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EVALUATION OF A STEEL CARTRIDGE CASE

FOR USE WITH

76MM/62 CALIBER AMMUNITION

By

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October 1975

## FOREWORD

This project was a continuation of work performed for the Technical Evaluation (TECHEVAL) of 76mm/62 Caliber ammunition. It was funded under NAVORD ORDTASK 55/065/090/4 Amendment A of 27 July 1973. This report was reviewed by Messrs J. A. Nunziato and R. Shank of the Technical Evaluation Department.

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## ABSTRACT

A series of tests were performed to evaluate the suitability of a steel cartridge case as a replacement to the brass cartridge case used in the 76mm/62 Caliber family of ammunition. The scope of the test program conducted was limited to cartridge case integrity at service and proof conditions, and compatibility with the 76mm MARK 75 gun mount. Tests performed included cartridge case integrity and compatibility tests in the MARK 75 gun mount, and structural overtests (proof firings) in a single fire mount. One cartridge case out of 205 cases tested was found to have failed structurally upon firing. After examination of the cartridge case by the Naval Ordnance Station/Indian Head, Maryland, it was determined that the cause of the failure was the presence of a manufacturing defect in the case wall. As a result of the test program and analysis conducted, it is concluded that the steel cartridge case is a suitable replacement for the 76mm brass cartridge with respect to structural integrity and compatibility with the MARK 75 gun mount.

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# INTRODUCTION

The U.S. Navy secured manufacturing rights to the 76mm/62 Caliber OTO Melara automatic mount as a result of its favorable showing in a survey of the European ordnance field. Original prototype mounts purchased were subjected to a technical evaluation at the Naval Surface Weapons Center/Dahlgren Laboratory (references 1 and 2). Both versions of the 76mm mount evaluated, designated the MARK 75 MODs 0 and 1, essentially met baseline requirements established beforehand.

Fuzes used on Italian-manufactured ammunition were considered unsuitable for U.S. use; consequently, a program was required to manufacture suitable ammunition in the U.S.. Because of time constraints, it was decided to copy the basic Italian cartridge design. A 76mm ammunition program was implemented to provide (a) design documentation of Italian ammunition to allow U. S. manufacture, (b) an engineering evaluation of U.S. manufactured ammunition to ensure comparibility with Italian ammunition, and (c) a technical evaluation of the U.S.-manufactured ammunition to determine overall performance, safety, reliability and producibility. Several changes to the original Italian ammunition design were made before these evaluations took place. Among them were minor changes to enhance producibility, use of new types (and shapes) of fuzes, the development of smoke-puff round, and the evaluation of a steel cartridge case as a substitute for the brass cartridge case used by the Italians.

Several tests were performed with the steel cartridge case during the 76mm Engineering Evaluation (reference 6), however, a malfunction in the mount/ammunition system in which a steel cartridge case was used forced postponement of the steel case evaluation. Reference 7 suggested that use of the steel cartridge case did not contribute to the malfunction. The remaining steel cartridge case tests were rescheduled. This report documents the subsequent tests.

## ITEM DESCRIPTION

Figure 1 shows a drawing of the 76mm steel cartridge case (NAVORD Dwg. No. 3028547). It is manufactured from steel conforming to MIL-S-3289. Each cartridge case was loaded with a MARK 161 percussion primer and with a propelling charge of M6/2 propellant from lot RAD-E33. Probing rounds were fired during the tests to determine approximate charge weights necessary to achieve specific test conditions of service and nominal proof pressures at various temperatures. Complete cartridge loading was completed in accordance with procedures established during the brass-cased ammunition program, i.e., a 1-inch thick polyethylene wad was glued on top of the propellant bed (3M Company 1099 adhesive used as a weather seal), a triangular cardboard spacer was installed, 30 grams of lead foil was placed in the cavity to act as a decoppering agent upon firing, and an inert 76mm BL&P projectile was loaded and crimped (125 tons crimping force).

