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AD-E402 499

Technical Report ARAED-TR-93016

FIELD ARTILLERY PROJECTILE PALLET (FAPP) PROTOTYPE

Alvin K. Lew

October 1993

US ARMY
ARMAMENT MUNITIONS
& CHEMICAL COMMAND
ARMAMENT RDE CENTER

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Armament Engineering Directorate

Picatinny Arsenal, New Jersey

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 1993	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

FIELD ARTILLERY PROJECTILE PALLET (FAPP) PROTOTYPE

5. FUNDING NUMBERS

6. AUTHOR(S)

Alvin K. Lew

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSES(S)

ARDEC, AED
Packaging Division (SMCAR-AEP)
Picatinny Arsenal, NJ 07806-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

Technical Report
ARAED-TR-93016

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S)

ARDEC, IMD
STINFO Br (SMCAR-IMI-I)
Picatinny Arsenal, NJ 07806-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report details the testing and results of rough handling/transportation tests performed on the field artillery projectile pallet (FAPP). The objective of these tests was to determine the adequacy of the FAPP for shipment of 155-mm projectiles.

14. SUBJECT TERMS

M483 A1 projectile FAPP Roll over test Pendulum impact test

15. NUMBER OF PAGES
34

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

SUMMARY

The field artillery projectile pallet (FAPP) was designed to replace the existing wood pallet for 155-mm artillery projectiles. The wood pallet exhibits several design deficiencies such as poor structural integrity, inability to be nuclear, biological, and chemical decontaminated, flammability, and the use of banding to constitute the pallet load. The FAPP is decontaminable, nonflammable, and by virtue of the rod/latch mechanisms, allows for manual repalletization of the projectiles in either full or partial loads without the use of banding.

Fielding the FAPP required extensive testing included: engineering rough handling testing, Battleking user evaluation, U.S. Army Defense Ammunition Center and School railcar testing, instrumented drop testing, and live-fire safety rough handling testing. All these tests are summarized in this FAPP final report covering a period from January 1988 to September 1991. As a result of successful qualification testing, the FAPP has been proven to meet the rough handling and transportation requirements, and is full ready to be fielded for the artillery user.

CONTENTS

	Page
Introduction	1
Background	1
Discussion	1
Original Field Artillery Projectile Container (FAPC) Design	1
Contract Award of FAPP	2
FAPP Requirements	2
Task I, Contractor Production Engineering	4
Task II, ARDEC Engineering Testing	6
Task III, Tooling Design	10
Task IV, Lanson Pallet Delivery	13
Conclusion	21
References	29
Distribution List	31

FIGURES

1	Current wood pallet	23
2	155-mm projectile pallet product improvement program	24
3	155-mm projectile packaging improvement program	25
4	ARDEC 155-mm pallet qualification test plant	26
5	Field artillery projectile pallet (FAPP) Dugway Proving Ground test	27

INTRODUCTION

The purpose of this report is to present a full discussion of development and testing of the field artillery projectile Pallet (FAPP). The discussion includes contractor testing, U.S. Army Armament Research, Development and Engineering Center, Picatinny Arsenal, NJ (ARDEC) engineering testing, Navy qualification testing, Battleking user evaluation at Ft. Sill, Oklahoma, instrumented FAPP versus wood pallet testing, "live" testing at Dugway Proving Ground (DPG), railcar testing at US Army Defense Ammunition Center and School (USADACS), "live" M864 testing at Yuma Proving Ground (YPG), and instrumented M864 7 ft drop testing. This report covers a period from September 1987 to September 1991 encompassing all qualification testing of the FAPP.

BACKGROUND

The objective of the FAPP program is to replace the existing wooden pallet [fig. 1, ARDEC drawing 8837839] for 155-mm projectiles with a steel pallet [fig. 2, ARDEC drawing 12926862]. The wood pallet has several design deficiencies such as poor structural integrity, inability to be nuclear, biological, and chemical (NBC) decontaminated, flammability, and the use of banding to constitute the pallet load. This new pallet is required to be structurally stronger, require reduced maintenance/replacement, be NBC decontaminable and nonflammable, allow easier quicker access to projectiles, and allow for repalletization of ammunition in either full or partial loads without banding or special tools (fig. 3).

The FAPP is designed to help prevent the spread of shipboard fires with its steel construction and prevents the safety hazard of loose rounds on trucks with its ability to repalletize projectiles in partial loads.

DISCUSSION

Original Field Artillery Projectile Container (FAPC) Design

The FAPC concept was the original program which was initiated in 1984. The FAPC was required to provide a sealed container from the load and assembly plant to the gun. The FAPC would allow projectiles to be cartridge loaded into the field artillery supply vehicle (FAASV). The empty FAPC would be used as a rack and contain 8 to 12 projectiles. It also would be usable in a NBC environment. The user/ developer working group meeting on 13 Aug 86 concluded that the cost/weight objectives were unachievable. The cost was 9% less ammunition fielded and a 100% fleet retrofit of the FAASV. As a result, the program was redirected to the FAPP.

Contract Award of FAPP

The FAPC program was redirected to the FAPP in September 1986. Lanson Industries was awarded a contract on 22 Sep 1987 to develop prototype FAPP pallets. Lanson was contracted to do the product design, production engineering, testing, and fabrication of an improved steel pallet for 155-mm projectiles within design-to-unit production cost limits. The contract consisted of four distinct phases:

- Task I was the production engineering of a suitable prototype
- Task II was the fabrication of 12 pallets and full engineering testing
- Task III was the manufacture of production quality tooling for mass production
- Task IV was the manufacture and delivery of 150 pallets for final government testing

FAPP Requirements

Lanson was responsible for providing a final design that met the following requirements:

- Provide capacity for eight projectiles.
- Maintain the same envelope dimensions as ARDEC drawing 8837839.
- Accommodate the following projectiles: M483A1, M825, M692/M731, M718/M741, XM864, M485, M804, and M107.
- Accommodate the current lifting plugs per ARDEC drawings 9347368 and 9341742.
- Provide an adjustment feature that ensures that all pallets that leave the load, assemble, and pack (LAP) facility have the same pallet compression, regardless of round length tolerances within a given round-type.
- Provide capability of pallet reconstitution at any point in the logistics system, in full or partial loads, once bulk is broken. This reconstitution is to be accomplished by hand, without banding equipment or tools (eliminate banding).

- Ensure useability and maintainability in a NBC environment with operating personnel clothed in MOP-IV protective garments and extreme climate cold weather clothing. Operational compatibility with "mitten set" (extreme cold weather) is exempted. Compatibility with "glove shell," leather using glove insert, is required.

- Provide a quick opening/closing latch feature(s) capable of being one hand activated by operator personnel. Maximum peak opening pull force (constant force measured) at and in the direction of level pull, shall not exceed 20 lb. Peak closure force (constant force measured) shall not exceed 80 lb when measured at or near the forcing lever. Latch specifications are applicable over an operating temperature range of -25°F to +145°F. Configuration of lever handle ends shall conform with design guidance/requirements of MIL-STD-1472 c, paragraph 5.9.11.5.; paragraph 5.9.11.5.6 is exempted.

- Be constructed of materials that can be readily decontaminated or that are NBC contamination resistant.

- Be configured so as not to trap NBC contaminants and to provide for drainage of liquids.

- Be rigid enough to maintain stability in stacks of pallets up to 16 ft high, and facilitate securing for more efficient storage while maintaining individual pallet access by materials handling equipment (MHE).

- Be compatible with current cranes and forklifts.

- Meet or exceed storage length requirements for the current wooden pallet (unprotected storage life - minimum 2 yr; protected (warehouse) storage life - minimum 20 yr).

- Shall not be constructed of dissimilar metals as defined in MIL-STD-889.

