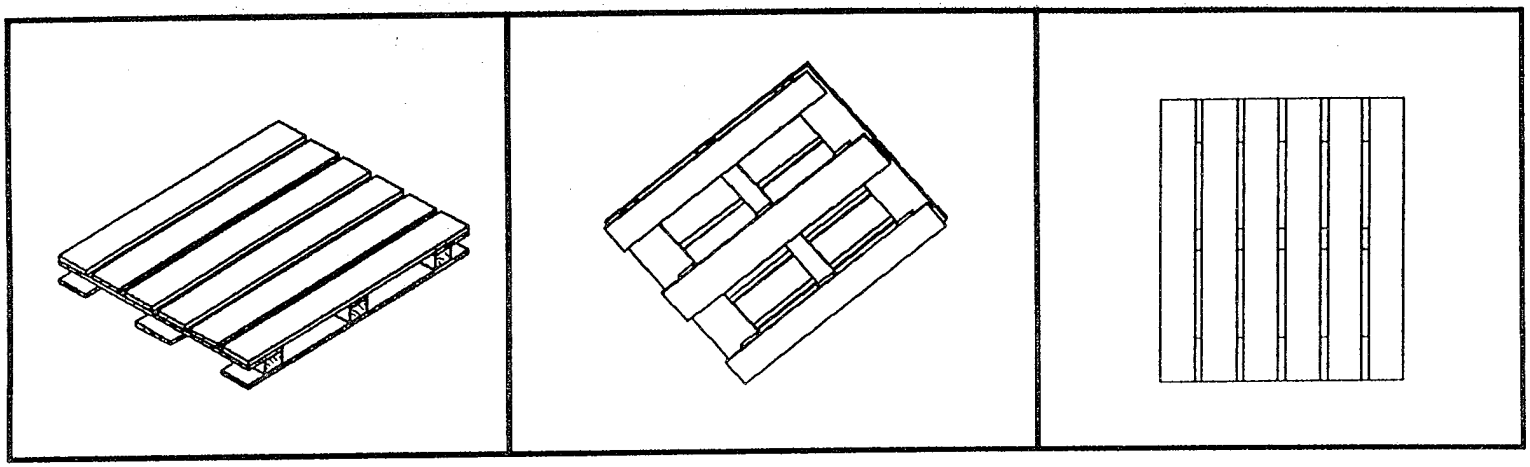
EFFECT OF TEMPERATURE ON THE TOUGHNESS OF L-18/P-13 TREATED WOOD

To determine the effect of temperatures on the strength of PU-treated wood, three sets of treated and untreated pine coupons · were conditioned at three sets of treated and untreated pine coupons were conditioned at three temperatures, 77°F, 149°F, and -88.6°F. Each set consisted of three treated and one untreated matched control coupons. The conditioned coupons were tested for toughness. The results of this test are summarized in Table 1.

TABLE 1. TOUGHNESS VALUES OF L-18/P-13 TREATED COUPONS AT DIFFERENT TEMPERATURES.

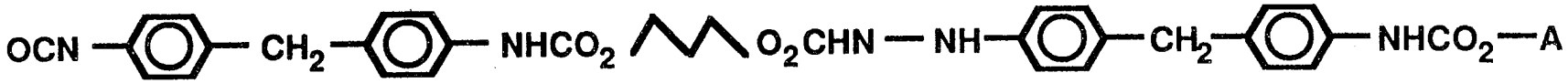
Temperature (°F)	Toughness Retention (% of control)
77	118
149	105
-88.6	106

Enhanced Wood Pallet



TREATED WITH L-18

(ISOCYANATE, POLYOL, OH TERMINATED POLYBUTADIENE)



