

**FINAL REPORT
OCTOBER 2004**

REPORT NO. 04-19-1



**INTERMODAL STORAGE AND TRANSPORT FRAME-2 (ISTF-2),
MIL-STD-1660, "DESIGN CRITERIA FOR AMMUNITION UNIT LOADS"
TESTING**

Prepared for:

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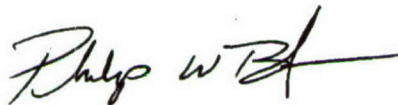
**INTERMODAL STORAGE AND TRANSPORT FRAME-2 (ISTF-2) MIL-STD-1660,
"DESIGN CRITERIA FOR AMMUNITION UNIT LOADS" TESTING****ABSTRACT**

The U.S. Army Defense Ammunition Center (DAC), Validation Engineering Division (SJMAC-DEV) was tasked by the Transportation Engineering Division, (SJMAC-DET) to conduct testing on the Intermodal Storage and Transport Frame-2 (ISTF-2), manufactured by Mobile Shelter Systems, Inc. The ISTF-2 was evaluated by the testing procedures set forth in MIL-STD-1660. Stacking, vibration, edgewise rotational drop, cornerwise rotational drop, incline impact, sling compatibility, forklifting, and disassembly testing were conducted on the ISTF-2 units.

The ISTF-2 units remained intact and were capable of safely handling ammunition after completion of testing. The ISTF-2 units successfully completed the test requirements of MIL-STD-1660. However, **the interlock devices are not approved for ammunition transport and storage.**

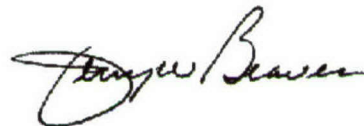
Additionally, **evaluation testing** was conducted on the interlock devices. As tested, the interlock devices satisfactorily completed the testing. The ISTF-2 units did not satisfactorily complete testing when connected. However, the testing was conducted for evaluation purposes only. Therefore, **the interlock devices are not approved for ammunition storage and transport.**

Prepared by:



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REPORT NO. 04-19-1

**INTERMODAL STORAGE AND TRANSPORT FRAME-2 (ISTF-2),
MIL-STD-1660, "DESIGN CRITERIA FOR AMMUNITION UNIT LOADS"
TESTS**

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PART 1 – INTRODUCTION

A. BACKGROUND. The U.S. Army Defense Ammunition Center (DAC), Validation Engineering Division (SJMAC-DEV) was tasked by the Transportation Engineering Division (SJMAC-DEV) to conduct testing on the Intermodal Storage and Transport Frame-2 (ISTF-2), manufactured by Mobile Shelter Systems, Inc. The ISTF-2 was evaluated by the testing procedures set forth in MIL-STD-1660. Stacking, vibration, edgewise rotational drop, cornerwise rotational drop, incline impact, sling compatibility, forklifting, and disassembly testing were conducted on the ISTF-2 units. The unitization procedures were provided by the DAC, Transportation Engineering Division (SJMAC-DET) (See Part 6).

B. AUTHORITY. This test was conducted IAW mission responsibilities delegated by the U.S. Army Joint Munitions Command (JMC), Rock Island, IL. Reference is made to the following:

1. AR 740-1, 15 June 2001, Storage and Supply Activity Operation
2. OSC-R, 10-23, Mission and Major Functions of U.S. Army Defense Ammunition Center (DAC) 21 Nov 2000.

C. OBJECTIVE. The objective of the testing was to determine if the ISTF-2 was adequate for unitization and transportation of ammunition and could successfully pass the MIL-STD-1660 test requirements. Also, evaluation testing was conducted with two interlocked ISTF-2 units.

D. CONCLUSION.

1. MIL-STD-1660 Testing.

The ISTF-2 units remained intact and were capable of safely handling ammunition after completion of testing. The ISTF-2 units successfully completed the test requirements of MIL-STD-1660. However, **the interlock devices are not approved for ammunition transport and storage.**

2. Evaluation Testing. As tested, the interlock devices satisfactorily completed the testing. The ISTF-2 units did not satisfactorily complete testing when connected. However, the testing was conducted for evaluation purposes only. Therefore, **the interlock devices are not approved for ammunition storage and transport.**

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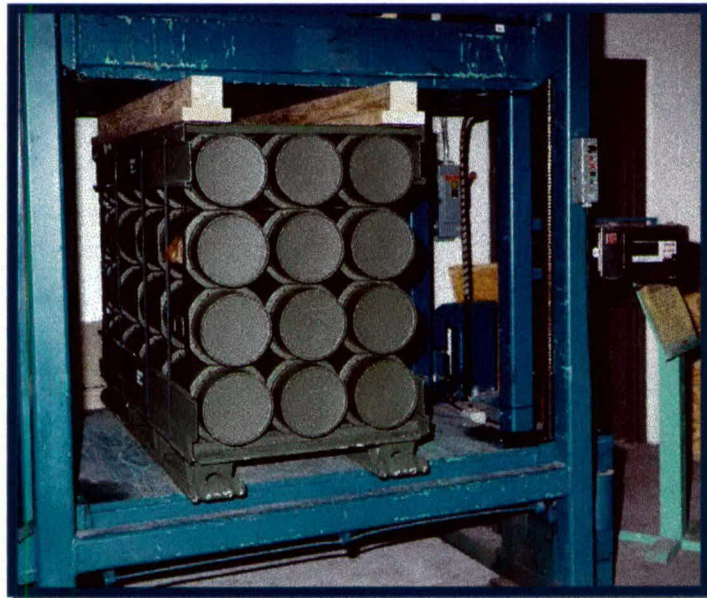
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Boise, ID 83706

PART 3 - TEST PROCEDURES

The test procedures outlined in this section were extracted from the MIL-STD-1660. The tests are conducted on ammunition pallet units or unit loads and are summarized as follows:

A. MIL-STD-1660:

1. **STACKING TEST.** The specimen will be tested to simulate a stack of identical items stacked 16 feet high, for a period of one hour. This stacking load will be simulated by subjecting the specimen to a compression weight equal to an equivalent 16-foot stacking height. Photo 1 below shows an example of a unit load in the compression tester.



