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AFPTEF PROJECT NO. 08-P-105**

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Qualification Testing of the C-5 Mated Tire / Wheel Shipping Crate

**AFMC 403 SCMS / GUEB
AIR FORCE PACKAGING TECHNOLOGY & ENGINEERING FACILITY
WRIGHT PATTERSON AFB, OH 45433-5540
09 July 2008**

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AFPTEF PROJECT NO. 08-P-105

TITLE: Qualification Testing of the C-5 Mated Tire / Wheel Shipping Crate

ABSTRACT

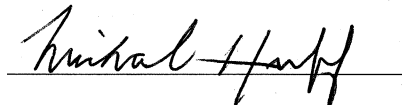
The Air Force Packaging Technology Engineering Facility (AFPTEF) was tasked to perform qualification testing of a shipping cradle, in support of Air Mobility Command and Dover TMF. Testing was performed in accordance with ASTM D4169, Distribution Cycle 18, for level B packaging (assurance level II).

AFPTEF found that the initial cradle design prevented the tire/wheel assembly from rolling (fwd-aft motion); however, reinforcement of the cradle was necessary to prevent side-to-side movement of the item during testing. During the forklift truck handling portion of testing, the item broke loose in the cradle, snapping one of the side-support beams. AFPTEF added diagonal framing and side block reinforcements, in addition to thicker side-support beams to prevent side-to-side motion of the item during shipment. The modified cradle design passed all testing.

Total man-hours: 45

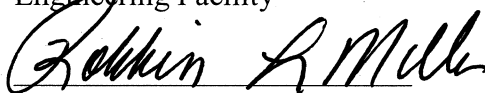
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INTRODUCTION

BACKGROUND – AMC 436 APS/TRTC (Dover AFB) contacted AFPTEF to request testing of the mated C-5 tire/wheel cradle to qualify its use as a level B reusable shipping and storage container. The current SPI does not allow the shipment of the mated wheel and tire, just the tire or the wheel. Dover moves approximately 150 to 200 shipments of these yearly but did not have an approval on the new cradle. Additionally, they could not be reimbursed since a TAC could not be established for an unapproved package.

REQUIREMENTS – Mated C-5 tire/wheel assemblies must be shipped to locations where the tire and wheel cannot be mated in the field. Level B packaging (IAW MIL-STD-2073) is required to protect this item during moderate worldwide shipment, handling, and storage conditions. The level B packaging and preservation method must be able to protect an item not directly exposed climate, terrain, and operational and transportation environments.

DEVELOPMENT

DESIGN – As received, the mated C-5 tire/wheel cradle (Appendix 2, Figure 1a-1d) consisted of a standard, 4-way, 40” x 48” wooden pallet fitted with wooden end blocks and side beams to restrain the item laterally. Steel strapping was used to restrain the item in the vertical direction. A large piece of fiberboard was placed underneath the strapping, over the top of the item, for an added layer of physical protection. The cradle is open and, therefore, not meant to be watertight or airtight. One of the 2x4 end pieces was split at the nail.

During the forklift truck handling portion of testing, the item broke loose in the cradle, snapping one of the side- beams (Appendix 2, Figure 5a-5b). AFPTEF added diagonal framing and side block reinforcements, in addition to thicker side beams to prevent side-to-side motion of the item during shipment (Appendix 2, Figure 2a-2b). The width of the existing fiberboard was increased and fiberboard strips were added to the end blocks to prevent scuffing of the tire sidewalls.

The cradle gross weight was 350 pounds as received and 381 pounds as modified, with an estimated item weight of 267 pounds. External dimensions were 49 in. (length) x 40 in. (width) x 56 in. (height).

PROTOTYPE – AMC 436 APS/TRTC provided one complete C-5 tire/wheel cradle described above to AFPTEF for testing.

Cradle direction was defined as follows: the tire treads faced the ends of the cradle, and the tire sidewalls faced the sides of the cradle.

QUALIFICATION TESTING

TEST LOAD – The test load consisted of one C-5 mated tire/wheel combination. The test load weight was approximately 267 pounds, with initial and final tested gross cradle weights of 350 and 381 pounds, respectively.

TEST PLAN – The test plan primary reference was ASTM D 4169, DC 18 (Appendix 1). The methods specified in the test plan constituted the procedure for performing the cradle testing. The performance criteria for evaluation of cradle acceptability were specified as no damage, deformation or degradation of the cradle or components that would permit damage to the item, reduce cradle strength, adversely affect safety during transport or storage, or interfere with forklifting or cradle use. All components shall remain in place throughout testing. The tests were performed at AFPTEF, Building 70, Area C, Wright-Patterson AFB.