WHERE, A IS  **,**

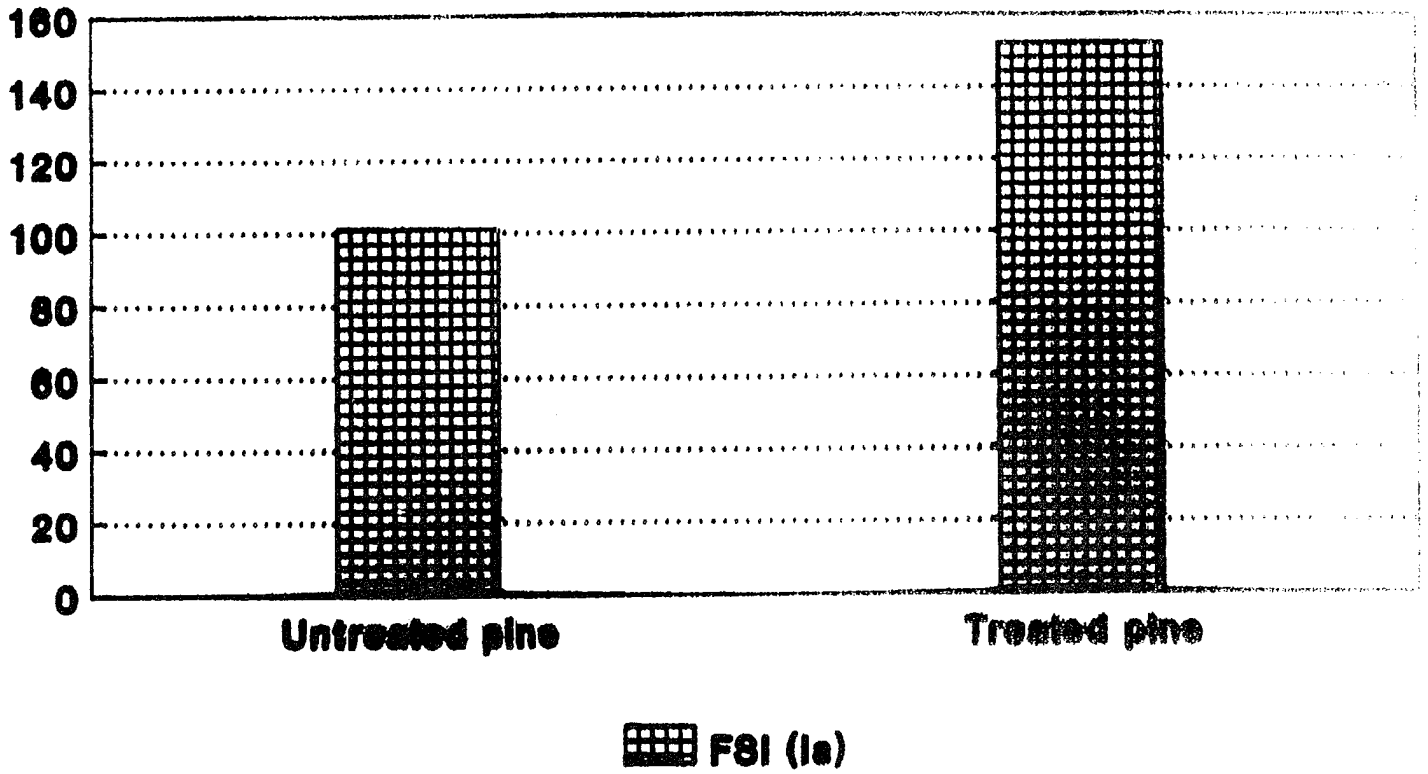
FROM OH TERMINATED POLYBUTADIENE, (MW=2000)

