ENGINEERING EVALUATION TESTS
OF
16 GAUGE VS 14 GAUGE STAPLES IAW MIL-STD-1660,
40MM CARTRIDGE ON WOODEN PALLET

Prepared for: Distribution Unlimited
ARDEC
Logistics Research and Engineering Directorate
AMSRD-AAR-AIL-TP(R)
Rock Island, IL 61299-7300

DEFENSE AMMUNITION CENTER
VALIDATION ENGINEERING DIVISION
MCALESTER, OKLAHOMA 74501-9053

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ENGINEERING EVALUATION TESTS
OF 16 GAUGE VS 14 GAUGE STAPLES IAW MIL-STD-1660,
40MM CARTRIDGE ON WOODEN PALLET

ABSTRACT

The U.S. Army Defense Ammunition Center (DAC), Validation Engineering Division (SJMAC-DEV) was tasked by Armament Research, Development and Engineering Center (ARDEC/AMSRD-AAR-AIL-TP[R]) to conduct Engineering Evaluation Tests IAW MIL-STD-1660, “Design Criteria for Ammunition Unit Loads” on the use of 16 gauge staples vs 14 gauge staples. The unit load tested simulated 40MM cartridges, packed 32 per PA120 metal container, and unitized 48 containers per 40” x 48” pallet. Three test units were tested with a load of 2,910 lbs, 2,915 lbs, and 2,915 lbs. The testing accomplished on the test units was the Stacking, Repetitive Shock, Edgewise-Rotational Drop, Incline-Impact, Forklifting, and Disassembly Tests. Test Units #1 and #2 were unitized using 16 gauge staples holding the wooden gates in place, while Test Unit #3 was unitized using the existing requirement of 14 gauge staples holding the gates in place.

Test Unit #1 was tested using the proposed 16 gauge staple in accordance with MIL-STD-1660 at ambient temperature. No damage was noted during the Stacking, Repetitive Shock, Edgewise-Rotational Drop, Forklifting, and Disassembly Testing. During all of the Incline-Impact tests, the optional timber was employed which extended approximately 9 inches above the carriage. It was noted that two (2) staples on opposite sides of the test unit partially disengaged. The test unit remained intact and all testing was completed with no further damage noted. Test Unit #2, utilizing the proposed 16 gauge staples, was tested similarly to Test Unit #1. No damage was noted during the Stacking, Repetitive Shock, Edgewise-Rotational Drop, Forklifting, and Disassembly Testing. However, during the Incline-Impact testing, one (1) leg each of four (4) staples (the two bottom staples on each side) partially pulled out of the gates. Test Unit #2 remained intact and all testing was completed with no further
damage noted. Test Unit #3 was tested using the existing requirement of 14 gauge staples. MIL-STD-1660 testing was completed with one (1) staple each on opposite sides being disengaged. Test Unit #3 was tested using the proposed 16 gauge staples as used for Test Unit #1. No damage was noted during the Stacking, Repetitive Shock, Edgewise-Rotational Drop, Forklifting, and Disassembly Testing. Incline-Impact testing resulted in the partial pull-out of one (1) staple on one side and the complete loss of one (1) staple on the opposite corner of the pallet unit.

The result of the staples being disengaged did not differ significantly between the use of the 14 gauge or 16 gauge staples. The use of 16 gauge staples on the 40MM cartridges packed 32 per PA120 metal container and unitized 48 containers per 40” x 48” pallet, as simulated for testing, meets the requirements of MIL-STD-1660 and can be utilized by the United States Army.

Prepared by: Reviewed by:

Walter Gordon
General Engineer

Phil Barickman
Chief (Acting), Validation Engineering Division
# Engineering Evaluation Tests for 16 Gauge vs 14 Gauge Staples IAW MIL-STD-1660, 40mm Cartridge on Wooden Pallet

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PART 1 – INTRODUCTION

A. BACKGROUND. The U.S. Army Defense Ammunition Center (DAC), Validation Engineering Division (SJMAC-DEV) conducted Engineering Evaluation Tests IAW MIL-STD-1660, “Design Criteria for Ammunition Unit Loads” on the use of 16 gauge staples vs 14 gauge staples. The unit load tested simulated 40MM cartridges, packed 32 per PA120 metal container, and unitized 48 containers per 40” x 48” pallet. Three test units were evaluated with a load of 2,910 lbs, 2,915 lbs, and 2,915 lbs. The Stacking, Repetitive Shock, Edgewise-Rotational Drop, Incline-Impact, Forklifting, and Disassembly Tests were conducted on the test units. Test Units #1 and #2 were unitized using 16 gauge staples holding the wooden gates in place, while Test Unit #3 was unitized using the existing requirement of 14 gauge staples holding the gates in place. The unitization procedures were provided by DAC, Transportation Engineering Division (SJMAC-DET).