**Photo 1. Example of Stacking Test.
(2.75-inch Hydra 70, PA151 Rocket Pallet in the Stacking Test.)**

2. REPETITIVE SHOCK TEST. The repetitive shock test is conducted IAW Method 5019, Federal Standard 101. The test procedure is as follows: The test specimen will be placed on (not fastened to) the platform. With the specimen in one position, the platform will be vibrated at ½-inch amplitude (1-inch double amplitude) starting at a frequency of approximately 3 cycles-per-second. The frequency will be steadily increased until the specimen leaves the platform. The resonant frequency is achieved when a 1/16-inch-thick feeler gage momentarily slides freely between every point on the specimen in contact with the platform at some instance during the cycle. Midway into the testing period, the specimen will be rotated 90 degrees, and the test continued for the duration. Unless failure occurs, the total time of vibration will be three hours. Photo 2 shows an example of the repetitive shock test.



**Photo 2. Example of the Repetitive Shock Test.
(ISTF-2)**

3. EDGEWISE ROTATIONAL DROP TEST. This test is conducted using the procedures of Method 5008, Federal Standard 101. The procedure for the edgewise rotational drop test is as follows: The specimen will be placed on its

skids with one end of the pallet supported on a beam 6 inches high. The height of the beam will be increased as necessary to ensure that there is no support for the skids between the ends of the specimen when the dropping takes place, but should not be high enough to cause the specimen to slide on the supports when the dropped end is raised for the drop. The unsupported end of the specimen is then raised and allowed to fall freely to the concrete, pavement, or similar unyielding surface from a prescribed height. Unless otherwise specified, the height of drop for level A protection will conform to the following tabulation:

GROSS WEIGHT (WITHIN RANGE LIMITS) (Pounds)	DIMENSIONS OF ANY EDGE, HEIGHT OR WIDTH (WITHIN RANGE LIMITS) (Inches)	HEIGHT OF DROPS ON EDGES	
		Level A (Inches)	Level B (Inches)
150-250	60-66	36	27
250-400	66-72	32	24
400-600	72-80	28	21
600-1,000	80-95	24	18
1,000-1,500	95-114	20	16
1,500-2,000	114-144	17	14
2,000-3,000	Above 145- No limited	15	12
Above – 3,000		12	9

Figure 1.

Photo 3. Example of Edgewise Rotational Drop Test
(ISTF-2)

4. CORNERWISE ROTATIONAL DROP TEST. This test is conducted using the procedures of Method 5005, Federal Standard 101. The procedure for the cornerwise rotational drop test is as follows: The specimen will be placed on its bottom. One corner of the base of the container shall be supported on a block nominally 6 inches in height, and a block nominally 12 inches in height shall be placed under the other corner of the same end. The height of the block will be increased as necessary to ensure that there is no support for the base between the ends of the specimen when the dropping takes place, but should not be high enough to cause the specimen to slide on the supports when the dropped end is raised for the drop. The unsupported end of the specimen is then raised and allowed to fall freely to the concrete, pavement, or similar unyielding surface from a prescribed height. Unless otherwise specified, the height of drop for level A protection will conform to the following tabulation:

GROSS WEIGHT (WITHIN RANGE LIMITS) (Pounds)	HEIGHT OF DROPS ON CORNERS (Inches)
500 or less	24
Over 500 to 4000	18
4000 and up	12

Figure 2.

5. INCLINE-IMPACT TEST. This test is conducted by 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 will be 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 will be brought to a predetermined position on the incline and released. If it were desired to concentrate the impact on any particular position on the container, a 4- x 4-inch timber may be attached

to the bumper in the desired position before the test. The carriage will not strike any part of the timber. The position of the specimen on the carriage and the sequence in which surfaces and edges are subjected to impacts may be at the option of the testing activity and dependent upon the objective of the test. When the test is to determine satisfactory requirements for a container or pack, and, unless otherwise specified, the specimen will be subjected to one impact on each surface that has each dimension less than 9.5 feet. Unless otherwise specified, the velocity at the time of the impact will be 7 feet-per-second. Photo 4 shows an example of this test.



Photo 4. Example of the Incline-Impact Test.
(2.75-Inch, Hydra 70, PA151 Rocket Pallet on incline-impact tester.)

6. SLING COMPATIBILITY TEST. The specimen utilizing special design or non-standard pallets will be lifted, swung, lowered and otherwise handled as necessary, using slings of the types normally used for handling the unit loads under consideration. Slings will be easily attached and removed. Danger of slippage or disengagement when load is suspended will be cause for rejection of the specimen.

7. FORKLIFTING TESTS. The specimen will be lifted clear of the ground by a forklift from the end of the specimen and transported on the forks in the level or back-tilt position. The forklift will pass over the Optional Rough Handling Course For Forklift Trucks as outlined in MIL-STD-1660. The course will consist of parallel pairs of 1-inch boards spaced 54 inches apart and will be laid flat wise on the pavement across the path of the forklift. One pair will be laid at an angle of approximately 60 degrees to the path so that the left wheel strikes first. Another pair will be laid securely across the path of the forklift so that the wheels strike simultaneously. Another pair will be laid at an angle of approximately 75 degrees to the path so that the right wheel strikes first. The specimen will be transported down and back the Optional Rough Handling Course one time. The forklift will be brought to a stop prior to transversing the course. The specimen shall be observed for deflection and damage. The specimen will be rotated 90 degrees and the specimen lifted from the side and the above steps repeated.

8. DISASSEMBLY TEST. Following all rough handling tests the specimen may be squared up within 2 inches of its original shape and on a flat level surface. The strapping will then be cut and removed from the palletized load. Assembly of the specimen will be such that it retains its unity upon removal of the strapping.

PART 4 - TEST EQUIPMENT

A. COMPRESSION TESTER.

- | | |
|-----------------------|----------------------|
| 1. Manufacturer: | Ormond Manufacturing |
| 2. Platform: | 60- x 60-inches |
| 3. Compression Limit: | 50,000 pounds |
| 4. Tension Limit: | 50,000 pounds |

B. TRANSPORTATION SIMULATOR.

- | | |
|------------------|---------------------|
| 1. Manufacturer: | Gaynes Laboratory |
| 2. Capacity: | 6,000-pound payload |
| 3. Displacement: | 1/2-inch amplitude |
| 4. Speed: | 50 to 400 RPM |
| 5. Platform: | 5- x 8-foot |

C. INCLINED PLANE.

- | | |
|------------------|--------------------|
| 1. Manufacturer: | Conbur Incline |
| 2. Type: | Impact Tester |
| 3. Grade: | 10 percent incline |
| 4. Length: | 12-foot |

PART 5 - TEST RESULTS

5.1. FRAME DATA. The ISTF-2 unit was inertly loaded to the specified design weight using inert simulation in metal cans and wirebound boxes. The test specimen was prepared using the unitization procedures specified in Part 6 – Drawings. Special care was taken to ensure that the inert load had the proper amount of weight in order to achieve a realistic pallet center of gravity (CG). Once properly prepared, the ISTF-2 unit was tested using the MIL-STD-1660 requirements.