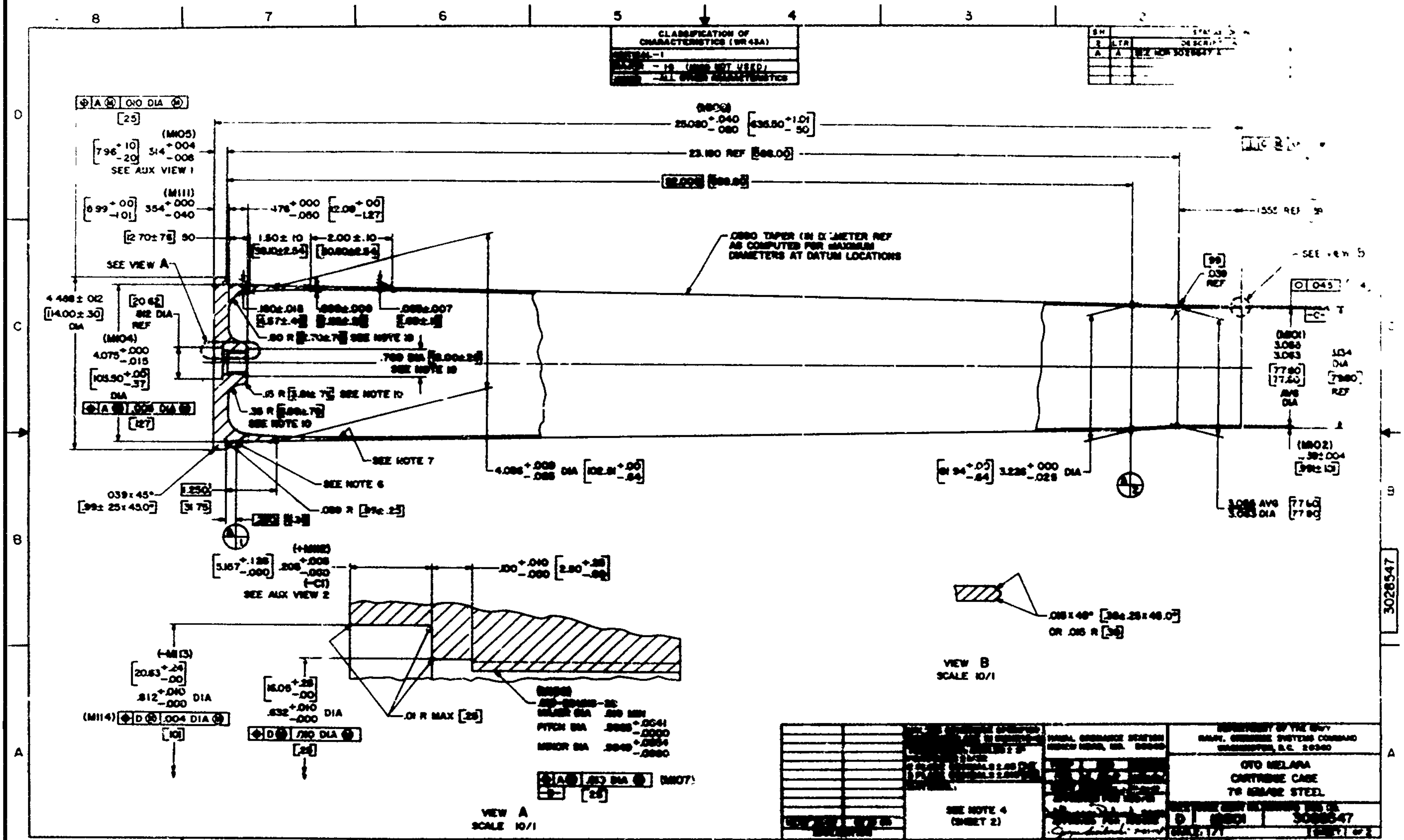





FIGURE 1

Schematic of 76mm/62 Caliber steel cartridge case.

## TEST DESCRIPTION

Tests performed in the evaluation of the steel cartridge case were as follows:

a. Mount Compatibility Test: Ten inert-loaded cartridges with fired primer and inert 5"/38 Caliber propellant were subjected to an ammunition system handling test in the MARK 75 gun mount. This involved cycling the cartridges 5 times through the handling system of the mount, and ramming the cartridges on the fifth cycle. Integrity of the cartridge case and crimp were evaluated after each cycle, and debulleting of the projectiles from the steel cases was verified.

b. Single Fire Proof Test: Fifteen cartridges were fired from a single fire mount as probing rounds to establish charge weights under service and proof conditions. Thirty cartridges were fired from a single fire mount with propelling charges adjusted to give proof pressure (19.5 to 21.0 long tons/in$^2$ nominal, in accordance with WS 14795A), ten cartridges at each of three conditioning temperatures (20°F, 90°F, and 120°F). The integrity of the cartridge cases under overtest or proof conditions was determined.

c. Single Fire Service Test: Sixty cartridges loaded to service charge were fired from the MARK 75 mount (single fire), thirty each conditioned to 20°F and 120°F. Compatibility of the cartridge case with the MARK 75 mount at various temperatures was determined.

d. Rapid Fire Service Test: Five 20-round bursts (service charge) were fired from the MARK 75 mount, one burst through a vertical target located 500 yards from the muzzle, and four bursts at a quadrant elevation of 15°. Phototriangulation techniques were used on the last four bursts to obtain range and deflection information as additional data for use in assessing the accuracy potential of the MARK 75 mount (accuracy data are included in this report but are discussed in detail in reference 8). Structural integrity of the cartridge case and compatibility with the MARK 75 mount in the rapid fire mode were determined.

The overall objectives of these four tests were to determine the suitability of the steel cartridge case as a replacement for the standard brass cartridge case now in use by assessing its performance in, and compatibility with, the MARK 75 gun mount. Complete descriptions of these tests are given in Appendices (A) through (D).