- Provide for a method to mark the pallet with all requirements of ARDEC drawing 8837839.

- Shall not introduce any additional safety hazard during handling, storage, transportation, and disposal.

- Shall pass all testing per paragraph 3.2.2 of the statement of work.

- Shall be designed to be produced and provided to the Gov ment in production quantities of 100,000 pallets per year, at a final cost not to exceed $45[1] (excluding grommets) for the full pallet assembly.

Task I, Contractor Production Engineering

The first concept was made from high strength steel and failed Lanson's in-house drop tests. Excessive deformation occurred in the forkwells, base, and cover. At an informal design review, Lanson and ARDEC decided that preliminary testing at ambient temperatures in task I would eliminate expensive retesting at temperature in an independent test laboratory. The contract was modified to require government testing of prototypes in task I. The following changes were made to the pallet:

- The corners of the base panel and cover panel were changed from round to square. This will reduce cost and provide more interface areas between pallets.

- Flanges were added to the forkwell to give added strength to resist buckling.

Two versions of this design were tested at ARDEC, one with high strength steel and one with commercial quality. Both pallets failed in edgewise and cornerwise drop testing when the latch doubler deformed. From these tests, it was determined that:

- High-strength steel would be required
- Cover has to be strengthened to prevent deformation
- A better way for retaining the latch handle is required

New designs incorporating these changes were made at Lanson and tested. The pallets still failed due to deformation of the cover and bases. It was also noticed that the latch trunnion could pivot out from under the latch nut. A tab was added to the latch handle to prevent the trunnion from rotating back.

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[1]This money reflects FY 87 prices.

Four pallets were made with these changes and tested at ARDEC. All passed the drop test, but failed the loose cargo test. Lanson then made a pallet with angle welded down the longitudinal side on the inside of the base flange. This pallet passed all testing except the secured vibration which was not run and made it clear that the following were needed:

- Increase the section modulus of the base to resist bending
- Minimize cost impact

In an effort to accomplish this, four more pallets were built for testing at ARDEC. Of the four pallets, the one with the increased base flange from 1.25 to 1.5 in. showed the greatest improvement. The bending moment could be reduced by widening the support provided by the forkwell. A ribbed forkwell was proposed, but rejected because the design was not practical for tooling purposes. Widening the forkwell from 3 in. to 3.5 in. required adding ribs to the cover for stacking purposes.

Since the 3.5 in. pallet was almost identical to the pallet from the previous contract which passed all the testing, a comparative analysis was done by the Armaments Engineering Directorate at ARDEC. The old pallet has 1/10 in. thick spacers while the new spacers were 1/4 in. thick. An old pallet with 1/4 in. spacers was tested and it failed. It was surmised that the thicker spacer was allowing resonant shock frequency to be transmitted to the pallet base and, thereby, increase the shock.

During this period of testing, a latch rod broke due to cold working caused by repeated use of the same latch rods. To prevent future occurrence of this, the material was changed from low-carbon steel (60,000 psi minimum tensile strength) to alloy steel bolting material per ASTM-A193, grade B7 (105,000 psi minimum tensile strength).

Prototype Engineering Testing

In September 1988, the first acceptable prototype from Lanson passed all the testing at ARDEC (ref 1). This pallet was constructed of A715, 14 gauge high-strength steel. The base had eight 3/4 in. drawn pockets and eight 1/8 in. high density polyethylene spacers. The cover was ribbed for rigidity and strength. The two assemblies were attached using a 7/16 in. coarse threaded A193 steel rod with ultimate tensile strength of 125,000 psi.

The edgewise drop test was conducted in accordance with ARDEC drawing 8837375, test no. 3, except the 24 in. and 36 in. drops. These tests were not conducted due to the high center of gravity of the pallet, which causes it to fall on its side and not on the skid if raised higher than 12 in. on one side. To perform the test, one skid of the pallet was placed on a 5 in. high block and the other end of the pallet was raised approximately 12 in. The pallet was released and allowed to fall onto its skid. This was done on each skid with no damage except for scratched paint.

The cornerwise drop was conducted in accordance with ARDEC drawing 8837375, test no. 4. The corner of the one skid was placed on 12 in. high block and the rest of the pallet was raised so that the pallet base was parallel to the floor. The pallet was released and allowed to drop on the corner of the skid opposite the block. The pallet was not damaged except for scratched paint.

The rollover test was performed in accordance with ARDEC drawing 8837375, test no. 7. The pallet was pushed onto its long side allowing the cover to impact the steel plate. It was then lifted onto its cover/projectile lifting plugs and pushed over, allowing the base panel to impact the steel plate. There was no additional damage to the pallet other than scratches and abrasions.

The loose cargo test was conducted in accordance with ARDEC drawing 8837375. The pallet was tested at 300 rpm on a loose cargo machine with a steel plate floor. There was a wood fence around the pallet to prevent it from falling off the table. The pallet was tested for 30 min with no damage to the pallet other than slight loosening. It was then tested for an additional 140 min to analyze the durability of the pallet. The cover, base, and rods remained intact. Extensive cracks were found in the welds around each cup in the base and near the forkwells. Basically the pallet was found to be very durable.

At the conclusion the pallet was damaged, but the projectiles were protected. These tests were the most severe for the pallet and provide sufficient confidence to proceed to full engineering testing of the pallet in task II.

Task II, ARDEC Engineering Testing

Lanson Industries was given the go ahead to fabricate twelve prototype pallets for full engineering testing. These prototypes were the same as the pallet which passed the ARDEC testing. These 12 pallets were then tested at Wyle Labs in Alabama in December 1988 with a packaging engineer attending (ref 2).

One pallet with M107 projectiles failed in secured cargo vibration when the table fixture cut into the pallet. One M483 pallet passed the testing. This test was not valid as the pallet was not properly blocked and braced. Aluminum bars and steel bolts were used to hold the pallet down. The proper procedure would be to strap down with tiedown straps and block/brace with 2 x 4 lumber. In addition, two lifting plugs were broken. Since sufficient quantities of lifting plugs were not available to continue secured cargo testing, loose cargo testing with partial pallets was run instead.

Pallets containing two, four, and six projectiles were tested at 300 rpm on a loose cargo machine for 30 min at 145°F and -65°F. This testing was to prove out the partial pallet capability of the FAPP. A loose cargo machine was prepared with 2 x 4 lumber walls and a steel plate floor. The pallets were packed out with projectiles and then conditioned for 24 hr at temperature.

All the pallets passed the testing with some damage to the spacers and cracks in the welds. All the latch rods were intact and no projectiles were spilled or damaged. Several lifting plugs were broken, but this is not cause for concern because the wood pallet also does this. The partial pallet testing indicated a need for better spacer material and a way to stiffen the base and reduce cracks between the forkwell and base flange. The result was the use of polyethylene instead of polypropylene for the spacer material and additional welds between the forkwell and the base flange.

Due to the failure, a new set of 10 pallets with these changes was fabricated and testing was moved to ARDEC and the Packaging Research Laboratory, Rockaway, New Jersey. These series of tests were fully successful and were conducted May to June 1989. Two pallets were packed with eight M107 each and two pallets were packed out with eight M483 each. Secured cargo tests were conducted on two pallets at 145°F and two pallets at -65°F at ARDEC. The pallets were conditioned for 24 hr before each test. In the random vibration test, the pallets are strapped down, blocked and braced onto a vibration head and then subjected to random vibration curves. These vibrations simulate the transportation conditions encounters in various trucks and tracked vehicles. The four pallets passed the vibration tests with no problems except for slight loosening.