INTERMODAL STORAGE AND TRANSPORT FRAME-2 (ISTF-2) UNIT #1

Testing Date: 22-27 July 2004

Gross Weight: 3,335 pounds

Length: 51-7/8 inches

Width: 41-3/4 inches

Height: 45 inches

Mfg: Mobile Shelter Systems, Inc.

A. INTERMODAL STORAGE AND TRANSPORT FRAME (ISTF) - TEST RESULTS:

1. COMPRESSION TEST. The test specimen was compressed with a load force of 10,122 pounds for 60 minutes on 22 July 2004. No damage was noted as a result of this test. See Photo 5 of the test specimen in the compression unit.

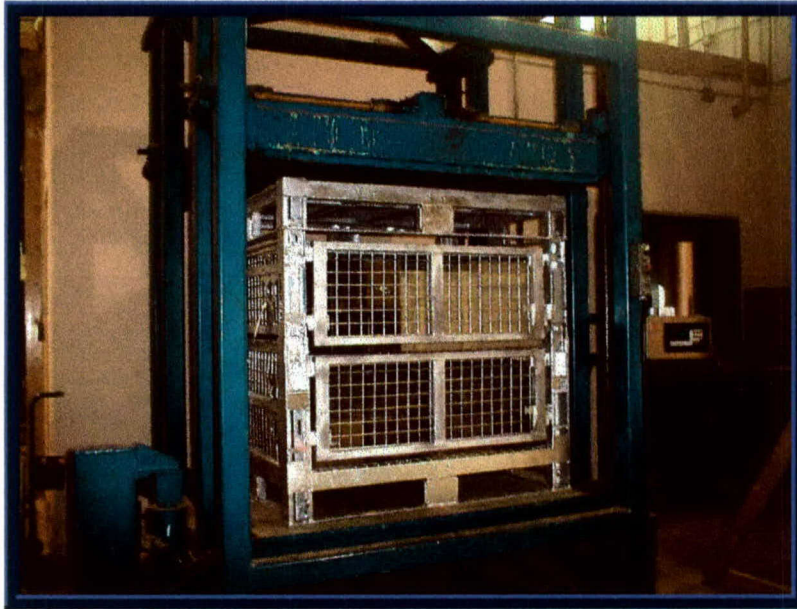


Photo 5. ISTF-2 Unit #1 During Compression Testing.

2. **REPETITIVE SHOCK TEST.** The specimen was vibrated 90 minutes at **217** RPM in the lateral orientation and 90 minutes at **232** RPM in the longitudinal orientation. No damage was noted as a result of this test. Photo 6 shows the specimen on the vibration platform.



Photo 6. ISTF-2 Unit #1 During Repetitive Shock Testing.

3. EDGEWISE ROTATIONAL DROP TEST. The specimen was edgewise rotationally dropped from a height of **12 inches** on both longitudinal sides and both lateral sides. Difficulty was encountered when installing the slings due to the small diameter of the slinging provisions. The holes for the slinging provisions need to be enlarged and chamfered to allow for easy attachment and to prevent damage to the slings. Photo 7 shows the specimen during the drop test.



Photo 7. Edgewise Rotational Drop Test on the ISTF-2 Unit #1.

4. INCLINE-IMPACT TEST. The specimen was impact tested on both longitudinal sides and both lateral sides. Inspection following the impacts revealed bent wire mesh and a damaged shelf slider locking clip. No significant damage was noted as a result of this test to the ISTF-2 Unit #1. See Photo 8 for the specimen during the lateral incline-impact test.



Photo 8. Incline-Impact Testing of the ISTF-2 Unit #1.



Photo 9. Bent Wire Mesh of the ISTF-2 Unit #1.



Photo 10. Bent Locking Clip on ISTF-2 Unit #1 Slider.

5. SLING COMPATIBILITY TEST. During testing the specimen was lifted, swung, lowered and handled as necessary using slings of the types normally used for handling the unit loads. The sling compatibility testing was conducted using a two-point lift, a three-point lift and a four-point lift. Photo 11 shows the specimen during the sling compatibility test. The sling hooks were engaged in the rectangular slinging provisions on the ISTF-2 due to the fact that the hook could not be properly engaged in the circular sling provisions on the ISTF-2. Photo 12 shows the hooks engaged in the rectangular slinging provision of the ISTF-2. No damage was noted as a result of this test.



Photo 11. ISTF-2 Unit #1 During the Sling Compatibility Test.

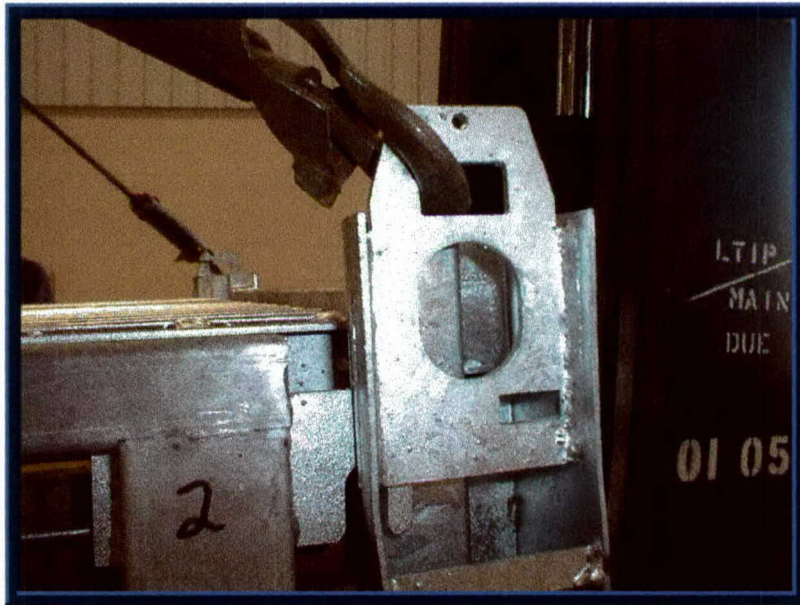


Photo 12. Rectangular Slinging Provision on ISTF-2 Unit #1.

6. **FORKLIFTING TEST.** The specimen was lifted clear of the ground by a forklift from the longitudinal and lateral sides and transported on the forks. Photo 13 shows the specimen during the Forklifting Test. The forklift tines

damaged the flange of the holder for the interlocking mechanism pin.
However, the interlocking pin could still be easily removed.



Photo 13. ISTF-2 Unit #1 During the Forklifting Test.