## RESULTS

Complete details on test results are given in Appendices (A) through (D). The results are summarized below:

a. The steel cartridge case will withstand handling, ramming, firing, and extractions in the MARK 75 gun mount (160 successes out of 160 attempts).

b. The steel cartridge case retains its structural integrity when subjected to proof pressures.

c. Extraction forces measured for the steel cartridge case are generally lower than those measured for the brass cartridge case.

d. The approximate service charge weight of 5.30 lb. of lot RAD-E33 propellant produced acceptable average chamber pressures (17.7 long tsi).

Based on the above results, it is concluded that the steel cartridge case is a suitable replacement for the 76mm brass cartridge case with respect to structural integrity and compatibility with the MARK 75 gun mount.

It is noted that to fully qualify the steel cartridge case for service use, an assessment of the effects of environmental conditioning during its logistic cycle is needed. It is not anticipated that an extensive evaluation would be required since the construction of the 76mm steel cartridge case is similar to other existing steel cartridge cases.

APPENDIX A

## STEEL CARTRIDGE CASE EVALUATION

### Mount Compatibility Test

Objective: Determine if 76mm steel cartridge cases can withstand cycling and ramming in the MARK 75 gun mount.

Test Description: Ten inert 76mm cartridges were prepared by loading steel cartridge cases with fired MARK 161 primers and 5.35 lbs of 5"38 Caliber inert propellant.* An inert BL&P projectile was installed and crimped with 125 tons crimping pressure. The cartridges were individually loaded into the revolving magazine of the MARK 75 gun mount and cycled through the ammunition handling system with each cartridge being removed just before the ramming process of the gun mount. Each cartridge was cycled through the handling system a total of 5 times. On the fifth cycle, the gun mount was allowed to complete its loading cycle, i.e., the automatic rammer placed the cartridge in the chamber of the gun barrel liner causing the projectile to debullet as it does under normal conditions in the 76mm gun system. After extraction of the rammed cartridge case, the seated projectile was removed with a rod pushed down the muzzle end of the barrel.

Deviations: No deviations were made from the test plan of reference (9).

Results: All cartridge cases were structurally sound after five cycles and a final ram. All crimps were tight after three cycles through the handling system. After the fourth cycle, six of the ten cartridges had loosened crimps and the projectiles could be rotated in the crimp, however, based on the previous experience on the MARK 75 mount with brass cased ammunition, none were loose enough to cause any problems when going through the ammunition handling system. After the last cycle, in which all cartridges were rammed in the mount, test cartridges 2 through 10 were observed to have debulleted after ramming. It is likely that the first cartridge also debulleted, but the evidence was destroyed when the projectile was inadvertently pushed back into the case before the case was extracted. Debulleting therefore was verified on 9 of 10 units.

*See NAVORD Dwg. 3028548 for loading details.

Conclusion: 76mm/62 Caliber steel-cased cartridges can successfully withstand the ammunition handling environment of the MARK 75 gun mount.

APPENDIX B

## STEEL CARTRIDGE CASE EVALUATION

### Single Fire Proof Test

Objective: Determine the ability of the steel cartridge case to withstand higher than normal chamber pressure (proof pressures) at various temperatures.

Test Description: Since a propelling charge weight determination had not been made to estimate the charge weight necessary for either service or proof pressures, several probing rounds were fired at various charge weights to establish charge weight/chamber pressure relationships. The purpose of the test was to assess the strength of the cartridge case at various temperatures, so charge weights were estimated that would achieve cartridge case proof pressures (nominally 19.5 to 21.0 long tons/in$^2$ (copper) in accordance with WS 14795) at 20°F, 90°F, and 120°F. At the same time, the charge weight to achieve service velocity and chamber pressure were estimated (3000 ± 10 ft/sec, 17 to 19 lon tons/in$^2$ at a temperature of 90°F). RAD-E33 M6/2 propellant was used in all instances. Once a charge weight was established, ten cartridges each were loaded with the proper propelling charge weight to achieve nominal proof pressures. The cartridges consisted of a steel cartridge case, a MARK 161 percussion primer, the proper charge weight of RAD-E33 propellant, and an inert BL&P projectile. Preconditioned components (except projectiles which were at ambient temperature) were used in all instances, and upon loading, each cartridge was placed back in the proper temperature conditioning chamber for stabilization. Copper crusher gauges were placed in all cartridges, two 10 and two 15-ton gauges in each probing cartridge, and three 15-ton gauges in each test cartridge. As each test cartridge was fired from a single fire mount, maximum chamber pressure and projectile velocity were measured and recorded. At the completion of the test, certain premeasured cartridge cases were rechambered as a check for fit and then returned to NOS/IH for analysis.

Deviations: There were no deviations from reference 9 on this test.