The next portion was the drop testing. After 24 hr conditioning at temperature, all four pallets were subjected to edgewise, cornerwise, and rollover tests. At the conclusion of the drops, the damage to the pallets were minimal and all the pallets passed the test. There was crushing of the bottom spacers (which was later redesigned), slight dents of the cover and base (later strengthened), and the handles in the cover came loose. The handle came loose because the handle indents were not canted sufficiently according to specification to properly engage the cover. Proper production units would not experience this problem.

The final portions of testing, the 300 rpm loose cargo and inclined impact, were conducted at the Packaging Research Laboratory on four pallets, two at 145°F and two at -65°F. A loose cargo machine was prepared for testing with a plywood enclosure and steel plate floor. Loose cargo testing was conducted on the four pallets from the drop and secured cargo testing and six additional pallets in partial pallet testing. All the pallets passed the testing conditionally pending improvements. Problems were encountered with the pallet ends bowing down, lifting plugs breaking, spacer crushing and welds cracking.

Essentially, additional changes would be required to improve the pallet. Among the changes would be a stronger bottom spacer with more ribs to prevent crushing and prevent round movement within the base cups. A new fuller top spacer that will encompass the lifting plug, helping prevent the lifting plug from backing off. When it backs off, the lifting plug is vulnerable to breaking. The forkwell will be 4 in. wide instead of 3.5 in. wide. This will reduce the length of the cantilever, reducing the stresses that cause the bowing of the pallet ends.

The four pallets after undergoing loose cargo testing were placed on an inclined impact machine. The machine was set at the maximum speed of 7 ft/s and the four pallets were impacted on all four sides. The main damage to the pallet was slight crushing of the base short side in the end impacts. One pallet, that was bowed badly from the loose cargo test, lost two projectiles that popped out in the inclined impact test. The problems encountered in this test will not occur with the improvements to the pallet.

The complete test sequence conducted is the one shown in figure 4. In all, the testing showed that the FAPP could pass the rough handling testing at temperature and also be used in partial loads testing.

Battleking User Evaluation

During this time, two FAPP pallets were sent to Fort Sill, Oklahoma for the Battleking evaluation (ref 3). From 10 to 13 January 1989, artillery soldiers at Fort Sill compared the wood and the metal pallets in handling characteristics, compatibility with ammunition resupply vehicles, and materiel handling equipment. The artillery soldiers practiced palletizing the FAPP.

The issues to be considered were:

- Can the pallet be handled by field artillery assets without damage to the projectiles?

- Ammunition pallets must be capable of being loaded and handled by the following ammunition carrying vehicles: M548, 5-ton truck, 1 1/2-ton ammunition trailer, M977 heavy expanded mobility tactical truck (HEMTT), 4,000 lb forklift, and 6,000 lb rough terrain forklift.

- Partially full pallets containing two to seven projectiles must be capable of being loaded and handled safely.

- Can projectiles be removed from and repacked in the pallet without degrading system responsiveness?

- The pallets must be capable of being opened and reassembled without special tools.

- Unpacking and repacking projectiles must be done in cold weather clothing, MOPP gear, and seasonal uniform.

Two metal pallets were used to conduct the evaluation, one packed with inert M107 projectiles and one packed with inert M483 projectiles. The metal pallet handling characteristics were examined by having the player personnel handle them with MHE, load and transport them in ammunition resupply vehicles, and unpack and repack them.

Fully loaded metal pallets were loaded and transported in a M548 cargo carrier, HEMTT and a 5-ton truck. Partially loaded pallets were transported in the M548 and the HEMTT. The M548 hoist and HEMTT crane were used to up-load and down-load fully and partially loaded metal pallets. A 4,000 lb forklift truck and 6,000 lb rough terrain forklift truck were required to handle, up-load, and down-load metal pallets containing two to eight projectiles.

Two-man 13B player crews were required to unpack and repack projectiles in the metal pallet and wood pallet. Players wore seasonal field uniforms for one portion, cold weather mittens for another and protective masks and butyl rubber gloves for the final portion. Players were timed packing and unpacking the pallets. Ammunition supply personnel were used to repack wood pallets with metal strapping equipment.

Assessments

- Metal pallets were handled by field artillery vehicles and associated MHE without damaging inert projectiles.

- Fully loaded metal pallets were safely handled by the M548 hoist, HEMTT crane, 4,000 lb forklift truck, and 6,000 lb rough terrain forklift truck. The pallets were safely loaded and transported in the M548, HEMTT, and 5-ton truck.

- Partially loaded metal pallets were safely handled by the M548 hoist, HEMTT crane, 4,000 lb forklift truck, and 6,000 lb rough terrain forklift truck. Partially loaded pallets were safely loaded and transported in the M548 and HEMTT.

- It required slightly less time to unpack and much less time to repack projectiles in the metal pallet than in the wood pallet.

- No tools were needed to unpack and repack projectiles in the metal pallet.

- Wearing cold weather mittens or protective mask and butyl rubber gloves did not degrade the 13B players' efficiency in unpacking and repacking tasks.

Conclusion

No unsafe incidents were observed and no damage to inert projectiles occurred while handling, loading, and transporting fully and partially loaded pallets.

The FAPP was demonstrated to be a viable alternative to the wood pallet. It met all of the required evaluation criteria and was well received by the soldiers.

Task III, Tooling Design

Upon successful completion of the required Task II testing, approval to enter Task III was given to Lanson except for a modification to the contract. Task III of the contract for Lanson was revised to call for soft tooling instead of hard tooling. This was done because of the cost overruns incurred during the extensive series of pallet designs of Task I. The use of soft tooling reduced the overall contract award total from $ 560,000 to $ 373,000, a reduction of $ 187,000[2]. A satisfactory tooling design review was conducted in Sept 1989. The tooling fabrication was completed in December 1989. Lanson then began producing pallets.

Naval Weapons Station Earle Testing

In September 1989, the Navy conducted a test and evaluation of a triple pack FAPP for amphibious operations at the Naval Weapons Station (NWS) Earle (ref 4). The 155-mm FAPP was tested in order to determine if a metal pallet can function in place of a wood pallet for this amphibious unit load. Three FAPP pallets were assembled with 24 projectiles. Three 2 in. x 4 in. spacer boards were placed across

[2]This money reflects FY 89 prices.

the top of the three FAPP pallets between the lifting eyebolts. One 4 in. x 4 in. support board was placed between the skids of the FAPP base. Three 1 1/4 in. steel straps held the loads together. The gross weight of the unit load was 2400 lb.

The assembled unit load was subjected to the following tests outlined in MIL-STD-1660. All tests were conducted at an ambient temperature of 70°F +/- 20°F.

- Fit and compatibility--The unit of three FAPP pallets, 24 projectiles, and four pieces of wood were assembled and strapped without difficulty.

- Stacking testing--The unit load was placed on a level surface with a load of 10,000 lb stacked on top and left for 1 hr. No visible damage or deformation was evident.

- Repetitive shock test--The assembled unit load was placed on the vibration table and vibrated at a input frequency of 3.4 Hz. There was no visible damage or deformation.

- Edgewise drop test--One edge of the unit load was placed on a 6 in. block. The opposite edge was raised to a height of 15 in. and allowed to free fall. The edge was allowed to impact onto a unyielding concrete surface. All four edges were tested. No visible damage or deformation was evident.

- Cornerwise drop test--Two adjacent corners of the load were raised to heights of 6 and 12 in. The corner opposite the 12 in. block was raised to 18 in. and allowed to free fall onto an unyielding surface. All four corners were tested. The test was satisfactory. Each end of the skids had minor dents.

- Impact test--The unit load was placed on the carriage of the inclined/impact tester. The carriage was raised to a predetermined point on a 10 deg track that would produce 7 ft/s. The carriage was released and the load was allowed to impact the bumper at the bottom of the incline. All four sides were impacted. The results were satisfactory. There was minor loosening of the straps and minor bending on the base panels of the pallets.