ITEM INSTRUMENTATION – No data recording instrumentation was used in the testing below. See Appendix 4 for other test instrumentation information.

TEST SEQUENCES – Note: All test sequences were performed at ambient temperatures.

TEST SEQUENCE 1 – Tip Test

Procedure – The cradle was lifted by means of a cargo strap and chains looped through the forklift openings on one long side, until an angle of 22° was reached (Appendix 2, Figure 3a-3b). The cradle was closely observed for any tendency to tip over. The cradle was then lowered gently and returned to a fully upright position. The procedure was repeated for both side and end tipping.

Results – No tendencies to tip over were observed; the cradle remained stable. The cradle passed the tip test with this test load.

TEST SEQUENCE 2 – Forklift Truck Transport Test

Procedure: The cradle was picked up by the tine openings on one side and driven over the test course 1 round trip (forward and backward) (Appendix 2, Figure 4a-4b).

Results: On the backward portion of the test for the baseline cradle, side-to-side motion of the item (fwd-aft with respect to direction of travel) caused one of the side beams to snap, with noticeable scuffing of the tire sidewalls (Appendix 2, Figure 5a-5b). The procedure was repeated for the modified cradle, with no visible damage to the cradle and all components remaining in place. The modified cradle met the test requirements.

TEST SEQUENCE 3 – Loose Load Vibration Test, Repetitive Shock

Procedure – A sheet of 3/4-inch plywood was bolted to the top of the vibration table, and the modified cradle was placed on the plywood. Restraints were used to prevent the cradle from sliding off the table. The cradle was allowed approximately 1/2-inch unrestricted movement in the horizontal direction from the centered position on the table (Appendix 2, Figure 6).

The table frequency was increased from 3.5 Hz until the cradle left the table surface (approximately 4.25 Hz). At one-inch double amplitude, a 1/16-inch-thick flat metal feeler could be slid freely between the table top and the cradle under all points of the cradle. Repetitive shock testing was conducted for 2 hours at ambient temperature.

Results - The loaded cradle was vibrated at 4.25 Hz for 2 hours. At the end of testing there was no visible damage to the cradle and all components had remained in place. The modified cradle met the test requirements.

TEST SEQUENCE 4 – Rotational Drops

Procedure – An initial drop height of 12 inches was used to perform four corner and four edge drops of the modified cradle onto a smooth concrete surface (Appendix 2, Figures 7 & 8). The cradle was visually inspected for damage. The procedure was repeated for a drop height of 18 inches (Appendix 2, Figures 9 & 10).

Results – The item remained secure in the cradle for all drops performed. The following issues were discovered during testing:

1. Cracking of end support beams (Appendix 2, Figure 11a) – caused by drops #9 and #10, which were 18” edge drops at the ends of the cradle. Due to a high impact angle, the lower, contour-cut crossbeam supported most of the item’s weight during drops #9 and #10. Based on analysis, a 2x4 stiffener was added to each end of the cradle, and drops #9 and #10 were repeated successfully: all components remained in place with no visible damage to the cradle.
2. Pullout of nails (Appendix 2, Figure 11b) joining upper, contour-cut crossbeams to the plywood – typical of all edge and corner drops of the cradle. Prior to testing the modified cradle, a single deck screw was added to the joint where the 2x4 was cracked (Appendix 2, Fig. 1d). This was the only one (of four joints) that never pulled apart during testing. Production cradles will replace nails with screws at these four locations.
3. Split end of 2x4 (Appendix 2, Figure 11c) – due to nails being angled and placed too close to the surface of the 2x4. This can be avoided by following standard rules for nail spacing on production cradles.

4. Splitting of lower deck board at the corner of the pallet (Appendix 2, Figure 11d) – a result of the corner drops, yet no real reason for concern. The crack appeared early on during the testing; it did not spread past the outer stringer or affect the pallet's overall structural integrity. In fact, testing showed that the wing-type pallet (with deck boards over-hanging the stringers) allows the deck boards to absorb a significant amount of impact energy from rotational drops.
5. Slight indentations along the tire sidewalls, caused by contact with the upper crossbeams. Fiberboard strips were added to prevent recurrence on production cradles.