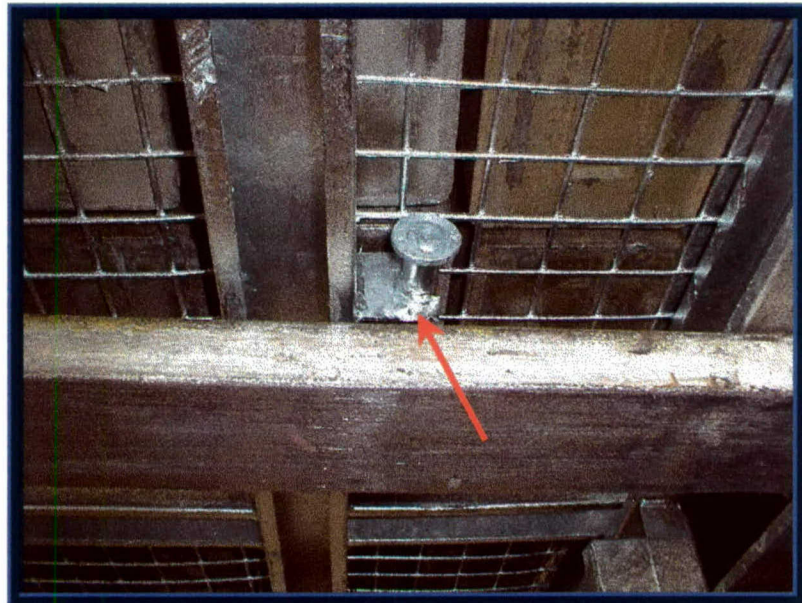


Photo 14. Damage to ISTF-2 Unit #1 Flange for Interlocking Pin.

7. **DISASSEMBLY TEST.** Inspection revealed bent wire mesh. The specimen maintained adequate integrity and was still considered safe to handle.

8. **CONCLUSION.** As tested, the Intermodal Storage and Transport Frame-2 (ISTF-2) Unit #1, manufactured by Mobile Shelter Systems, Inc. successfully completed the MIL-STD-1660 test requirements. The slinging provisions should be enlarged so that the slings can be more easily installed/removed and should have a chamfered edge to prevent damaging the slings.

5.2. FRAME DATA. The ISTF-2 unit was inertly loaded to the specified design weight using inert simulation in metal cans and wirebound boxes. The test specimen was prepared using the unitization procedures specified in Part 6 – Drawings. Special care was taken to ensure that the inert load had the proper amount of weight in order to achieve a realistic pallet center of gravity (CG). Once properly prepared, the ISTF-2 unit was tested using the MIL-STD-1660 requirements.

INTERMODAL STORAGE AND TRANSPORT FRAME-2 (ISTF-2) UNIT #2

Testing Date: 27-28 July 2004

Gross Weight: 3,325 pounds

Length: 51-7/8 inches

Width: 41-3/4 inches

Height: 45 inches

Mfg: Mobile Shelter Systems, Inc.

1. COMPRESSION TEST. The test specimen was compressed with a load force of 10,122 pounds for 60 minutes on 27 July 2004. No damage was noted as a result of this test. See Photo 16 of the test specimen in the compression unit.



Photo 16. ISTF-2 Unit #2 in the Compression Tester.

2. **REPETITIVE SHOCK TEST.** The specimen was vibrated 90 minutes at 197 RPM in the lateral orientation and 90 minutes at 228 RPM in the longitudinal orientation. No damage was noted to the ISTF-2 as a result of this test. Photo 17 shows the specimen on the vibration platform.



Photo 17. ISTF-2 Unit #2 During the Repetitive Shock Testing.

3. **EDGEWISE ROTATIONAL DROP TEST.** The specimen was edgewise rotationally dropped from a height of 12 inches on both longitudinal sides and both lateral sides. Difficulty was encountered when installing the slings due to the small diameter of the slinging provisions. The holes for the slinging provisions need to be enlarged and chamfered to allow for easy attachment and to prevent damage to the slings. No damage was noted as a result of this test. Photo 18 shows the specimen during the drop test.



Photo 18. Edgewise Rotational Drop Test on the ISTF-2 Unit #2.

4. **INCLINE-IMPACT TEST.** The specimen was impact tested on both longitudinal sides and both lateral sides. Inspection following the impacts revealed bent wire mesh and a damaged shelf slider locking clip. No significant damage was noted as a result of this test to the ISTF-2 Unit #2. See Photo 19 for the specimen during the lateral incline-impact test.



Photo 19. Incline-Impact Testing of the ISTF Unit #2.

5. SLING COMPATIBILITY TEST. During testing the specimen was lifted, swung, lowered and handled as necessary using slings of the types normally used for handling the unit loads. The sling compatibility testing was conducted using a two-point lift, a three-point lift and a four-point lift. The sling hooks were engaged in the rectangular slinging provisions on the ISTF-2 due to the hook could not be properly engaged in the circular sling provisions on the ISTF-2. Photo 20 shows the specimen during the sling compatibility test. A top shelf tab was bent during the sling compatibility testing.



Photo 20. ISTF-2 Unit #2 Sling Compatibility Testing.



Photo 21 Bent Top Shelf Tab of ISTF-2 Unit #2.

6. **FORKLIFTING TEST.** The specimen was lifted clear of the ground by a forklift from both longitudinal sides and both lateral sides and transported

on the forks. No damage was noted as a result of this test. Photo 22 shows the specimen during the Forklift Test. .



Photo 22. ISTF-2 Unit #2 During the Forklift Test.

7. DISASSEMBLY TEST. Inspection revealed bent wire mesh. The specimen maintained adequate integrity and was still considered safe to handle.

8. CONCLUSION. As tested, the Intermodal Storage and Transport Frame-2 (ISTF-2) Unit #2, manufactured by Mobile Shelter Systems, Inc. successfully completed the MIL-STD-1660 test requirements. The slinging provisions should be enlarged so that the slings can be more easily installed/removed and should have a chamfered edge to prevent damaging the slings.

5.3 INTERLOCK EVALUATION. The following testing was conducted as **evaluation** testing of the interlocks on the ISTF-2 units. **The testing was not conducted to verify the interlocks for ammunition storage and transport.** The evaluation testing included the Cornerwise Drop Test on a Single ISTF-2, a Cornerwise Drop Test of Two ISTF-2 units interlocked, Incline-Impact Test of Two ISTF-2 units interlocked. The testing was conducted in accordance with MIL-STD-1660.

INTERMODAL STORAGE AND TRANSPORT FRAME-2 (ISTF-2)

Testing Date: 1 September 2004

Gross Weight: 2,175 pounds each

Mfg: Mobile Shelter Systems, Inc.