Results: All data are summarized in Table B-1 and shown in detail in Table B-2. Service and proof charges of RAD-E33 in the 76mm/62 Caliber steel cartridge case with U.S. projectiles were determined to be (velocities and pressures were obtained from data cartridges):

| | Temperature ($^{o}F$) | Charge Weight (lbs) | Average Velocity (ft/sec) | Average Pressure long tsi (Cu) |
|---|---|---|---|---|
| Service | 90 | 5.30 | 3000 | 17.2 |
| | 20 | 6.10 | 3250 | 20.8 |
| | 90 | 5.80 | 3229 | 21.1 |
| | 120 | 5.71 | 3207 | 20.9 |

All steel cartridge cases performed satisfactorily, with no case failures occurring. Most cases were hard to extract from the single fire mount but this is attributed to normal case expansion during proof firings. The range in chamber pressure at a specific charge weight in most instances was less than 2 tsi (Cu) normally experienced with the brass cartridge case. The largest variation was at 120$^{o}$F, with pressures ranging from a high of 21.4 to a low of 20.3 tsi at a charge weight of 5.71 lbs. (using the 15 tsi gauge readings as the standard). Projectile velocities are nominally 3225 ft/sec., typical of previous results in 76mm tests at a similar pressure level (TECHEVAL test TS-2, fired at proof pressure at ambient temperature had a nominal chamber pressure of 21.2 tsi and an average velocity of 3204 ft/sec. with a standard deviation of 8.4 ft/sec.). It is noted that because of the lower than expected variations in chamber pressure, small adjustments in charge weight were made during the course of firings in attempts to achieve pressures slightly closer to nominal proof (21.0 tsi). Great care was exercised when doing this because the proper combination of charge weight and temperature can sometimes cause large jumps in pressure for small charge weight increases. Indeed, this did occur in one instance, when an increase of 0.3 lbs. in charge weight (at 20$^{o}$F) produced a jump in chamber pressure of almost 4 tsi, to 23.7 tsi when only a 1 to 1.5 tsi increase was to be expected. Fortunately the steel cartridge case handled even this extreme overtest with no problems other than indications of a slightly deeper than normal "pressure ring" on the back of the case. This ring is merely an impression of the breechblock on the base of the case due to high pressures and is to be expected on all cartridge cases fired.

Conclusion: 76mm/62 Caliber steel-cased ammunition can successfully withstand chamber pressures up to proof pressures and beyond, with no ill effects.

TABLE B-1

76MM STEEL CARTRIDGE CASE EVALUATION

Single Fire Proof Test

Summary of Results

| Test Temperature ($^oF$) | Charge Weight (lbs) | Chamber Pressures (Long Tons/in$^2$ (Copper)) 10 TSI Gauge Mean | 10 TSI Gauge Standard Deviation | 15 TSI Gauge Mean | 15 TSI Gauge Standard Deviation | Velocity (ft/sec) Mean | Velocity (ft/sec) Standard Deviation |
|---|---|---|---|---|---|---|---|
| 20 | 6.00 | 20.1 | 0.15 | 20.0 | 0.17 | 3253 | 14.4 |
| | 6.10 | 20.2 | 0.96 | 20.8 | 0.28 | ---- | ---- |
| 90 | 5.78 | 20.6 | 0.12 | 21.2 | 0.32 | 3212 | 4.4 |
| | 5.80 | 20.8 | 0.04 | 21.1 | 0.17 | 3229 | 5.8 |
| 120 | 5.71 | 20.8 | 0.33 | 20.9 | 0.33 | 3207 | 7.5 |

TABLE B-2

76MM STEEL CARTRIDGE CASE EVALUATION

Single Fire Proof Test

Propellant: Lot RAD-I 33. Mount: Single fire. Barrel No.: NOSL Liner 1.