- Tipover qualification test--The unit load was placed on a tilt platform and tilted to a 20 deg angle with the floor. This test was repeated on an adjacent side. The results was satisfactory. The load remained stable and did not tip over.

- Forklift truck compatibility--The unit load was raised 6 in. off the floor with an electric powered forklift truck. The forklift was driven over three sets of 1 in. thick pieces of wood, spaced 30 ft apart on a 100 ft course. The results were satisfactory. The unit load was handled with no difficulty.

• Sling compatibility--The unit load was lifted, swung, lowered, and handled with the same choker slings used on the 155-mm wood pallet unit load. The load was also pulled back 9 in. and released into a concrete wall to determine if the sling would disengage. The results were satisfactory. There was no slippage or disengagement.

• Disassembly test--The unit load strapping was cut and the load retained its unity.

• Unstacking test--One pallet load was stacked on another pallet load. The top pallet was easily removed without interference.

Conclusion

The satisfactory test results indicate that the FAPP pallet unit load is acceptable for use. The FAPP passed all of their tests and the Navy has accepted the FAPP for their use.

Instrumented FAPP Versus Wood Pallet Testing

Side-by-side FAPP versus wood pallet instrumented loose cargo and drop testing was conducted in April 1990 (ref 5). In addition, bare round loose cargo and drop testing was also conducted. This testing was performed to compare the FAPP pallet, the wood pallet and the bare round in rough handling testing.

Eight inert M107 rounds were packed in the FAPP and a wood pallet and then tested on a loose cargo machine in accordance with (IAW) MIL-STD-1660. The loose cargo machine has 1 in. double amplitude synchronous orbital motion, plywood floor, and wood floor. The tester was set at 185 rpm to cause the pallets to lift off 1/16 in. and was checked by feeler gauge. A single axis accelerometer was bolted to one projectile which read the vertical accelerations. An oscilloscope recorded the g levels on diskette.

The 8.5 in. free fall drop tests were conducted in the same manner. The 8.5 in. height was chosen because that is the height that a pallet center of gravity falls in the edgewise drop in ARDEC drawing 8837375.

The loose cargo acceleration results areas follows:

Wood pallet	average = 3.37 g's
FAPP pallet	average = 3.49 g's
Bare round (300 rpm)	average = 30 g's

The 8.5 in. drop acceleration results are as follows:

Wood pallet	average = 73 g's
FAPP pallet	average = 75 g's
Bare round	average = 4,560 g's

The results indicate little difference between the FAPP and the wood pallet in acceleration in loose cargo or drop testing. The results also indicate that the palletized rounds experience far less g forces than the bare round. These tests provide the confidence to precede to live testing at DPG.

Task IV, Lanson Pallet Delivery

Lanson Industries delivered 150 task IV pallets in July 1990. These pallets were of the latest design and were made from production-type soft tooling to prove out the manufacturing process. Fifty pallets went to DPG for the FAPP live rough handling testing, fifty was sent to USADACS for railcar testing, and the remaining fifty went to ARDEC for a physical configuration audit. As required to complete the contract, Lanson delivered the FAPP final report (ref 6) in December 1990.

Physical Configuration Audit

A physical configuration audit was conducted in July/August 1990 on eight samples from Lanson at the Product Assurance Division with assistance from Packaging, ARDEC. This was done to find the actual dimensions of the pallets produced by Lanson and compare them to the contractor drawings. It is important to know what were the dimensions of the item that passed the required qualification testing. Critical dimensions were measured in the cover, base, and other components for deviation from the contractor drawings. The majority of the dimensions were within the drawing tolerance. Only a small percentage (0.04%) of the dimensions were out of tolerance. The critical dimension that concerned Packaging was the width of the trough in the cover being too wide. This was noted and revised on the engineering change proposal (ECP) drawings so that future pallets would not have this problem. The most important criteria is the form, fit, and function which was not affected. The Lanson pallets were accepted for testing.

Dugway "Live' Rough Handling Test

As part of the qualification testing of the FAPP, U.S. Army Test and Evaluation Command (TECOM) safety confirmation was needed. However, despite numerous meetings between TECOM and PM-Ammolog/Packaging (ARDEC), a test plan for safety testing the FAPP could not be agreed on. TECOM insisted on unusual testing of the FAPP, such as multiple 7 ft drops on the FAPP and mismatch projectile testing. It was not possible nor was it required for the FAPP or wood pallet to survive multiple 7 ft drops. The intentional loose cargo testing of M107, M549, and M483 projectiles in the same pallet is contrary to ammunition manual procedures and is doomed to cause a safety problem. In the interest of meeting the ammunition production deadlines, it was decided that a "live" customer test at DPG would qualify the implementation of the FAPP (ref 7).

DPG conducted live testing of the FAPP with M483A1 projectiles in August 1990, according to the test plan in figure 5. The DPG test plan is precisely the same as the test plan for qualifying the wood pallet. This test plan was to:

- Determine the safety of the 155-mm FAPP

- Determine the ability of the FAPP to be transported and handled throughout the logistical system from the LAP to the end user in the field

- Qualify the proficiency of the FAPP in protecting the 155-mm projectiles

- Show the ability of the FAPP to be repalletized

Two FAPP were packed out with 16 M483A1 high explosive 155-mm projectiles. Two wood pallets were also packed with 16 M483A1 for comparison. All M483A1 projectiles were x-rayed and moments of inertia measured before and after testing. The test plan for the FAPP and the wood pallet was as follows:

- Secured cargo vibration--Each pallet was subjected to three axis vibration in composite wheeled vehicle and tracked vehicle spectrum IAW ITOP 1-2-601

- Loose cargo vibration--The pallets are placed on a loose cargo table and tested at 200 rpm for 30 minutes IAW MIL-STD-1660

- Rollover test--Each pallet was rolled over onto its side one complete revolution

- Edgewise drop--Each pallet was dropped once onto each skid from 12 in.; two drops total

- Cornerwise drop--Each pallet was dropped onto a corner and the diagonal opposite corner from a height of 12 in.

- Inclined impact--Two sides of the pallets were impacted at 10.5 ft/s onto a unyielding surface

Results. All rounds were x-rayed and found suitable for testing. Moments of inertia showed that the rounds have not been affected by prefiring testing. X-rays after rough handling testing showed no change in the rounds.

- Secured cargo vibration--The wood pallets fell apart after five minutes in secured cargo vibration. The FAPP showed some wear on the plastic inserts. The load remained intact.

- Loose cargo vibration--The FAPP showed some dents; the pallets remained functional and intact inside the pallets.

- Rollover--The FAPP received some dents, the projectiles were not damaged.

- Edgewise drop--The FAPP received some dents, the rounds were not damaged. No rounds were released from the pallets.

- Cornerwise drop--The FAPP received some dents; the rounds were not damaged. No rounds were released form the pallet.

- Inclined impact--The FAPP received some dents and were bent on the top; the rounds remained intact and undamaged.

- Launch safety--There were no premature functioning in-bore or within the arming limits of the fuze.

- Flight safety--There were no premature functions after fuze arming or before the end of normal flight trajectory. No metal parts separation or distortions were observed, which could have caused erratic flight. The rounds functioned normally and within two probable errors. Due to safety constraints, no count was performed with respect to the number of submunitions expelled from the M483A1 that did or did not function.

- Observation/opinions--The FAPP are far superior to the wooden pallets in protecting 155-mm rounds. The FAPP gave no indication that it would cause a safety hazard to its cargo. The FAPP are much easier to put together and can be repalletized more readily than the wooden pallets. The FAPP is far superior to the wooden pallet in all areas observed. The FAPP passed all the testing with no problems. After the rough handling tests, the M483A1 projectiles were fired successfully with accuracy within two probable errors. Two probable errors is an excellent score.