1. CORNERWISE ROTATIONAL DROP TEST.

a. The single ISTF-2 was cornerwise rotationally dropped from a height of 18 inches on each bottom corner. Inspection following the test revealed bent wire mesh. Also damage occurred to some of the metal cans due to contact with the 120MM projectiles. No damage occurred to the interlock devices. Photo 18 shows the specimen during the drop test.



Photo 23. Cornerwise Rotational Drop Test on the ISTF-2 Unit.

b. Two ISTF-2 units when interconnected were cornerwise rotationally dropped from a height of 12 inches on each bottom corner. Photo 24 shows the specimen during the drop test. The door panel and top shelf disengaged during testing. The door panel disengaged on the side where there were not locking sliders. Installation of additional locking sliders would most likely prevent the disengagement of the door panel. Inspection following the test also revealed bent wire mesh. The sling hooks were engaged in the rectangular slinging provisions on the ISTF-2. The rectangular slots were not of an adequate size to allow the sling hooks to fully engage. However, the door panel and top shelf were reengaged and testing continued. No damage occurred to the interlock devices.



Photo 24. Cornerwise Rotational Drop Test of the Interconnected ISTF-2 Units.

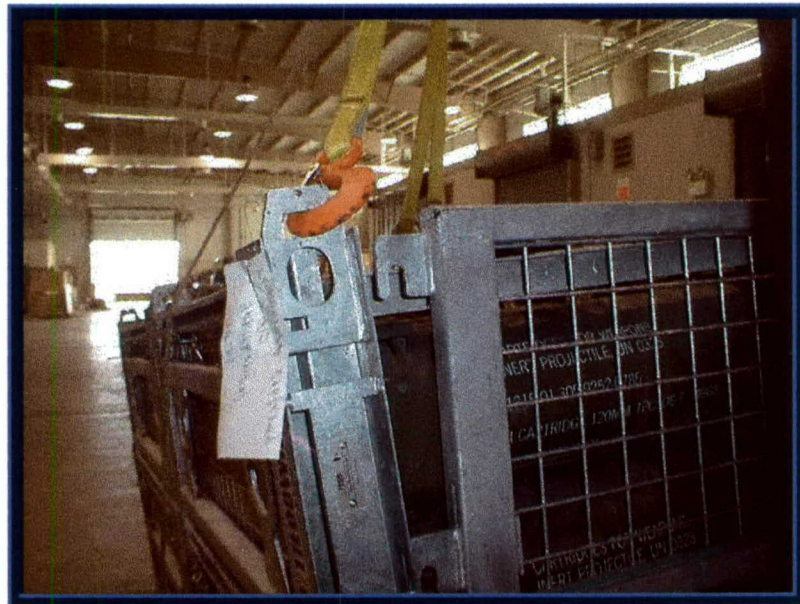


Photo 25. Door Panel Disengagement of Interconnected ISTF-2 Units.

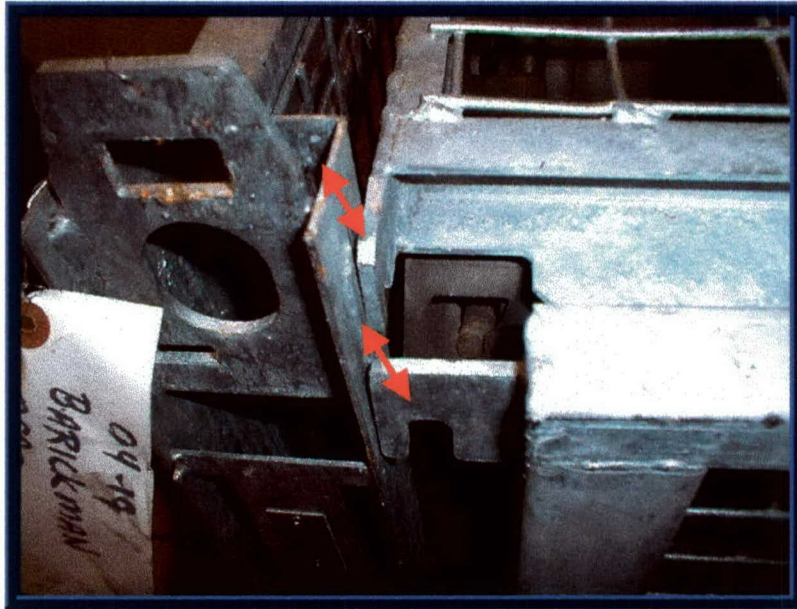


Photo 26. Top Shelf Disengagement of Interconnected ISTF-2 Units.

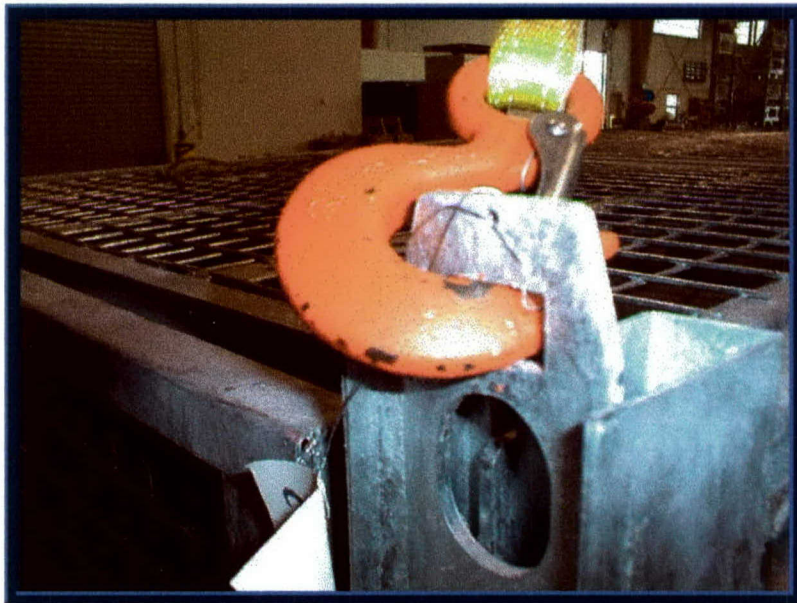


Photo 27. Improperly Engaged Sling Hooks.

2. **INCLINE-IMPACT TEST.** The specimen was impact tested on both longitudinal sides and both lateral sides with the ISTF-2 units interconnected. Inspection following the impacts revealed bent wire mesh. No damage occurred

to the interlock devices. See Photo 28 for the specimen during the lateral incline-impact test.