| Date | Test Unit No. | Case Serial No. | Projectile Serial No. | Conditioning Temperature (°F) | Charge Weight (lbs) | Average Pressure 10 TSI Gauge | Average Pressure 15 TSI Gauge | Velocity (ft/sec) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 05/21/75 | ---- | --- | --- | 90 | 5.27 | ---- | ---- | 3169 | Italian warming round. |
| | ---- | 22 | --- | 90 | 5.35 | 17.4 | ---- | 3025 | Probing round. |
| | ---- | 91 | --- | 90 | 5.40 | 18.0 | ---- | 3049 | Probing round. |
| | ---- | 179 | --- | 90 | 5.50 | 18.7 | ---- | 3079 | Probing round. |
| | ---- | 34 | --- | 90 | 5.50 | 18.7 | ---- | 3077 | Probing round. |
| | ---- | 183 | --- | 90 | 5.65 | 20.2 | 19.5 | 3155 | Probing round. |
| | ---- | 6 | --- | 90 | 5.70 | 20.5 | 19.4 | 3180 | Probing round. |
| | ---- | 132 | --- | 90 | 5.75 | 20.4 | 21.2 | 3202 | Probing round. |
| 05/22/75 | ---- | --- | --- | 75 | 5.27 | ---- | ---- | 3149 | Italian warming round. |
| | ---- | 123 | --- | 90 | 5.30 | 17.2 | ---- | 3000 | Probing round. |
| | ---- | 113 | --- | 90 | 5.50 | 18.7 | ---- | 3086 | Probing round. |
| | ---- | 122 | --- | 90 | 5.60 | 19.2 | ---- | 3134 | Probing round. |
| | ---- | 25 | --- | 90 | 5.70 | 20.0 | 19.4 | 3184 | Probing round. |
| | ---- | 16 | --- | 90 | 5.75 | ---- | 20.3 | 3207 | Probing round. |
| | ---- | 176 | --- | 90 | 5.78 | ---- | 21.2 | 3214 | Probing round. |
| | ---- | 11 | --- | 120 | 5.70 | ---- | 20.7 | 3199 | Probing round. |
| | ---- | 181 | --- | 20 | 5.90 | 20.1 | 20.5 | 3209 | Probing round. |
| | CS-56 | 174 | --- | 90 | 5.78 | 20.6 | 21.7 | 3212 | |
| | 57 | 127 | --- | 90 | 5.78 | 20.5 | 21.3 | 3209 | |
| | 66 | 46 | - | 120 | 5.71 | 20.3 | 21.0 | 3205 | |
| | 67 | 106 | --- | 120 | 5.71 | 20.6 | 20.3 | 3200 | |
| | 76 | 116 | --- | 20 | 6.00 | 20.3 | 20.6 | 3263 | |
| | 77 | 71 | --- | 20 | 6.00 | 19.9 | 20.1 | 3264 | |
| 05/23/75 | --- | --- | --- | 90 | 5.27 | ---- | ---- | 3165 | Italian warming round. |
| | --- | 164 | --- | 90 | 5.60 | 18.9 | 18.6 | 3218 | Near proof round. |
| | CS-58 | 63 | --- | 90 | 5.78 | 20.6 | 20.9 | 3220 | |
| | 59 | 39 | --- | 90 | 5.78 | 20.5 | 21.1 | 3210 | |
| | 60 | 85 | --- | 90 | 5.78 | 20.8 | 20.8 | 3208 | |
| | 61 | 180 | --- | 90 | 5.80 | 20.8 | 21.1 | 3219 | |
| | 62 | 162 | --- | 90 | 5.80 | 20.0 | 21.1 | 3229 | |
| | 63 | 157 | --- | 90 | 5.80 | 20.9 | 20.9 | 3232 | |
| | 64 | 153 | --- | 90 | 5.80 | 20.8 | 20.9 | 3230 | |
| | 65 | 14 | --- | 90 | 5.80 | 20.8 | 21.3 | 3234 | |
| | 68 | 114 | --- | 120 | 5.71 | 21.1 | 20.6 | 3222 | |
| | 69 | 167 | --- | 120 | 5.71 | 20.9 | 20.5 | ---- | Case hard to load. |
| | --- | --- | --- | 90 | 5.27 | ---- | ---- | 3201 | Relieving round. |
| 06/04/75 | --- | --- | --- | 90 | 5.27 | ---- | ---- | 3167 | Italian warming round. |
| | --- | 68 | --- | 90 | 5.70 | ---- | 20.4 | 3178 | Near proof round. |
| | CS-70 | 21 | --- | 120 | 5.71 | 21.0 | 21.4 | 3217 | |
| | 71 | 10 | --- | 120 | 5.71 | ---- | 21.2 | 3201 | |
| | 72 | 18 | --- | 120 | 5.71 | ---- | 21.0 | 3203 | |
| | 73 | 13 | --- | 120 | 5.71 | ---- | 20.8 | 3203 | |
| | 74 | 7 | --- | 120 | 5.71 | ---- | 20.9 | 3206 | |
| | 75 | 5 | --- | 120 | 5.71 | ---- | 21.0 | 3208 | |
| | 78 | 124 | --- | 20 | 6.00 | 20.1 | 19.9 | 3260 | |
| | 79 | 109 | --- | 20 | 6.00 | 20.1 | 20.0 | 3248 | |
| | 80 | 33 | --- | 20 | 6.00 | 20.2 | 19.9 | 3230 | |
| | 81 | 97 | --- | 20 | 6.30 | ---- | 23.7 | 3406 | |
| 06/30/75 | --- | --- | --- | 90 | 5.2 | ---- | ---- | 3153 | Relieving round. |
| | 82 | 95 | --- | 20 | 6.10 | 20.6 | 20.8 | ---- | Fired from Liner FCA-078. |
| | 83 | 56 | --- | 20 | 6.10 | 18.8 | 20.6 | ---- | Fired from Liner FCA-078. |
| | 84 | 59 | --- | 20 | 6.10 | 20.6 | 21.2 | ---- | Fired from Liner FCA-078. |
| | 85 | 30 | --- | 20 | 6.10 | 20.9 | 20.6 | ---- | Fired from Liner FCA-078. |

APPENDIX C

## 76MM STEEL CARTRIDGE CASE EVALUATION

### Single Fire (Service Pressure) Test

Objective: Determine the compatibility of the steel cartridge case with the MARK 75 gun mount when fired at various temperatures in the single fire mode.