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:


C. OBJECTIVE. The objective of the tests was to determine if the 16 gauge staples could be utilized in lieu of the required 14 gauge staples on the 40 MM cartridge packed 32 per PA120 metal container, and unitized 48 containers per 40” x 48” pallet, by meeting MIL-STD-1660 test requirements prior to the acceptance of the unitization procedures by the U.S. Army.
D. **CONCLUSION.** The result of the staples being disengaged did not differ significantly between the use of the 14 gauge or 16 gauge staples. The use of 16 gauge staples on the 40 MM cartridge packed 32 per PA120 metal container, and unitized 48 containers per 40” x 48” pallet, as simulated for testing, meets the requirements of MIL-STD-1660 and can be utilized by the United States Army.
PART 2 - ATTENDEES

DATE PERFORMED:
Test Unit #1- June 19 and 25, 2008
Test Unit #2- June 25-26, 2008
Test Unit #3- June 27, 2008

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PART 3 - TEST PROCEDURES

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

1. STACKING TEST. The test unit 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 unit will be placed on (not fastened to) the platform. With the test unit 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.
(MSTF Low)

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 test unit 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:
<table>
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<th>GROSS WEIGHT (WITHIN RANGE LIMITS) (Pounds)</th>
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<th>HEIGHT OF DROPS ON EDGES (Inches)</th>
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</tr>
<tr>
<td>1,000-1,500</td>
<td>95-114</td>
<td>20</td>
</tr>
<tr>
<td>1,500-2,000</td>
<td>114-144</td>
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</tr>
<tr>
<td>2,000-3,000</td>
<td>Above 145- No limited</td>
<td>15</td>
</tr>
<tr>
<td>Above – 3,000</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Figure 1.

Photo 3. Example of Edgewise Rotational Drop Test (MSTF Low)

4. **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 test unit 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.)](image)

5. **SLING COMPATIBILITY TEST.** The test unit 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.

6. **FORKLIFTING TESTS.** The test unit will be lifted clear of the ground by a
forklift from the end of the test unit 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 test unit will be transported
over the Optional Rough Handling Course. The test unit shall be observed for
deflection and damage. The test unit will be rotated 90 degrees and the test unit
lifted from the side and the above steps repeated.

7. **DISASSEMBLY TEST.** Following all rough handling tests the test unit
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 test unit 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 (REPETITIVE SHOCK)

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. TEST UNIT DATA. The test unit was inertly loaded to the specified design weight using inert materials. The test unit was prepared using the unitization procedures specified in Part 6 – Drawings. Special care was taken to ensure that each PA120 metal container had the proper amount of weight in order to achieve a realistic pallet unit center of gravity (CG). Once properly prepared, Test Units #1, #2, and #3 were tested using MIL-STD-1660 requirements. Photo 5 shows a typical test unit. Photo 6 shows the 16 gauge staple versus the 14 gauge staple.

TEST UNIT #1:
Test Date: 19, 25 June 2008
Weight: 2,910 pounds
Length: 51 inches
Width: 40 inches
Height: 36 1/8 inches
Pallet inertly loaded with:
48 PA120 metal containers loaded to 58 pounds each with inert material,
16 gauge staples in gates

TEST UNIT #2:
Test Date: 25-26 June 2008
Weight: 2,915 pounds
Length: 51 inches
Width: 40 inches
Height: 36 1/8 inches
Pallet inertly loaded with:
48 PA120 metal containers loaded to 58 pounds each with inert material,
16 gauge staples in gates

TEST UNIT #3:
Test Date: 27 June 2008
Weight: 2,915 pounds
Length: 51 inches
Width: 40 inches
Height: 36 1/8 inches
Pallet inertly loaded with:
48 PA120 metal containers loaded to 58 pounds each with inert material,
14 gauge staples in gates
A. MIL-STD-1660 TEST RESULTS - TEST UNIT #1:

1. STACKING TEST. The test unit was compressed with a load force of 11,640 pounds for 60 minutes on 19 June 2008. No damage was noted as a result of this test. See Photo 7 for the test unit in the compression tester.
2. **REPETITIVE SHOCK TEST.** The test unit was vibrated 90 minutes at 194 RPM in the longitudinal orientation and 90 minutes at 205 RPM in the lateral orientation on 19 June 2008. No damage was noted as a result of this test. Photo 8 shows the test unit on the vibration platform.
3. **EDGEWISE-ROTATIONAL DROP TEST.** The test unit was edgewise-rotationally dropped from a height of 15 inches on both longitudinal sides and both lateral sides. No significant damage was noted as a result of this test. Photo 9 shows the test unit during the Edgewise-Rotational Drop Test.