Photo 28. Incline-Impact Testing of the Interconnected ISTF-2 Units

3. **DISASSEMBLY TEST.** Inspection revealed bent wire mesh. No damage occurred to the interconnecting devices. The door panel tabs bent the door panel tabs also damaged the material around the slot in the corner post.



Photo 29. Bent Wire Mesh on the Interconnected ISTF-2 Units.

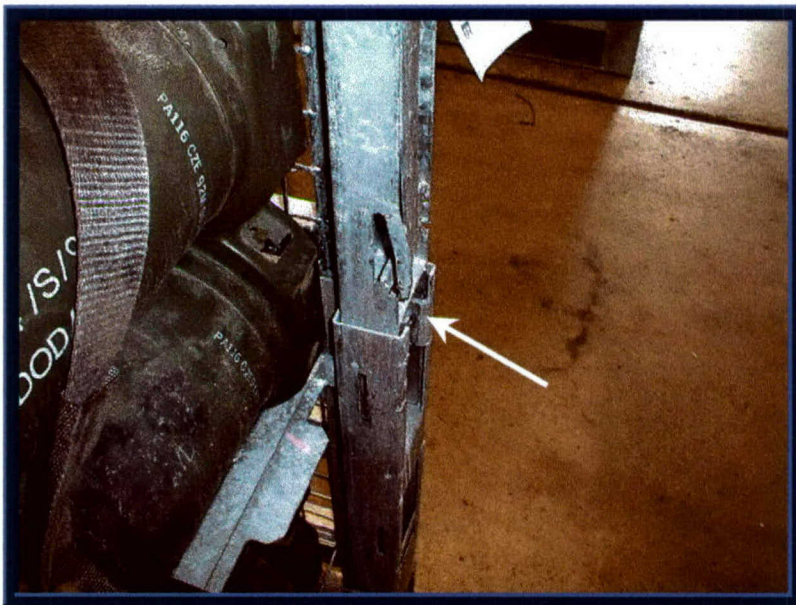


Photo 30. Damaged Metal in Corner Post Slot of Interconnected ISTF-2 Units.

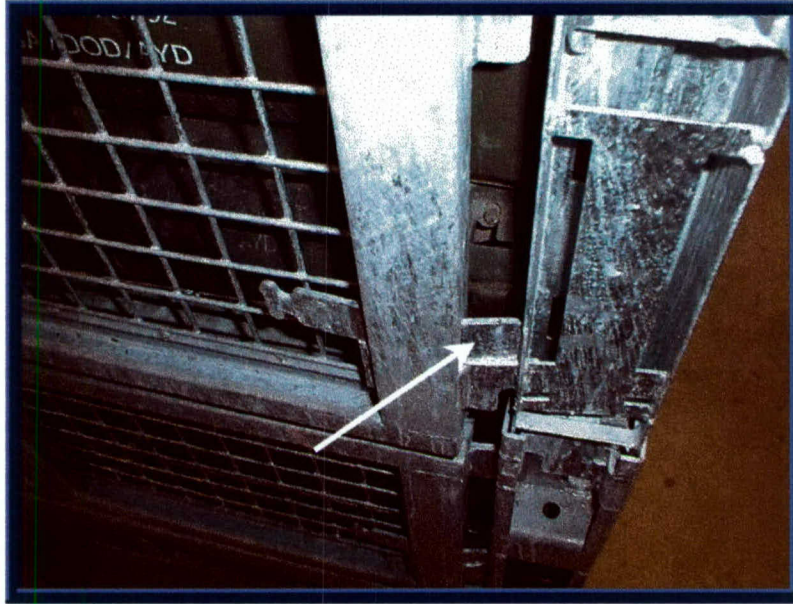


Photo 31. Bent Door Panel Tabs of Interconnected ISTF-2 Units.

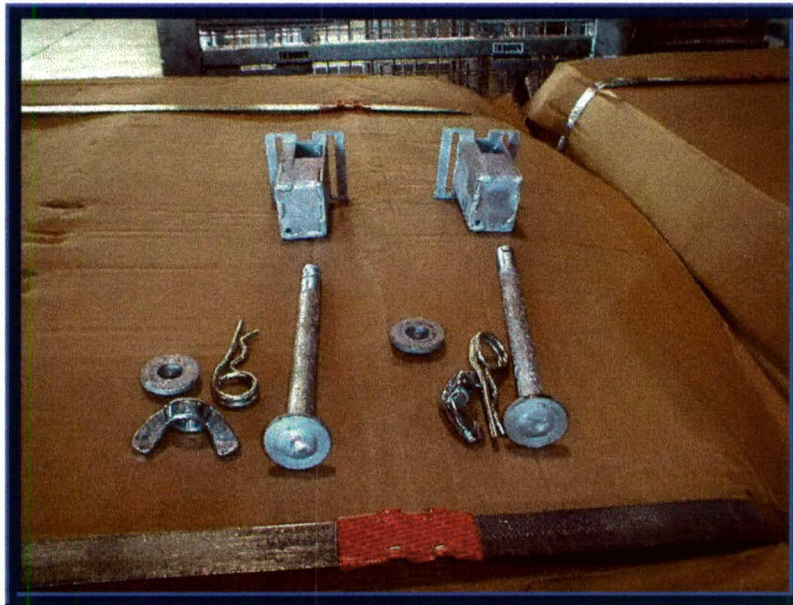


Photo 32. Interlocking Devices Following Testing.

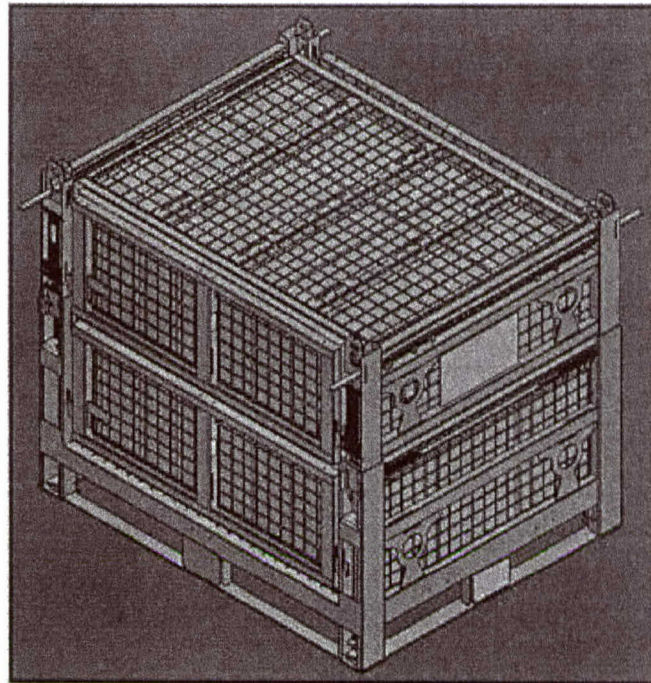
4. CONCLUSION. As tested, the interlock devices satisfactorily completed the testing. The ISTF-2 units did not satisfactorily complete testing when connected. Stresses caused by connecting two ISTF-2 units damaged the frames that created a potentially unsafe condition for the transport of

ammunition. If the disengagement of the side panels could be eliminated by the use of side panel tabs on both sides of the panels, the ISTF-2 units may avoid corner post damage. However the testing was conducted for **evaluation** purposes only. Therefore, **the interlock devices are not approved for ammunition storage and transport.**

PART 6- DRAWINGS

The following test sketches represent the load configurations that were subjected to the test criteria.