COATED WITH P-13

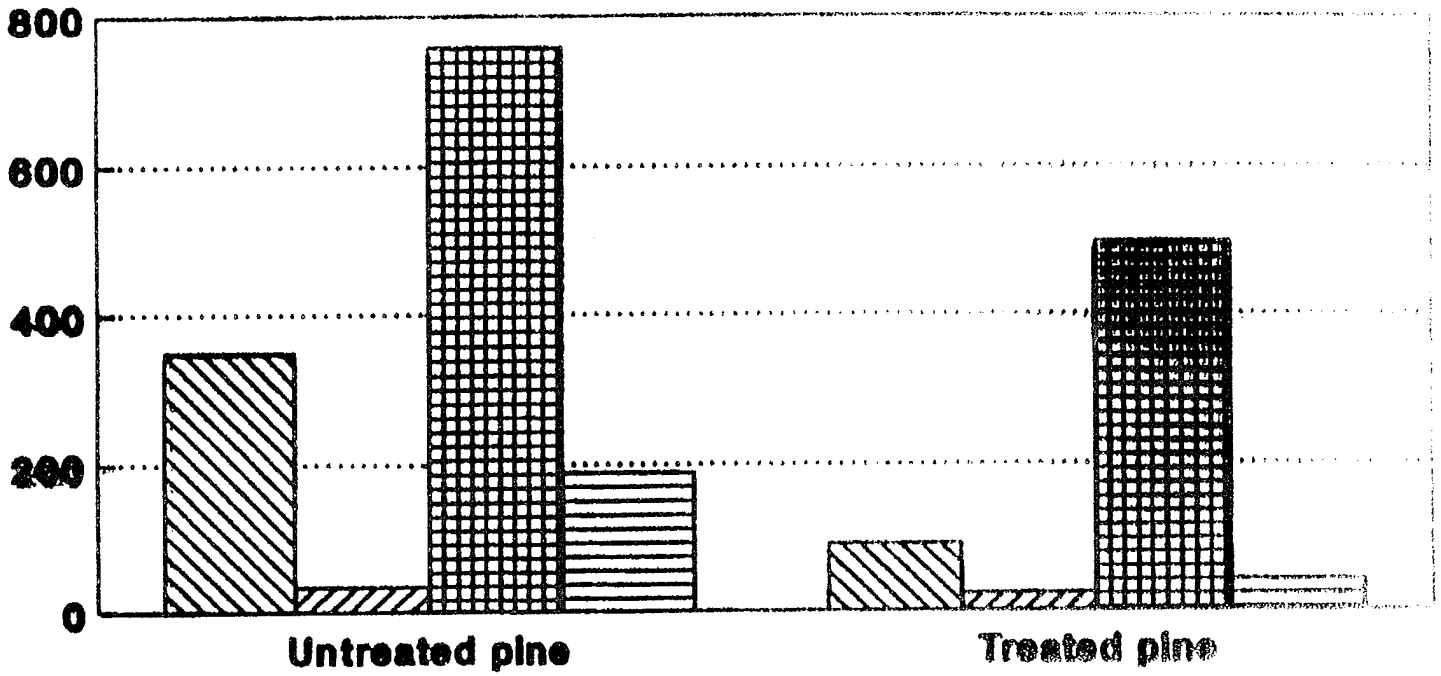
PREPOLYMERS OF: EPOXY, URETHANE, MELAMINE FORMALDEHYDE

MONOMERS OF: TRI METHYLOL PROPANE TRIMETHACRYLATE AND SILANE

Fire retardant properties of L-18/P13 treated pine samples (ASTM E 162)