TEST CONCLUSIONS – The baseline version of the C-5 tire/wheel cradle failed the forklift truck transport test, so the cradle design was modified and retested. Then the cradle satisfied test requirements for all but two rotational drops, which were repeated successfully after further modification. As tested, there was no damage, deformation or degradation of the cradle or components that would permit damage to the item, reduce cradle strength, adversely affect safety during transport or storage, or interfere with forklifting or cradle use.

CONCLUSIONS & RECOMMENDATIONS

The modified version of the C-5 mated tire/wheel cradle satisfied all qualification test requirements for level B packaging. When built and used in accordance with SPI documentation, it can be expected to secure and physically protect the item during moderate worldwide shipping, storage, and handling conditions.

APPENDIX 1: Test Plan

AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY (Container Test Plan)				AFPTEF PROJECT NUMBER: 08-P-105	
CONTAINER SIZE (L x W x D) (IN) INTERIOR: N/A EXTERIOR: 48 X 40 X 54		WEIGHT (LB) GROSS: 350 TARE: ----		CUBE (CU. FT) Approx 60	QUANTITY: 1 DATE: Jun08
ITEM NAME: C-5 Main / Nose Tire; C-5 Main Wheel				MANUFACTURER: ----	
CONTAINER NAME: Shipping Crate / Modified Pallet				CONTAINER COST:	
PACK DESCRIPTION: Mated MLG Tire / Wheel					
CONDITIONING: Ambient					
TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS	CONTAINER ORIENTATION	INSTRUMENTATION	
<u>PASS/FAIL CRITERIA FOR ALL TESTS</u>					
There shall be no damage, deformation or degradation of the shipping crate or components that would permit damage to the items, reduce container strength, adversely affect safety during transport or storage, or interfere with forklifting or container use. All components shall remain in place throughout testing.					
1.	Product examination.	Fully assembled container shall be measured, and all components, assembly and closure requirements examined for accordance with manufacturer instructions and documentation. Weight Test.	Ambient temp. Ambient temp.	Visual Inspection (VI), tape measure Scale	
<u>Schedule A – Handling - Manual & Mechanical</u> Ambient temperature, Assurance Level II					
2.	Tip Test ASTM D4169, Sched. A, para. 10.3.3(1), DC-18 ASTM D6179, Method F	This test shall be performed in all potentially unstable directions. The container with test load shall be slowly tipped to a 22° angle from vertical. The container shall right itself and not tip over into the tipped direction..	Ambient temp.	Hoist, cargo straps, quick release, slope gauge	
COMMENTS:					
PREPARED BY: Michael R. Harff, Mechanical Engineer			APPROVED BY: Robbin L. Miller, Chief AFPTEF		

AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY (Container Test Plan)				AFPTEF PROJECT NUMBER: 08-P-105	
CONTAINER SIZE (L x W x D) (IN)		WEIGHT (LB)		CUBE (CU. FT)	QUANTITY:
INTERIOR:	EXTERIOR:	GROSS:	ITEM:		DATE:
N/A	48 X 40 X 54	350	----	Approx 60	Jun 08
ITEM NAME: C-5 Main / Nose Tire; C-5 Main Wheel				MANUFACTURER: ----	
CONTAINER NAME: Shipping Crate / Modified Pallet				CONTAINER COST:	
PACK DESCRIPTION: Mated MLG Tire / Wheel					
CONDITIONING: Ambient					
TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS		CONTAINER ORIENTATION	EQUIPMENT & INSTRUMENTATION
Schedule A – Handling - Manual & Mechanical, cont. Ambient temperature, Assurance Level II					
3.	Forklift Truck Transport Test ASTM D4169, Sched. A, para. 10.3.3(2), DC-18 ASTM D6055, Method A, 1 cycle	Lay 3 pairs of 1 in. x 6 in. boards on 100-ft test course at 30, 60, and 90 feet. Angle boards to the forklift's path at 90°, 60°, and 75° respectively; the left wheel strikes 1 st over the second board pair, the right wheel 1st over the 3rd pair. Pick up shipping crate through the tine openings of the pallet and drive over course 1 rd trip.		Ambient temp.	Fork-lift, boards, timer, tape measure.
Schedule F – Loose Load Vibration Ambient Temperature, Assurance Level II					
4.	ASTM D4169, Schedule F, para. 13.3, DC-18 ASTM D999, Method A1	Container with test load shall be tested as described with a dwell time of 2 hours, in one position.		Ambient temp.	Vibration table, controller.
Schedule A – Handling - Manual & Mechanical, cont. Ambient temperature, Assurance Level II					
5.	Rotational (cornerwise & edgewise) Drops. ASTM D4169, Sched. A, para. 10.3.3(3), DC-18, ASTM D6179 Methods A&B	Drops shall be performed on all edges and corners, using an 18" drop height. 6-in. and 12-in. wood edge & corner supports shall be used as needed. One drop shall be performed on each edge and corner.		Ambient temp.	Support blocks, hoist, quick-release, cargo straps, tape measure.
COMMENTS:					
PREPARED BY: Michael R. Harff, Mechanical Engineer				APPROVED BY: Robbin L. Miller, Chief AFPTEF	