LOAD SKETCH FOR THE MIL-STD-1660 TESTING OF THE INTERMODAL STORAGE AND TRANSPORT FRAME - TWO PANEL VERSION (ISTF-2)

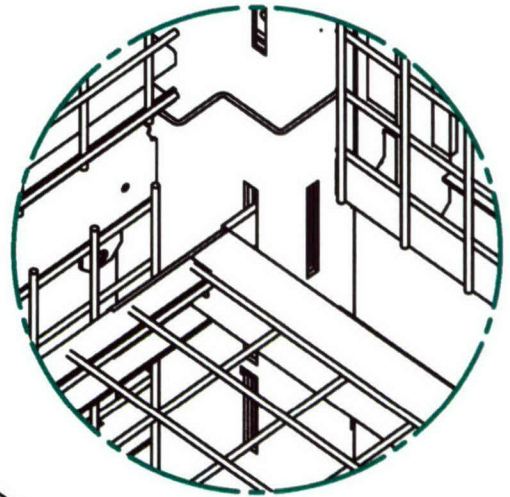
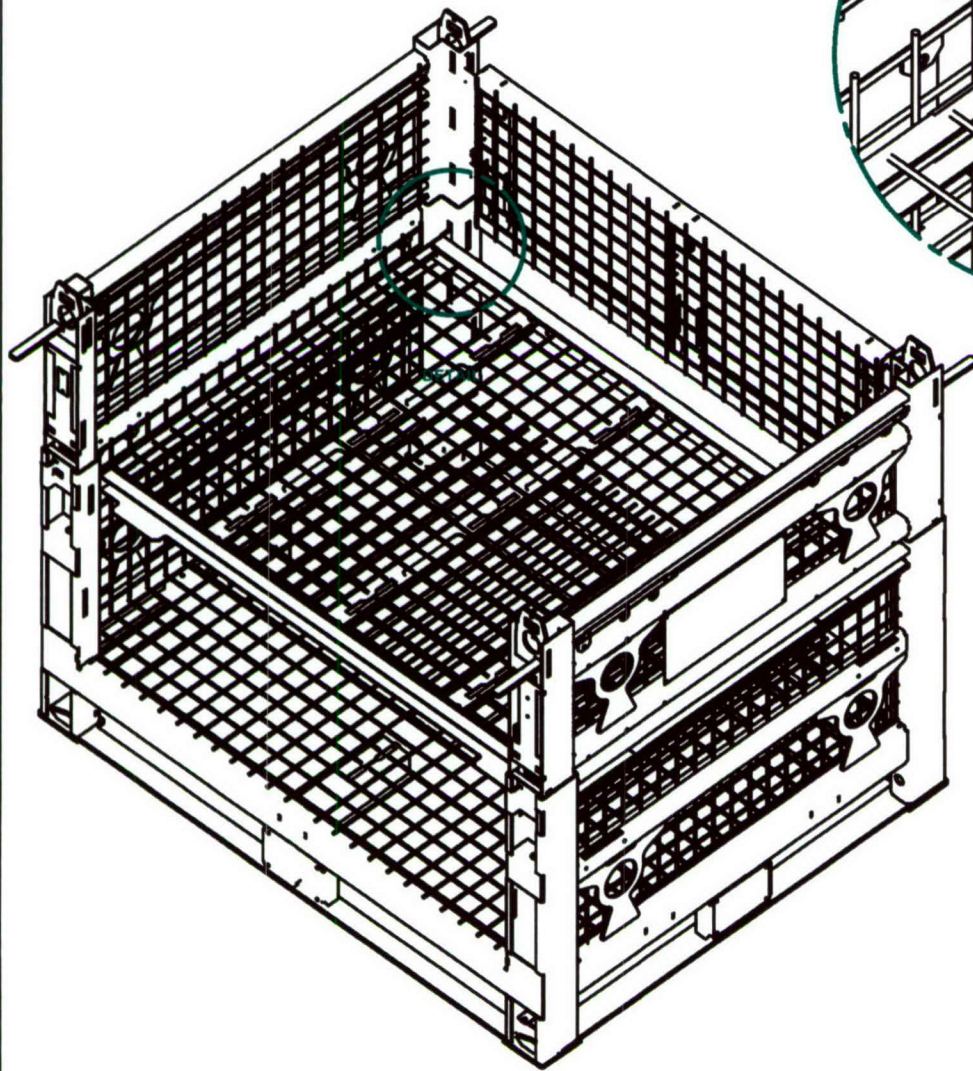


THIS FOUR PAGE DOCUMENT DEPICTS PROCEDURES FOR UNITIZING THE TEST LOAD FOR THE ISTF-2 MIL-STD-1660 TESTING.