Test Description: Sixty steel cartridge cases were loaded with 5.30 lbs of M6/2 76mm propellant from Lot RAD-E33. BL&P cartridges were assembled in accordance with NWL Dwg. 40997 using inert projectiles. This charge weight was previously estimated (from Appendix B) to provide service velocity and pressure (3000 $\pm$ 10 ft/sec, $\hat{s}$ = 15 ft/sec; 17 to 19 tsi (Cu), $\hat{s}$ = .60 tsi) when fired at standard temperature (90°F) and using steel cartridge cases. Copper crusher gauges in gauge holders were placed in each cartridge case to provide an indication of chamber pressures after each shot. Thirty cartridges each were preconditioned to temperatures of 20° and 120°F. As each individual cartridge was removed from conditioning, it was placed in the lower loading drum of a MARK 75 MOD 0 gun mount, cycled through the handling system, rammed, and fired. The gun mount was instrumented to measure left and right cartridge case extraction forces, and projectile ejection time. Coils along the line of fire were used to measure projectile velocity. Chamber pressures were measured using three 15-ton copper crusher gauges in each cartridge case.

Deviations: Two deviations occurred from the test plan of reference 9. First, facilities were not available at the time of the test to precondition the test cartridges to 130°F. After consultation with the Design Agent for the steel cartridge case (NOS/IH), the temperature requirement was lowered to 120°F. Secondly, reference 9 required that ten cartridges loaded to achieve proof pressure be fired from the MARK 75 mount. NAVSEA's policy throughout the 76mm Ammunition Technical Evaluation (TECHEVAL) was that no proof firings were to be conducted from the MARK 75 mount so this requirement was deleted.

Test Results: An initial attempt was made to conduct this test using a worn Italian barrel liner (FCA-064) in order to accumulate enough wear on this liner to perform one of the last brass case TECHEVAL tests. It was found, however, that wear on this liner was sufficient to produce chamber pressures far below service pressure, even when fired at high temperatures.

This was verified by firing a brass-cased cartridge, conditioned to 90°F, and observing a chamber pressure of 15.5 tsi vice 17 to 19 (see Table C-1 for tabulation of the data).

Italian liner FCA-100 (four previous cartridges fired) was substituted and most of the remainder of the cartridges fired. Two additional liner changes were made, with the last 23 cartridges being fired from either NOSL Liner 7 (four previous cartridges fired) or 8 (ten previous cartridges fired). Following is a summary of the ballistic data for these three liners:

| Conditioning Temperature (°F0 | Liner No. | Average Velocity (ft/sec) | Standard Deviation (ft/sec) | Average Pressure (Long tsi) | Standard Deviation (Long tsi) |
|---|---|---|---|---|---|
| 20 | FCA-100 | 2923 | 9.9 | 16.1 | 0.2 |
| | NOSL No. 7 | 2912 | 8.1 | 15.4 | 0.3 |
| | NOSL No. 8 | 2953 | 8.5 | 16.4 | 0.4 |
| 120 | FCA-100 | 3008 | 9.6 | 18.5 | 0.3 |

A liner-to-liner comparison of the data at 20°F shows that there is a statistically significant (t test at 0.01 confidence level) difference in ballistic performance either in velocity or pressure, that prevents pooling the data. Several factors can contribute to the observed variations in ballistic performance including performance differences between Italian and American 76mm liners (documented in reference 10), and day-to-day variations in performance that can occur even when all other conditions are identical.

A comparison of the data with velocity/temperature and velocity/pressure curves generated during the 76mm brass-cased ammunition TECHEVAL shows steel-cased ammunition to be slightly less affected by temperature than the brass-cased ammunition (see Figures C-1 and C-2). From the limited data available, a correction factor of approximately 0.80 ft/sec/°F for velocity and 0.025 long tsi/°F for chamber pressure was obtained. Using these values, velocity and pressure corrected to a standard of 90°F became:

| Conditioning Temperature (°F) | Barrel Liner | Corrected Velocity to 90°F (ft/sec) | Corrected Pressure to 90°F (Long tsi) |
|---|---|---|---|
| 20 | FCA-100 | 2979 | 17.9 |
| | NOSL No. 7 | 2968 | 17.2 |
| | NOSL No. 8 | 3009 | 18.2 |
| 120 | FCA-100 | 2984 | 17.8 |

Average corrected velocity for the three liners with the estimated charge weight of 5.30 lbs. of Lot RAD-E33 is slightly lower than nominal service velocity (3000 ± 10 ft/sec). Each given liner performs consistently with the steel case since standard deviations are all less than 10 ft/sec.. Pressures are all within nominal service limits.