USADACS Railcar Test

The American Association of Railroads (AAR) Bureau of Explosives (BOE) required railcar impact testing prior to certification for shipping by rail. The test consists of a series of impacts of a railcar loaded with FAPP against a fixed set of railcars. This test simulates railcar humping as when railcars bump into each other to form a train.

Railcar Test Procedures. The following are the test procedures mandated by USADACS for certifying ammunition outloading procedures and to simulate operating conditions when shipping munitions by railcar (ref 8).

- The test load car is prepared by using the same blocking and bracing procedures specified in the outloading diagrams.

- Equipment needed to perform the test includes the specimen (hammer) car, five empty railroad cars connected together to serve as an anvil, and a railcar locomotive. These anvil cars are positioned on a level surface with air and hand brakes set. The locomotive pushes the specimen car towards the anvil at a predetermined speed, then releases the hammer car to roll freely along the track until it strikes the anvil. This is an impact and is accomplished at 4, 6, and 8 mph in one direction and 8 mph in the opposite direction.

First Railcar Test Results. In July 1990, 50 FAPP pallets were delivered to Savanna Army Depot for the first railcar test. On 2 Aug 90, one row of 40 FAPP was loaded with inert M107 projectiles and placed side-by-side down the length of the railcar. The FAPP was initially impacted at 4 mph with some minor deformation of the pallet cover and base. The damage was small and the test was continued. The FAPP was then impacted at 6 mph and the test sequence was then stopped. There was extensive permanent deformation of the pallet covers and bases. The covers buckled in the corners and the bases bowed at the ends. It was felt at the time that the mode of failure was crushing due to excessive columnar loading. This position would be modified upon subsequent analysis.

First Railcar Test Analysis. It was clear that a stronger base and cover were needed. The only data available was the estimated peak acceleration of 4 g's for 8 mph impacts from other tests. From the limited information available, it was calculated that the peak force on the base was 18,800 lb. The peak force on the cover was calculated to be 54,000 lb. These calculations assumed all 40 pallets impact each other at the same time. If the pallets do not impact each other at the same time, the forces are greatly reduced.

Redesign, Modification, and Testing of the FAPP. Several new designs with increased column strength were manufactured for testing. The strongest design was the pallet with a 1 in. flange added to the base and cover. The pallets were tested in a compression testing machine. The new pallet base showed a four fold increase in column strength of 21,000 lb versus 4,400 lb of force for the original design. The pallet cover showed a threefold increase in strength to 33,000 lb versus 11,000 lb of force for the original. Pendulum impact testing was conducted to provide a visual verification of the pallet improvements. The new design required three impacts to produce the same damage as one impact on the original pallet. There was sufficient confidence in the strength increases to proceed to railcar testing.

Second Railcar Test Results. Twelve modified pallets were manufactured at ARDEC and sent to USADACS. The railcar was loaded with one row of 28 unmodified pallets and 12 modified pallets in critical locations. Instrumentation was requested for the second railcar test. Two accelerometers were placed on the first and last pallets.

On 4 Oct 90, the FAPP was tested at 4 mph with no deformation resulting. The test was repeated at 6 mph with only slight deformation of the ends of the base. There was no damage to any of the covers. At 8 mph, there was extensive damage to the bases. A decision was made to further evaluate the pallet covers, the railcar was reversed and impacted at 8 mph again. The base damage noted was worsened. The covers performed satisfactorily. The accelerometers showed 4.5 g's on the 8 mph impact.

Second Railcar Test Analysis. One failed pallet base was brought back to Picatinny. Examination of the base indicated the mode of failure appeared to be bending and crushing of the impact face and not columnar buckling as originally thought. The base passed the 6 mph 3 g peak impact force but failed the 8 mph 4.5 g impact force. It was felt that by increasing the bending and crushing strength by greater than 50%, the 8 mph 4.5 g impact criteria would be met. In addition, the blocking and bracing did not adequately transfer or spread the forces evenly to the ends of the pallet as needed. Improved blocking and bracing with the use of load spreaders would be used in the next railcar test.

Second Redesign, Modification, and Testing of the FAPP. Several new designs were developed that were stronger in bending and column strength than the pallets used in the second test. It was decided that the most economical way to achieve the increased strength required would be to change the material from 14 gauge steel to 12 gauge steel.

Upon completion of these modifications, the bases and covers were again subjected to a static column crushing test and static bending test. The new base showed a 500% increase in bending strength (18,500 lb versus 3,600 lb) and 60% increase in column strength (35,600 lb versus 21,000 lb) over the bases subjected to the second railcar test. Side-by-side pendulum impact testing of second railcar test design versus the third design pallet was conducted at the drop tower. A total of five 8 mph impacts were conducted on the third design pallet with no damage.

Third Railcar Test Results. The third and final railcar test was conducted 10 Jan 91 at USADACS (ref 9). The railcar was packed with three rows of pallets of 40 each instead of one row. This was calculated to reduce the acceleration from 4.5 g's to 3.9 g's. Eight 12 gauge pallets were placed in critical locations and the rest were wood pallets as ballast. Three accelerometers and six load cells were used to measure the exact forces. The new blocking and bracing procedure featured load-spreading separator gates.

The FAPP was impacted at 4 mph, 6 mph, and 8 mph with no damage. The railcar was reversed and again impacted at 8 mph. Very minor denting of the cover resulted, but was not cause for failure. Overall, the pallet did very well and passed the test in excellent condition.

Third Railcar Test Analysis

Extensive analysis of the instrumentation was conducted at ARDEC. The measured acceleration was 4 g's, a reduction of from 4.6 g's of the second test which was due to the full car loading. The load cell data shows 6,000 lbs on each base. The second railcar base was compression tested to only 3,600 lbs in bending. The third design was compression tested to 18,000 lbs in bending. Therefore the third base should pass the test. The load cell data showed 42,000 lbs on the cover. The cover was compression tested at 50,000 lbs so it should pass the railcar test.

The load cell data also showed that the pallets do not impact each other at the same time. This will reduce the impact load on the pallets.

Conclusion. After extensive testing and analysis, the FAPP has successfully passed the USADACS railcar test and is ready for implementation.

Instrumented M864 FAPP Testing

At FSAC request, additional instrumented FAPP versus wood loose cargo tests were conducted on 18 Mar 91 on inert M864 projectiles (ref 10). These tests showed the same results as previous tests on M107 rounds, there was little difference between the FAPP pallet and the wood pallet in g levels in loose cargo.

Yuma "Live" M864 Rough Handling Testing

In order to receive FSAC approval of the FAPP, additional testing was conducted with live M864 projectiles at YPG in July 91. This testing consisted of two phases, a sequential rough handling portion and a 300 rpm loose cargo portion.

Three FAPP pallets and one wood pallet were packed out with 32 live M864 projectiles. One wood pallet and one FAPP pallet were tested at ambient on a 300 rpm loose cargo machine for 20 min. The loose cargo machine had a steel plate floor and wood fences that allow 1 in. clearance in each direction. FSAC required the 20 minutes of 300 rpm loose cargo although there is no such requirement for palletized projectiles. At the conclusion of this test, the FAPP was in excellent condition with only loosening of the pallet due to spacer wear. The wood pallet passed the test also, but with damage to the base cups and loosening of the pallet.

The sequential rough handling test was the same one used in the DPG test. One FAPP was tested at -65°F and the other at 145°F. Three axis secured cargo vibrations were conducted on the two pallets in the composite wheeled vehicle spectrum, tracked wheeled vehicle and two wheeled trailer. At the conclusion of secured cargo vibration, the two FAPP were in excellent condition.