APPENDIX 2: Cradle and Testing Photographs



Figure 1a. Baseline cradle – oblique view.



Figure 1b. Baseline cradle – side view.



Figure 1c. Baseline cradle – end view.

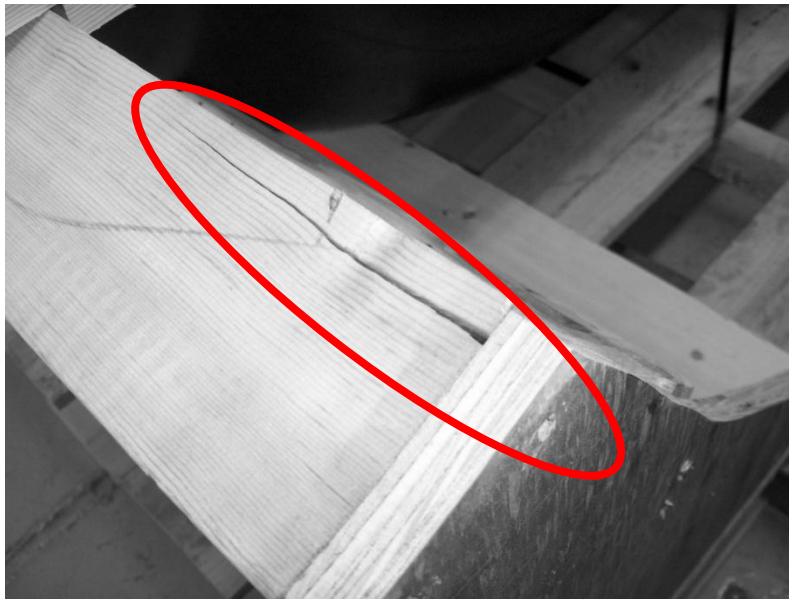


Figure 1d. Baseline cradle as received: 2x4 split at the nail.

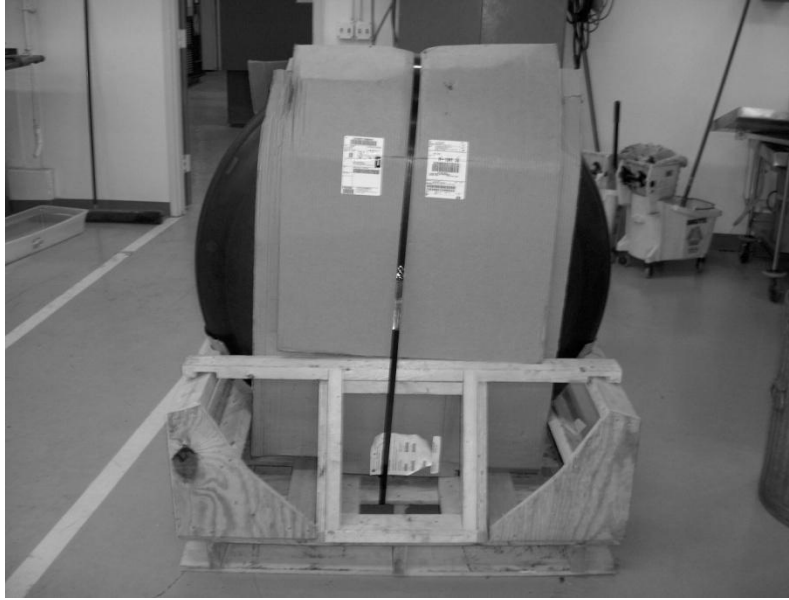


Figure 2a. Modified cradle, side view.



Figure 2b. Modified cradle, end view.



Figure 3a. Tip Test – on side of cradle.