Each cartridge case was examined for damage after firing. No damage to any cartridge case was found. Extraction forces were measured to determine the compatibility of the cartridge case with the gun mount, i.e., is the case harder to extract than a brass case, a condition that can cause fatigue of the extractor mechanism. Average extraction forces were:

| Conditioning Temperature (°F) | Extraction Forces (lbs) | | | |
|---|---|---|---|---|
| | Left | | Right | |
| | Average | Standard Deviation | Average | Standard Deviation |
| 20 | 1993 | 741 | 2012 | 750 |
| 120 | 2421 | 846 | 2784 | 952 |

Analysis shows that there is no significant difference in left or right extraction forces at either temperature (tests at 0.01 confidence level). There is some dependence on temperature indicated on the right extractor for which no explanation can be given. In general, extraction forces are much lower than those measured during the brass case tests. For example, average extraction forces in the order of 3500 to 5000 lbs. were obtained during accuracy tests of brass-cased U.S.-made ammunition. Equivalent values were measured in other TECHEVAL tests.

Conclusions:

a. Steel cased 76mm ammunition experiences no structural problems when fired at nominal service conditions and at temperature extremes.

b. Extraction forces measured with the steel cartridge case are consistent, and are lower than those measured on the brass cartridge case.

FIGURE C-1

76MM STEEL CASE EVALUATION VELOCITY VS. TEMPERATURE

ON

BRASS AND STEEL CARTRIDGE CASES

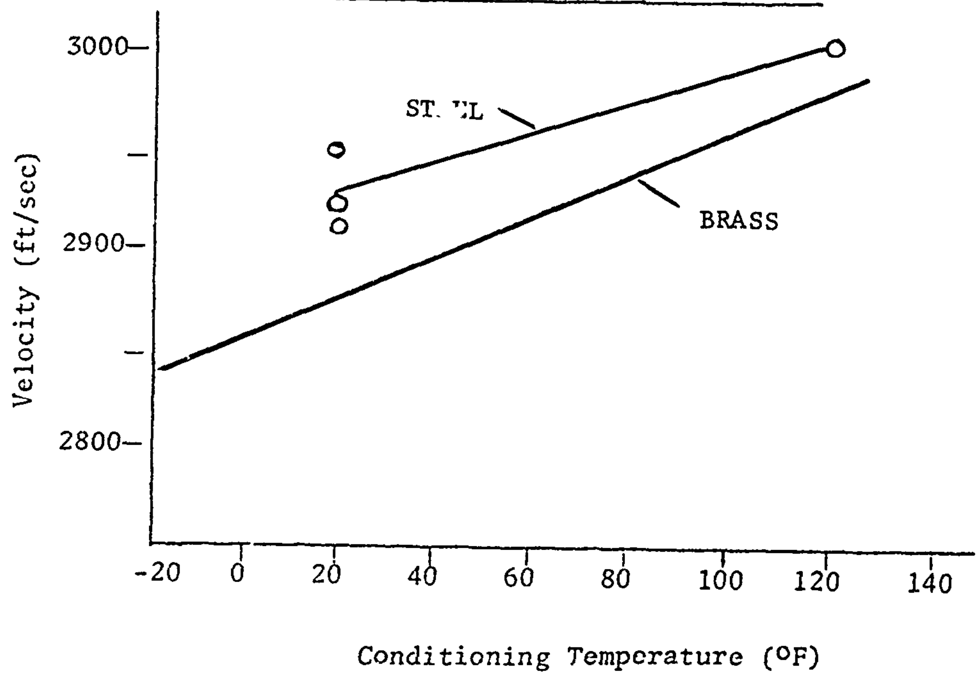
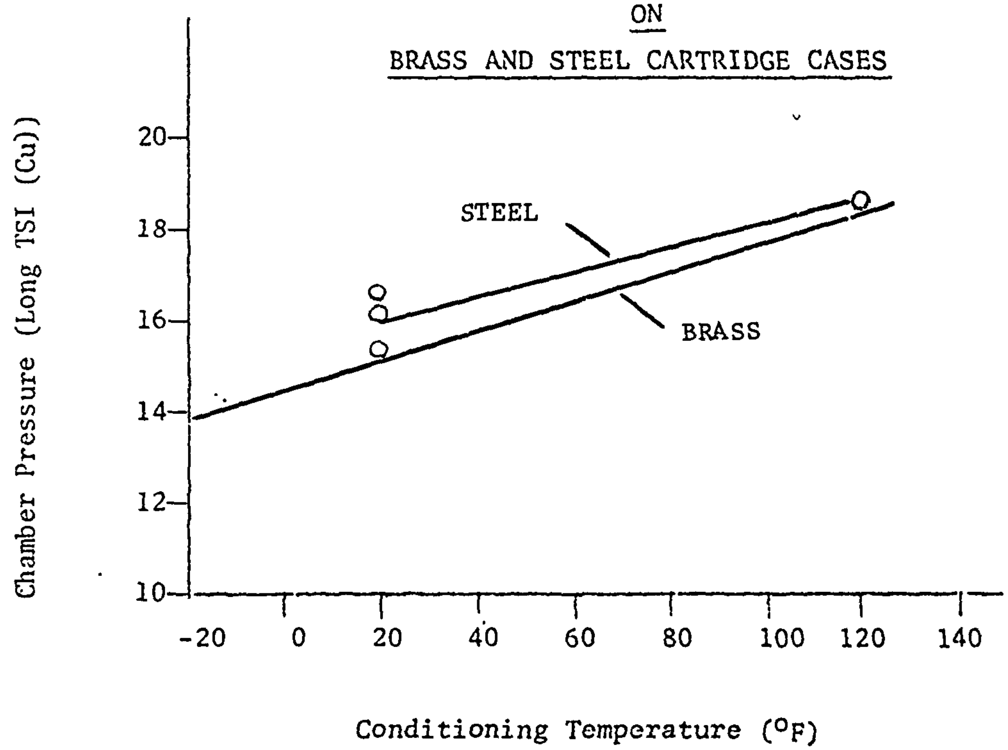