![Photo 9. Edgewise Drop Test on Test Unit #1.](image)

4. **INCLINE-IMPACT TEST.** The test unit was impact tested on both longitudinal sides and both lateral sides. During the Incline-Impact Tests, the optional timber was employed which extended approximately 9 inches above the carriage. It was noted that two (2) staples on opposite sides of the test unit partially disengaged. The test unit remained intact and all testing was completed with no further damage noted. See Photo 10 for the test unit during the lateral Incline-Impact Test and Photo 11 for one of the partially disengaged staples.
5. **SLING COMPATIBILITY TEST.** N/A.

6. **FORKLIFTING TEST.** On 25 June, 2008 Test Unit #1 was lifted from the end of the pallet on the forks of the forklift truck and carried over the Hazard Course three times with no damage or instability noted. The test unit was lifted
from the adjacent side of the pallet and the above steps accomplished with no problems encountered. See Photo 12 for the test setup during the Forklifting Test.

Photo 12. Forklift Testing of Test Unit #1.

7. **DISASSEMBLY TEST.** Inspection revealed no damage.

8. **CONCLUSION.** No additional problems were encountered during the completion of the required testing. Test Unit #1 passed the requirements of the MIL-STD-1660.

B. **MIL-STD-1660 TEST RESULTS TEST UNIT#2:**

1. **STACKING TEST.** The test unit was compressed with a load force of 11,640 pounds for 60 minutes on 25 June 2008. No damage was noted as a result of this test.
2. **REPETITIVE SHOCK TEST.** The test unit was vibrated 90 minutes at 211 RPM in the longitudinal orientation and 90 minutes at 212 RPM in the lateral orientation on 26 June 2008. No damage was noted as a result of this test.

3. **EDGewise-ROTATIONAL DROP TEST.** The test unit was edgewise-rotationally dropped from a height of 15 inches on both longitudinal sides and both lateral sides. No significant damage was noted as a result of this test.

4. **INCLINE-IMPACT TEST.** The test unit was impact tested on both longitudinal sides and both lateral sides. During the Incline-Impact Tests, the optional timber was employed which extended approximately 9 inches above the carriage. It was noted that one (1) leg each of four (4) staples (the two bottom staples on each side) partially pulled out of the gates. The test unit remained intact and all testing was completed with no further damage noted. See Photo 13 for a typical disengaged staple.

![Photo 13. Disengaged Staple During Incline-Impact Testing on Test Unit #2.](image)

5. **SLING COMPATIBILITY TEST.** N/A.
6. **FORKLIFTING TEST.** On 26 June, 2008 Test Unit #2 was lifted from the end of the pallet on the forks of the forklift truck and carried over the Hazard Course three times with no damage or instability noted. The test unit was lifted from the adjacent side of the pallet and the above steps accomplished with no problems encountered.

7. **DISASSEMBLY TEST.** Inspection revealed no damage.

8. **CONCLUSION.** No additional problems were encountered during the completion of the required testing. Test Unit #2 passed the requirements of the MIL-STD-1660.

C **MIL-STD-1660 TEST RESULTS TEST UNIT#3.**

1. **STACKING TEST.** The test unit was compressed with a load force of 11,640 pounds for 60 minutes on 27 June 2008. No damage was noted as a result of this test.

2. **REPETITIVE SHOCK TEST.** The test unit was vibrated 90 minutes at 203 RPM in the longitudinal orientation and 90 minutes at 207 RPM in the lateral orientation on 27 June 2008. No damage was noted as a result of this test.

3. **EDGEWISE-ROTATIONAL DROP TEST.** The test unit was edgewise-rotationally dropped from a height of 15 inches on both longitudinal sides and both lateral sides. No significant damage was noted as a result of this test.

4. **INCLINE-IMPACT TEST.** The test unit was impact tested on both longitudinal sides and both lateral sides. During the Incline-Impact Tests, the optional timber was employed which extended approximately 9 inches above the carriage. The testing resulted in the partial pull-out of one (1) staple on one side
and the complete loss of one (1) staple on the opposite corner of the pallet unit. The test unit remained intact and all testing was completed with no further damage noted. See Photo 14 for the disengaged staple.

5. **SLING COMPATIBILITY TEST.** N/A.

6. **FORKLIFTING TEST.** On 27 June, 2008 Test Unit #3 was lifted from the end of the pallet on the forks of the forklift truck and carried over the Hazard Course three times with no damage or instability noted. The test unit was lifted from the adjacent side of the pallet and the above steps accomplished with no problems encountered.