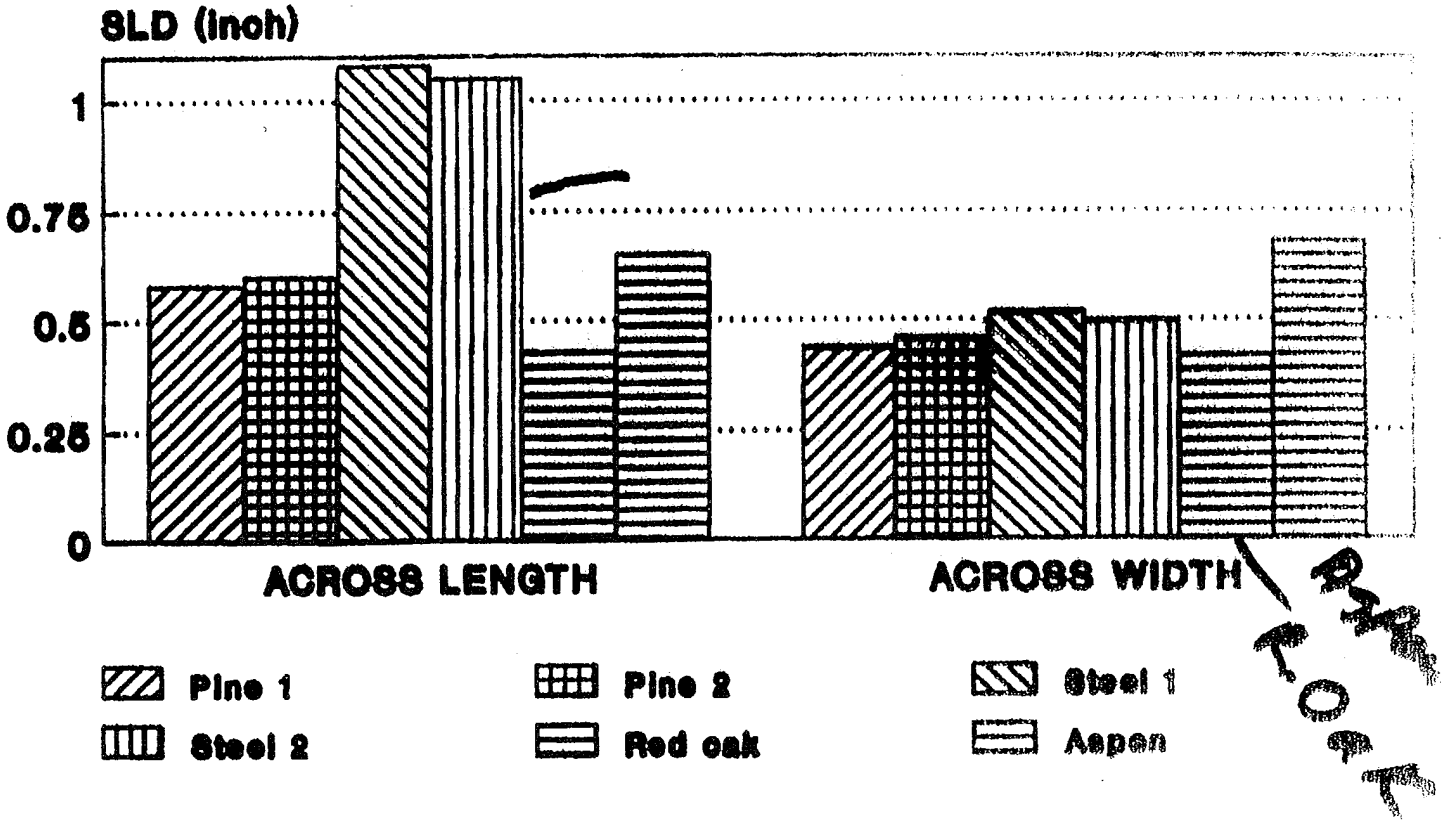
Fire retardant properties of L-18/P13 treated pine samples (ASTM E 662)



SOD = Smoke Optical Density

SOI = Smoke Optical Index

Average Static Load Deflection (SLD) for L-18/P-13 treated wooden pallets and metal pallets



SLD LIMIT ACROSS LENGTH = 0.75"
SLD LIMIT FOR WOOD ACROSS WIDTH = .45"
SLD LIMIT FOR STEEL ACROSS WIDTH = 0,45"

Qualitative test results on rough handled wooden and metal pallets (conducted at VPI)

Pallet type	Rigidity drop test	Resistant to impact test	Abrasion test
Pine 1	good	good	pass
Pine 2	good	good	pass
Red oak	superior	V. good	pass
Aspen	superior	good	pass
Steel 1	fair	good	pass
Steel 2	fair	good	pass

Retention values of nerve agents for L-18/P-13 treated wood coupons and CARC coated metal coupons

Sample	Unexposed			Weathered			Rough handled		
	HD	VX	TGD	HD	VX	TGD	HD	VX	TGD
Pine:									
4-6	0	3.4	0	0	0	0	401	4.7	0
K-3	0	0.6	0	0	0	0	0	2.6	0
3-3a	0	0	0	0	1.7	0	227	15	0
Metal:	ND	0.4	-	ND	112	ND	ND	94	ND
Aspen:									
A-21	-	1.6	-	-	-	-	-	-	-
A-23	-	1.0	-	-	-	-	-	-	-
A-25	-	0.6	-	-	-	-	-	-	-
Red oak:									
2-1	-	3.0	-	-	-	-	-	-	-
2-5	-	3.4	-	-	-	-	-	-	-
2-7	-	15.7	-	-	-	-	-	-	-