The next part of the YPG test was the loose cargo IAW MIL-STD-1660, which is the requirement for palletized munitions. The FAPP was placed in the same loose cargo machine used in the previous loose cargo test except that the table speed was set at 200 rpm and the duration was 2 hr. Both the hot and cold pallets were tested in this manner with only slight loosening of the pallets. Otherwise the pallets were in excellent condition.

The next test was the drop and pendulum impact test. In the edgewise drop, each pallet was dropped from 12 in. onto each skid; a total of two drops per pallet. In the cornerwise drop, each pallet is dropped from 12 in. onto one corner and the diagonally opposite corner; a total of two drops per pallet. In the rollover, each pallet is pushed over onto its long side again and again until one 360 deg revolution was made. In the pendulum impact, each pallet is impacted on one short side and one long side at 10.5 ft/s against an unyielding surface. At the conclusion of this series of tests, the two FAPP pallets were in excellent condition with only minor scratches.

The final testing was the live firing of the M864 projectiles at conditioning temperature at maximum firing pressure and range. As of this writing, fifteen rounds were fired with no problems except for an unrelated partial cargo expulsion in one projectile. This problem was not attributed to the FAPP. All other rounds functioned perfectly. A test report describing the successful live M864 testing of the FAPP is due in November.

Instrumented 7 ft Drop Testing

There was concern at TECOM that the introduction of the FAPP might have a detrimental impact on the round palletized therein; particularly with respect to the accidental 7 ft pallet drops. TECOM therefore, initially requested that the 7 ft drops be run with live M864 projectiles. The high cost of conducting this test in relation to the available program funds required that an alternative strategy be pursued. The type classification of 155-mm projectiles requires a 7 ft drop of bare rounds in five orientations. It was felt that as long as the shock response on the palletized projectile is less than that on the bare round, then no damage to the projectile would result.

Instrumented 7 ft Drop Data. To quantify these test results, a series of instrumented 7 ft drop tests were conducted (ref 11). The bare rounds and FAPP pallets weie dropped on a steel plate backed by concrete. The data is as follows:

Drop 1--bare round flat	5,000 g's
Drop 2--bare round 45 deg	3,000 g's
Drop 3--FAPP pallet flat	300 g's
Drop 4--FAPP pallet 45 deg	650 g's

This data clearly shows that the acceleration forces experienced by the palletized configuration is an order of magnitude less than in the bare round drops. The conclusion to be drawn from this data is that the 155-mm projectile could not possibly be damaged by the FAPP pallet when dropped from 7 ft.

M549 Incompatibility Comparison

There was concern at TECOM that the introduction of the FAPP might cause additional safety hazards associated with soldiers mistakenly placing a M549 projectile in a M483 family FAPP pallet. A photo demonstration was conducted to show that the M549 was obviously shorter than a M483, that the M549 is obviously loose inside the M483 pallet, and that the M549 would fall out of the FAPP in this configuration.

The conclusion to be drawn from the photos is that the M549 is very obviously shorter than a M483 and this could be easily seen. Ammunition manuals will properly define which projectiles are qualified to be used with the two FAPP designs (ref 12).

FAPP ECP Submittal to Rock Island

The ECP for the M804 and M864 were completed in February 1991 (ref 13). The M804 was concurred by ARDEC. The M864 was nonconcurred by FSAC pending live testing of the M864 on the FAPP. Both ECP were submitted to Rock Island (RI). The RI level I Configuration Control Board (CCB) meeting was held on 18 Apr 91. The board disapproved the ECP until a unified user position supporting the program is received and live M864 on the FAPP testing is complete. A second RI level II CCB meeting is scheduled for October. The M804 and M864 ECP will be updated and resubmitted at the end of September.

CONCLUSION

The field artillery projectile pallet has successfully passed all of the U.S. Army Armament Research, Engineering and Development Center's engineering tests, Battleking user evaluation at Ft. Sill, "live" rough handling test at Dugway and Yuma Proving Ground, and the U.S. Army Defense Ammunition Center and School railcar testing and is ready for implementation. The actual implementation is dependent on the availability of sufficient funds for the purchase of pallets.