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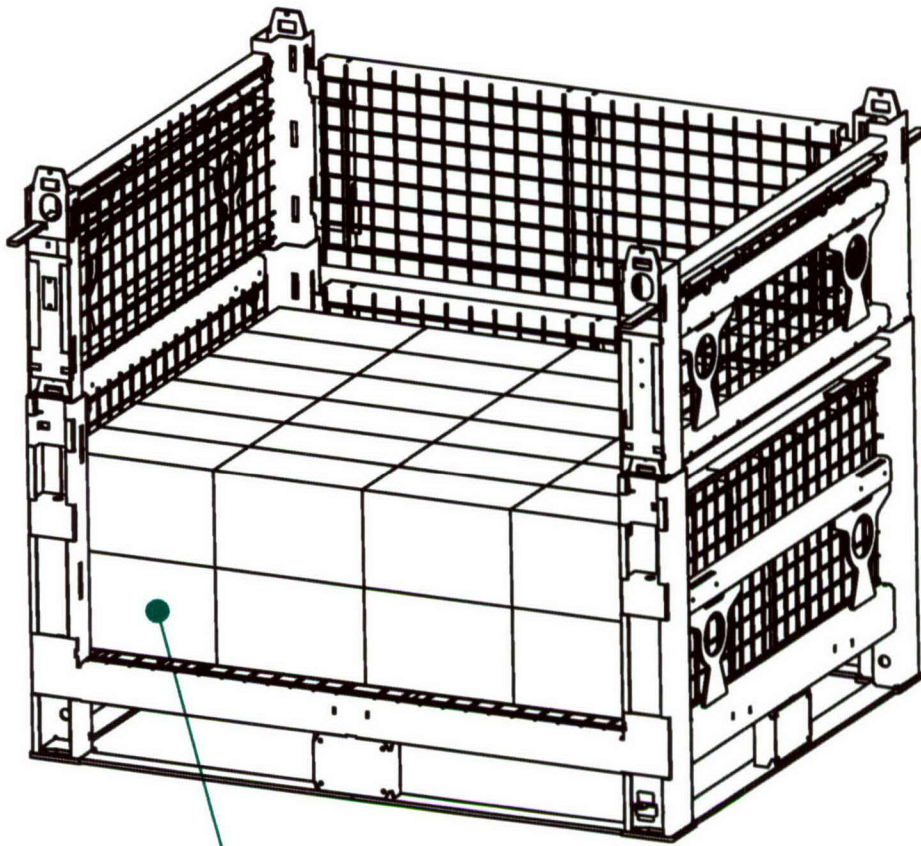


SHELF SLOT DETAIL

ISTF-2 INTERNAL SETUP

PLACE INTERNAL SHELF IN THE THIRD SHELF SLOT FROM THE BOTTOM OF THE ISTF-2 UNIT.

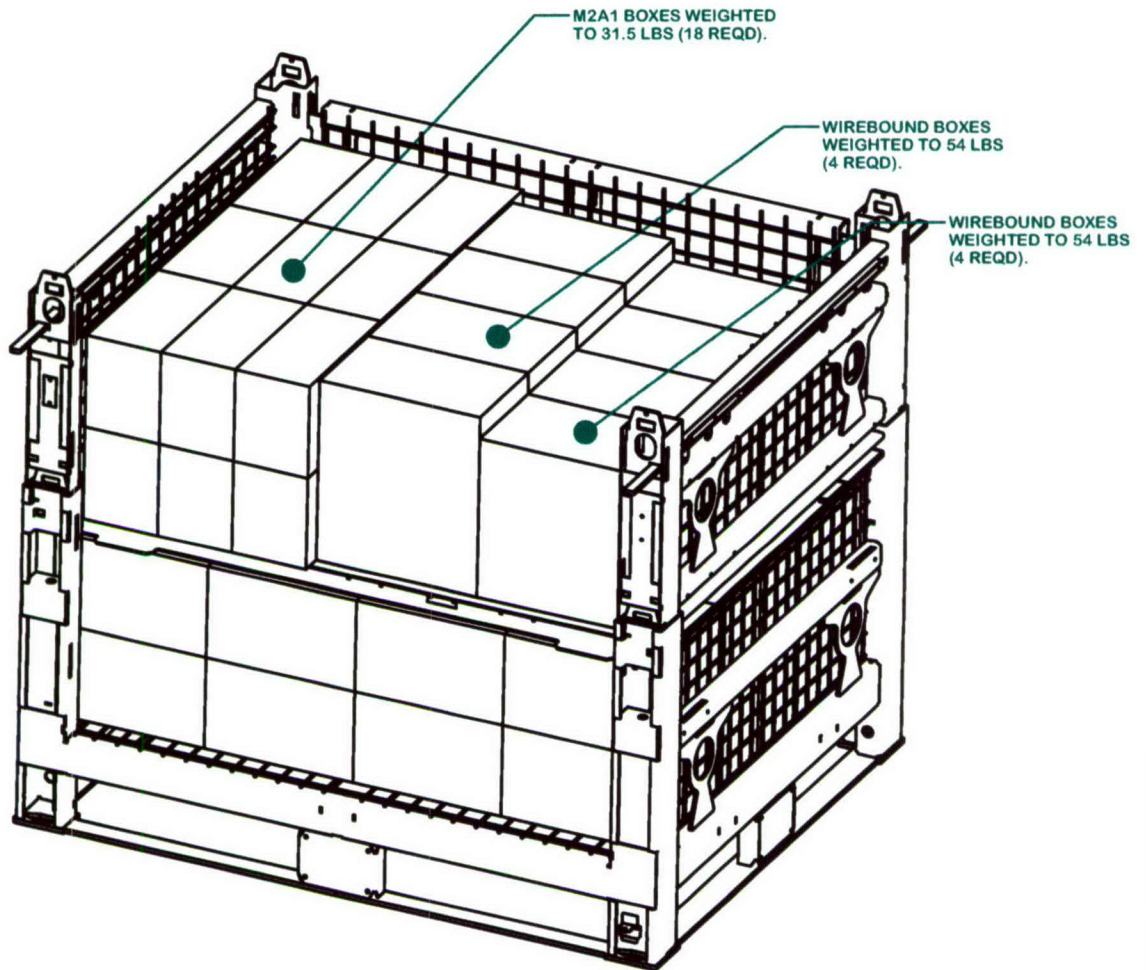
OVERALL DIMENSIONS OF THE ISTF-2 UNIT:
52" L X 42" W X 45"H



M2A1 BOXES FILLED TO 40 LBS
48 REQD.

ISTF-2 BOTTOM FRAME LOAD

ISTF-2 BOTTOM FRAME COMPOSITION CHART		
PGK TYPE	NO. REQD	WEIGHT EA (LBS)
M2A1 / METAL CAN	48	40
TOTAL WEIGHT - - - - -		1,920 LBS (APPROX)



ISTF-2 SHELF LOAD

ISTF-2 SHELF COMPOSITION CHART		
PKG TYPE	NO. REQD	WEIGHT EA (LBS)
M2A1 / METAL CAN	18	31.5
WIREBOUND	8	54
TOTAL WEIGHT - - - - -		999 LBS (APPROX)

TOTAL ISTF-2 LOAD

ITEM	QUANTITY	WEIGHT (APPROX)
M2A1 BOX (40LBS)	48	1,920 LBS
M2A1 BOX (31.5LBS)	18	567 LBS
WIREBOUND	8	432 LBS
ISTF-2		455 LBS
TOTAL WEIGHT - -		3,374 LBS