7. **DISASSEMBLY TEST.** Inspection revealed no damage.

8. **CONCLUSION.** No additional problems were encountered during the completion of the required testing. Test Unit #3 passed the requirements of the MIL-STD-1660.
Test Units #1, #2, and #3 had similar results during testing. The result of the staples being disengaged did not differ significantly between the use of the 14 gauge or 16 gauge staples. The use of 16 gauge staples on the 40MM cartridge packed 32 per PA120 metal container, and unitized 48 containers per 40" x 48" pallet, as simulated for testing, meets the requirements of MIL-STD-1660 and can be utilized by the United States Army.
PART 6—DRAWINGS

The following test sketches represent the load configuration that was subjected to the test criteria.

Note: A weight of approximately 58 lbs per container was used instead of the 45 lbs depicted in the drawing.
APPENDIX 26S

UNITIZATION PROCEDURES FOR BOXED AMMUNITION AND COMPONENTS ON 4-WAY ENTRY PALLETS

CARTRIDGE, 40MM, PACKED 32 PER PA120 METAL CONTAINER, UNITIZED 48 CONTAINERS PER 40" X 48" PALLET; APPROX BOX SIZE 18-3/4" L X 6-3/8" W X 10-3/8" H

NOTICE: THIS APPENDIX CANNOT STAND ALONE BUT MUST BE USED IN CONJUNCTION WITH THE BASIC UNITIZATION PROCEDURES DRAWING 19-48-4116-20PA1002.

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PATRICK DOUGHERTY

REVISION NO. 3

DECEMBER 2004

SEE THE REVISION LISTING ON PAGE 2

CLASS DIVISION DRAWING FILE

19 48 4116/26S 20PA1002

PROJECT FSA146/26S-75
**PALLET UNIT DATA**

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*HAZARD CLASSIFICATION DATA CONTAINED IN THE ABOVE CHART IS FOR GUIDANCE AND INFORMATIONAL PURPOSES ONLY. VERIFICATION OF THE SPECIFIED DATA SHOULD BE MADE BY CONSULTING THE MOST RECENT JOINT HAZARD CLASSIFICATION SYSTEM LISTING OR OTHER APPROVED LISTING(S).*

**REVISION**

REVISION NO. 1, DATED AUGUST 1995, CONSISTS OF:

1. CHANGING DIMENSIONS ON END AND SPACER ASSEMBLIES.

REVISION NO. 2, DATED DECEMBER 1999, CONSISTS OF:

ADDING A NATIONAL STOCK NUMBER AND ASSOCIATED DATA TO PALLET UNIT DATA BLOCK ON PAGE 2.

REVISION NO. 3, DATED DECEMBER 2004, CONSISTS OF:

ADDING A NATIONAL STOCK NUMBER AND ASSOCIATED DATA TO PALLET UNIT DATA BLOCK ON PAGE 2.
END ASSEMBLY (2 REQD). SEE PAGE 3. SEE GENERAL NOTES "J" AND "K" AT RIGHT.

SPACER ASSEMBLY (1 REQD). SEE THE SPACER ASSEMBLY DETAIL ON PAGE 4. SEE GENERAL NOTES "J" AND "K" AT RIGHT.

SPACER ASSEMBLY (1 REQD). SEE THE SPACER ASSEMBLY DETAIL ON PAGE 4. SEE GENERAL NOTES "J" AND "K" AT RIGHT.

LOADING CARTON - 58.25 LBS each to make a total pallet weight of 2928#
VERTICAL PIECE, 1" X 6" X 29-5/8" (4 REQD). NAIL TO THE HORIZONTAL PIECES W/3-6d NAILS AT EACH JOINT AND CLINCH.

HORIZONTAL PIECE, 3/4" PLYWOOD X 2" X 49-3/4" (3 REQD).

END ASSEMBLY
(2 REQD)
SEE GENERAL NOTES "J" AND "K" ON PAGE 3.

VERTICAL PIECE, 1" X 4" X 29-5/8" (4 REQD).

HORIZONTAL PIECE, 3/4" PLYWOOD X 2" X 49-3/4" (6 REQD). NAIL THROUGH ONE SIDE ONLY, INTO HORIZONTAL PIECE THROUGH VERTICAL PIECE THROUGH SECOND HORIZONTAL PIECE W/3-10d NAILS AT EACH JOINT AND CLINCH.

SPACER ASSEMBLY
(1 REQD)
SEE GENERAL NOTES "J" AND "K" ON PAGE 3.