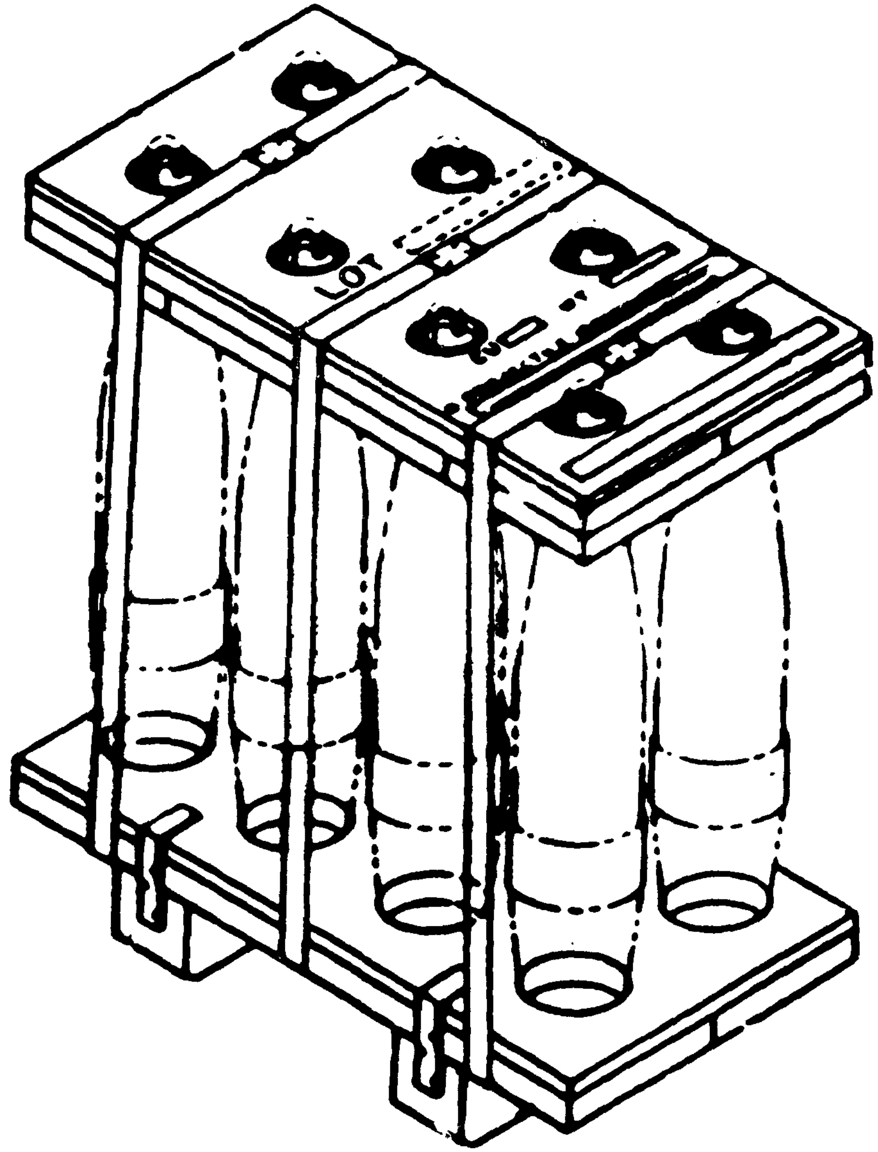

Figure 1. Current wood pallet

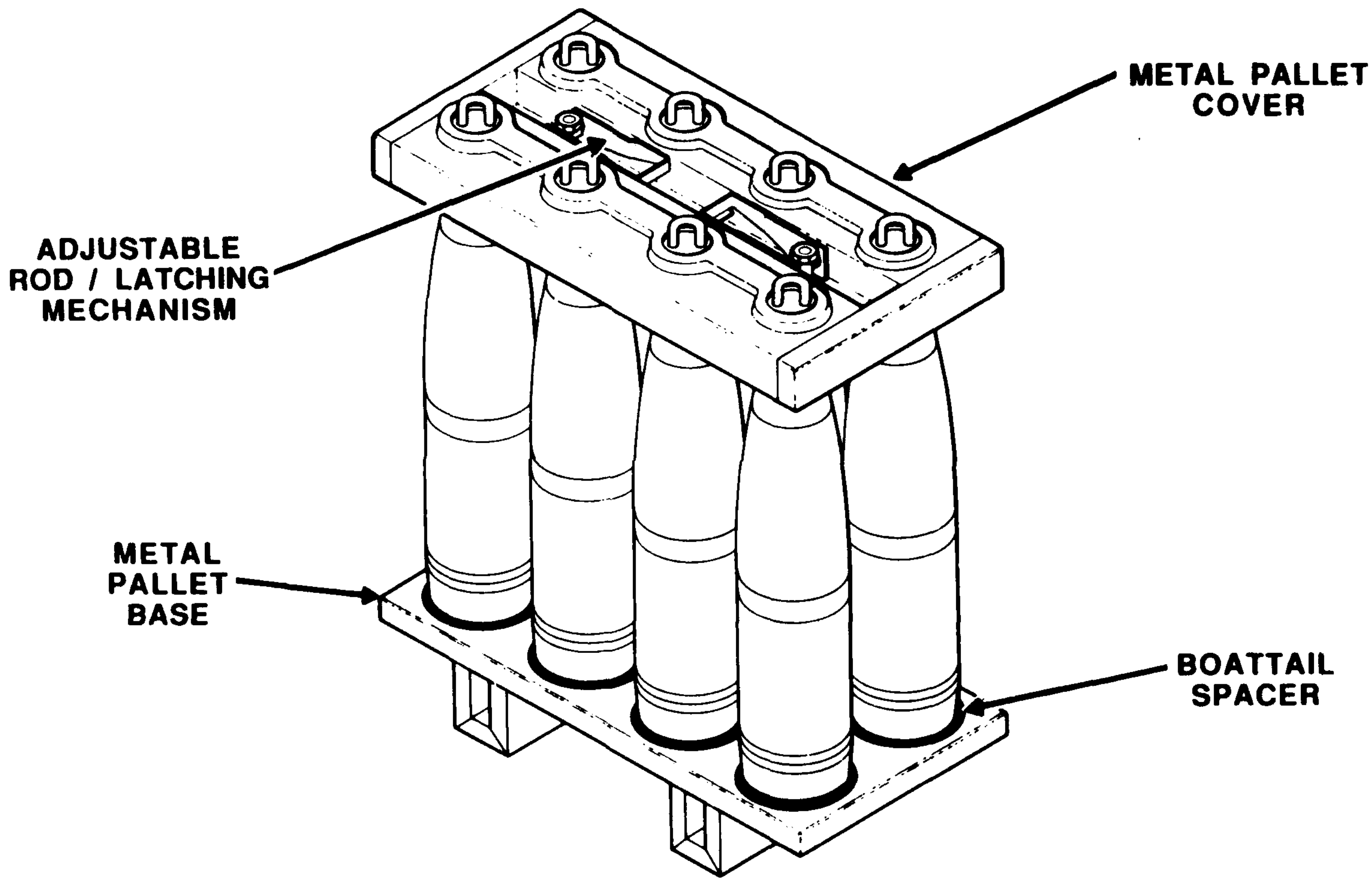

Figure 2. 155-mm projectile pallet product improvement program

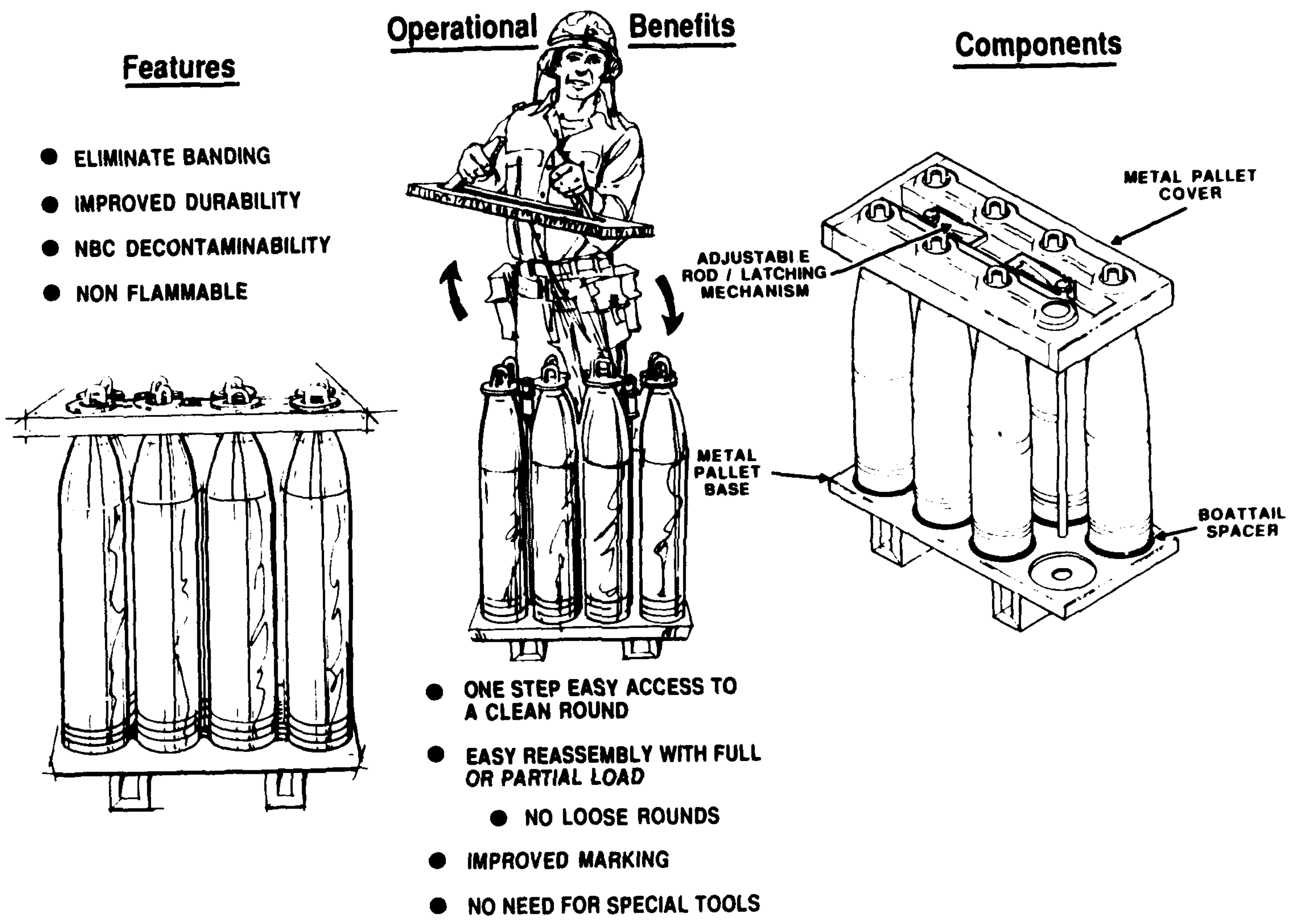

Figure 3. 155-mm projectile packaging improvement program