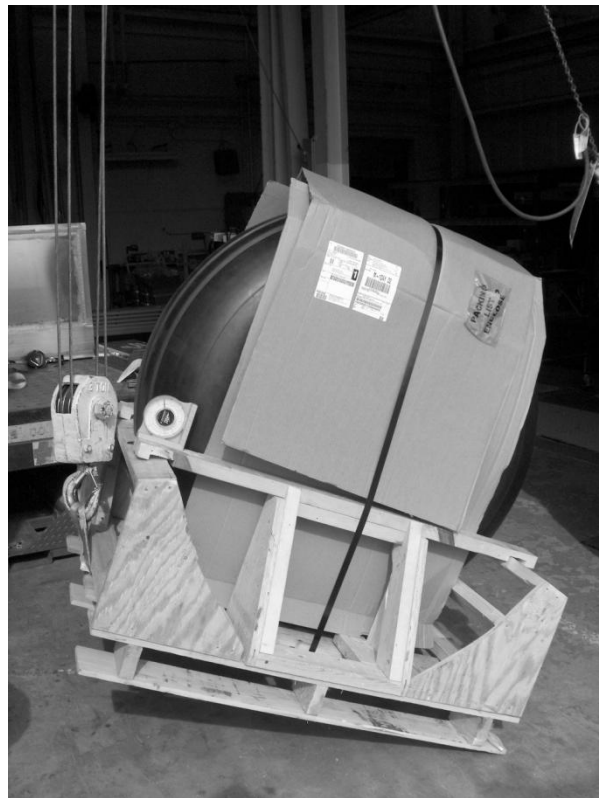


Figure 3b. Tip Test – on end of cradle.



Figure 4a. Forklift Truck Transport Test – prior to forward leg.



Figure 4b. Forklift Truck Transport Test – backwards leg in progress.



Figure 5a. Forklift Truck Transport Test – Baseline cradle, snapped side beam.



Figure 5b. Forklift Truck Transport Test – Baseline cradle, sidewall scuffing due to contact with side beam.



Figure 6. Loose Load Vibration Test.



Figure 7. Rotational Edge Drop Test –12” height.



Figure 8. Rotational Corner Drop Test –12” height.



Figure 9. Rotational Edge Drop Test –18” height.



Figure 10. Rotational Corner Drop Test –18” height.

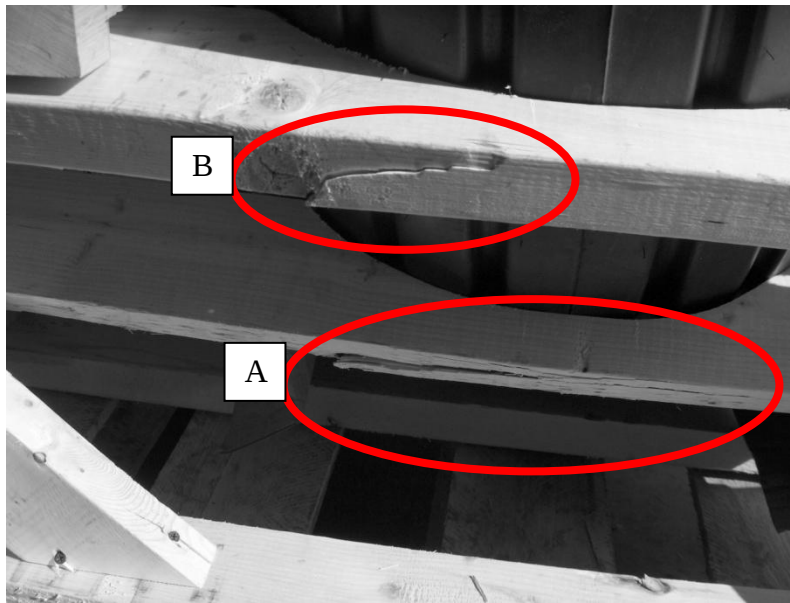


Figure 11a. Rotational Drop Test – Cracked crossbeams; beams were replaced (A and B) with 2x4 stiffeners added (to beam A) at both ends of the cradle, and drops were repeated successfully.