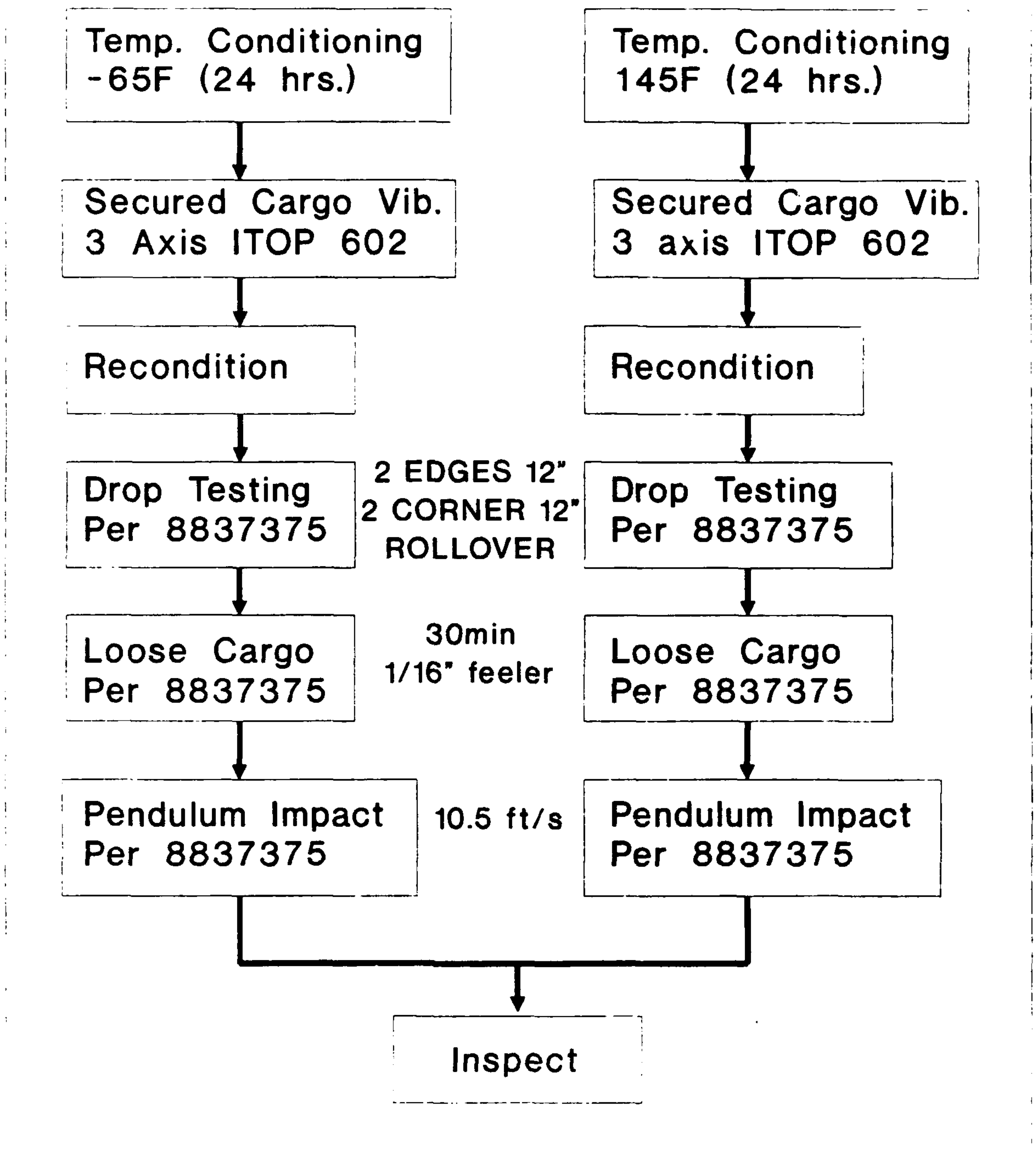

Figure 4. ARDEC 155-mm pallet qualification test plan

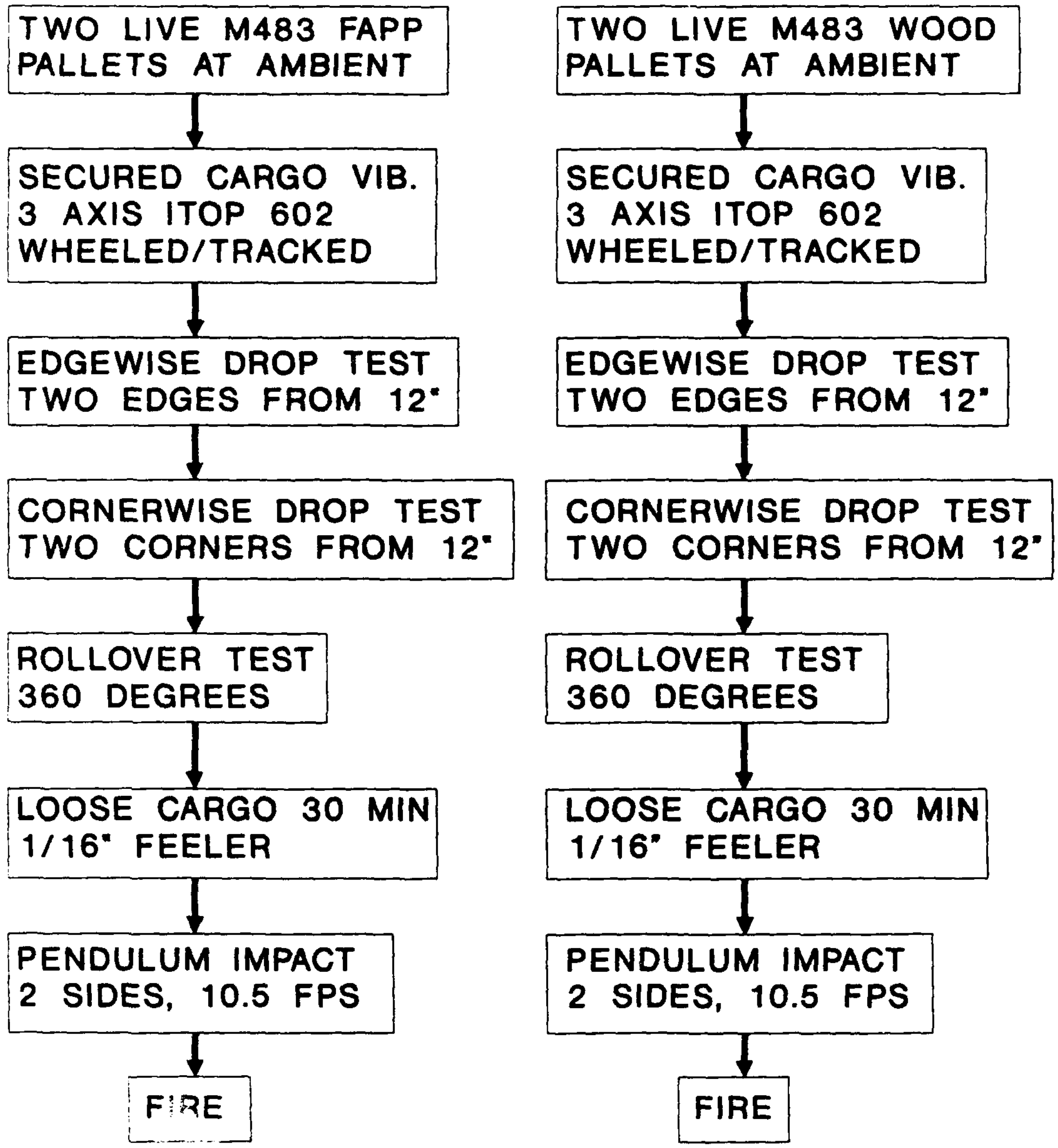

Figure 5. Field artillery projectile pallet (FAPP) Dugway Proving Ground test

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