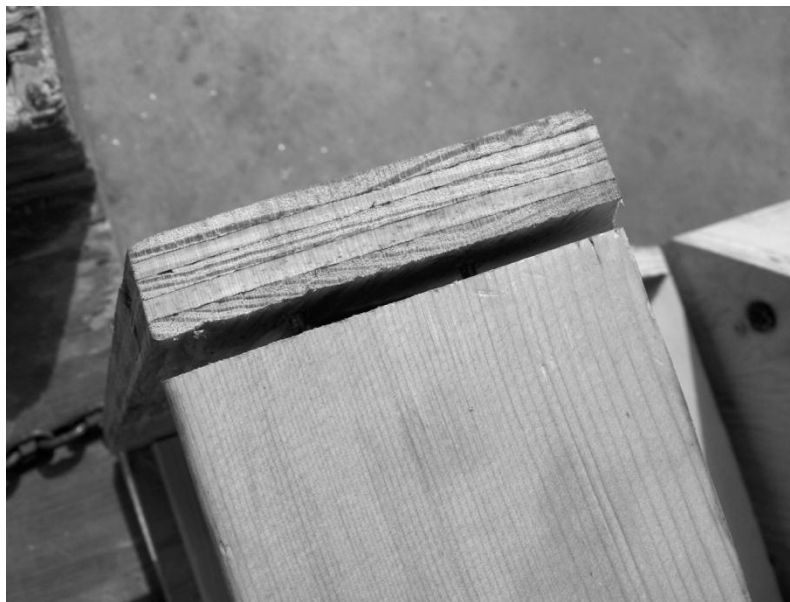


Figure 11b. Rotational Drop Test – Nail pullout typical for all drops; nails were replaced with screws.



Figure 11c. Rotational Drop Test – End of 2x4 split, due to nails being angled and placed too close to surface of the 2x4.



Figure 11d. Rotational Drop Test – Splitting of lower deck board at the corner of the pallet.

APPENDIX 3: Test Instrumentation

VIBRATION TEST EQUIPMENT - Test sequence 3

EQUIPMENT	MANUFACTURER	MODEL	SN	CAL. DATE
Servohydraulic Vibration Machine	Team Corp.	Special	1988	N/A
Feedback Hardware Controller	Dactron Corp.	PCI DSP Card Front End DSP Box	2208515 4544828	Sep 07 N/A
Feedback Software Controller	Dactron Corp.	Version 2.1	N/A	N/A
Table Feedback Accelerometer	Endevco	2271AM20	103870	Nov 07
Feedback Amplifier	Endevco	2775A	EL65	N/A

APPENDIX 4: Distribution List

DISTRIBUTION LIST

DTIC/O
DEFENSE TECHNICAL INFORMATION CENTER
FORT BELVOIR VA 22060-6218

403 SCMS/CL
5215 THURLOW ST, STE 5
BLDG 70C
WRIGHT-PATTERSON AFB OH 45433-5547

436 APS/TRTC
ATTN JOHN SCHARMACH
202 LIBERTY WAY
DOVER AFB, DE 19901

436 APS/TRTC
ATTN SSGT CASEY FLOOD
202 LIBERTY WAY
DOVER AFB, DE 19901

436 APS/TRTCO
ATTN TSGT SCOTT SIKORSKI
202 LIBERTY WAY
DOVER AFB, DE 19901

418 SCMS/GULAAA
ATTN THELMA LOOCK
7973 UTILITY DR
BLDG 1135
HILL AFB UT 84056

420 SCMS/GUMAA
ATTN CAROL BAXTER
7701 ARNOLD ST
BLDG 1, RM 112
TINKER AFB OK 73145

406 SCMS/GUMA
ATTN WAYNE OSBORN
375 PERRY ST
BLDG 255
ROBINS AFB GA 31098

APPENDIX 5: Report Documentation

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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			5c. PROGRAM ELEMENT NUMBER	
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			11. SPONSORING/MONITORING AGENCY REPORT NUMBER	
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14. ABSTRACT The Air Force Packaging Technology Engineering Facility (AFPTEF) was tasked to perform qualification testing of a shipping cradle, in support of Air Mobility Command and Dover TMF. Testing was performed in accordance with ASTM D4169, Distribution Cycle 18, for level B packaging (assurance level II). AFPTEF found that the initial cradle design prevented the tire/wheel assembly from rolling (fwd-aft motion); however, reinforcement of the cradle was necessary to prevent side-to-side movement of the item during testing. During the forklift truck handling portion of testing, the item broke loose in the cradle, snapping one of the side-support beams. AFPTEF added diagonal framing and side block reinforcements, in addition to thicker side-support beams to prevent side-to-side motion of the item during shipment. The modified cradle design passed all testing.				
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