FIGURE C-2

76MM STEEL CASE EVALUATION PRESSURE VS. TEMPERATURE

ON

BRASS AND STEEL CARTRIDGE CASES



APPENDIX D

## 76MM STEEL CARTRIDGE CASE EVALUATION

### Rapid Fire (Service Pressure) Test

Objective: Determine structural ability of a steel cartridge case and its compatibility with the MARK 75 mount in the rapid fire mode.

Test Description: One hundred steel cartridge cases were loaded with 5.30 pounds of M6/2 76mm propellant from lot RAD-E33. Complete BL&P cartridges were then assembled in accordance with NWL Dwg. 40997 using inert projectiles from a lot manufactured for IOT&E tests aboard PHM-1. The 5.30 pound charge weight had been previously established (Appendix B) to provide nominal service velocity and pressure. Twenty cartridges, conditioned to 90°F, were fired (at a firing rate of 80 rounds/minute) from the MARK 75 MOD 0 mount at a vertical plywood target located 500 yards from the gun muzzle. The gun mount was instrumented to measure left and right cartridge case extraction forces, and projectile ejection time. Coils along the line of fire were used to obtain the velocity of each projectile. A 16mm photosonic camera recorded the order of impact of each projectile on the target board.

The remaining 80 cartridges were fired as four 20-round bursts from the MARK 75 MOD 0 mount. The barrel/liner was elevated to a quadrant elevation of 15° for each burst, and range and drift of each projectile impact on the water was measured using phototriangulation techniques (four 70mm photosonic cameras and two 5-inch format Bowen cameras located at various range stations near the point of impact). As before, the gun mount was instrumented to measure left and right cartridge case extraction forces, and projectile ejection time. Coils along the line of flight were used to measure projectile velocity.

Deviations: Two deviations occurred from the test plan of reference 9. First, instrumentation was added to the test to allow measurement of extraction forces, and projectile range and drift information. Second, to allow comparison of the range information with existing range data, the conditioning temperature was changed from ambient to 90°F. It is noted that the vertical target test and the obtaining of range information were piggybacked tests to obtain accuracy data. These data will be discussed in an upcoming 76mm accuracy report and will not be discussed in this report.

Test Results: All cartridges functioned successfully in the rapid fire mode of the MARK 75 mount. One cartridge case was found to have developed a longitudinal split near the base of the case (see Figure D-1). An investigation by NOS/IH disclosed that the split was caused by the presence of a large inclusion near the surface of the steel which the manufacturer had tried to remove by buffing the surface of the case. This apparently weakened the case material sufficiently to allow splitting upon firing. It is noted that all steel cartridge cases were examined after firing, and no other instance of splitting was discovered. Velocity and extraction force information is summarized as follows:

| Liner No. | Average Velocity (ft/sec) | Standard Deviation (ft/sec) | Extraction Forces (lbs) Left Average | Left Standard Deviation | Right Average | Right Standard Deviation |
|---|---|---|---|---|---|---|
| NOSL No. 8 | 3001 | 13.8 | 2374 | 358 | 4538 | 1310 |
| FCA-101 | | | | | | |
| (Burst 1) | 2970 | 13.2 | 2558 | 606 | ---- | ---- |
| (Burst 2) | 2968 | 12.1 | 2569 | 511 | ---- | ---- |
| (Burst 3) | 2969 | 10.8 | 3045 | 441 | ---- | ---- |
| (Burst 4) | 2966 | 7.2 | ---- | --- | ---- | ---- |

Velocity is again low in one liner (FCA-101), however, it easily meets requirements of nominal service requirements on the other liner. Both liners were new, FCA-101 having four previous rounds and liner 8 having 16 previous rounds. As noted before (Appendix C), velocity differences as observed here occur in other gun systems and are usually caused by liner-to-liner variations or by day-to-day variations. Since this test was performed on two different days with two different liners, both sources of variation are felt to have caused the observed velocity differences.

Extraction forces are in general comparable with those reported in Appendix C. No explanation can be given for the atypical high right extraction force reading observed on liner 8. New strain gauges had been installed prior to this test, the gauges from previous tests having been damaged during a barrel change. The observed extraction force is still lower than the minimum extraction force observed on brass-cased ammunition.

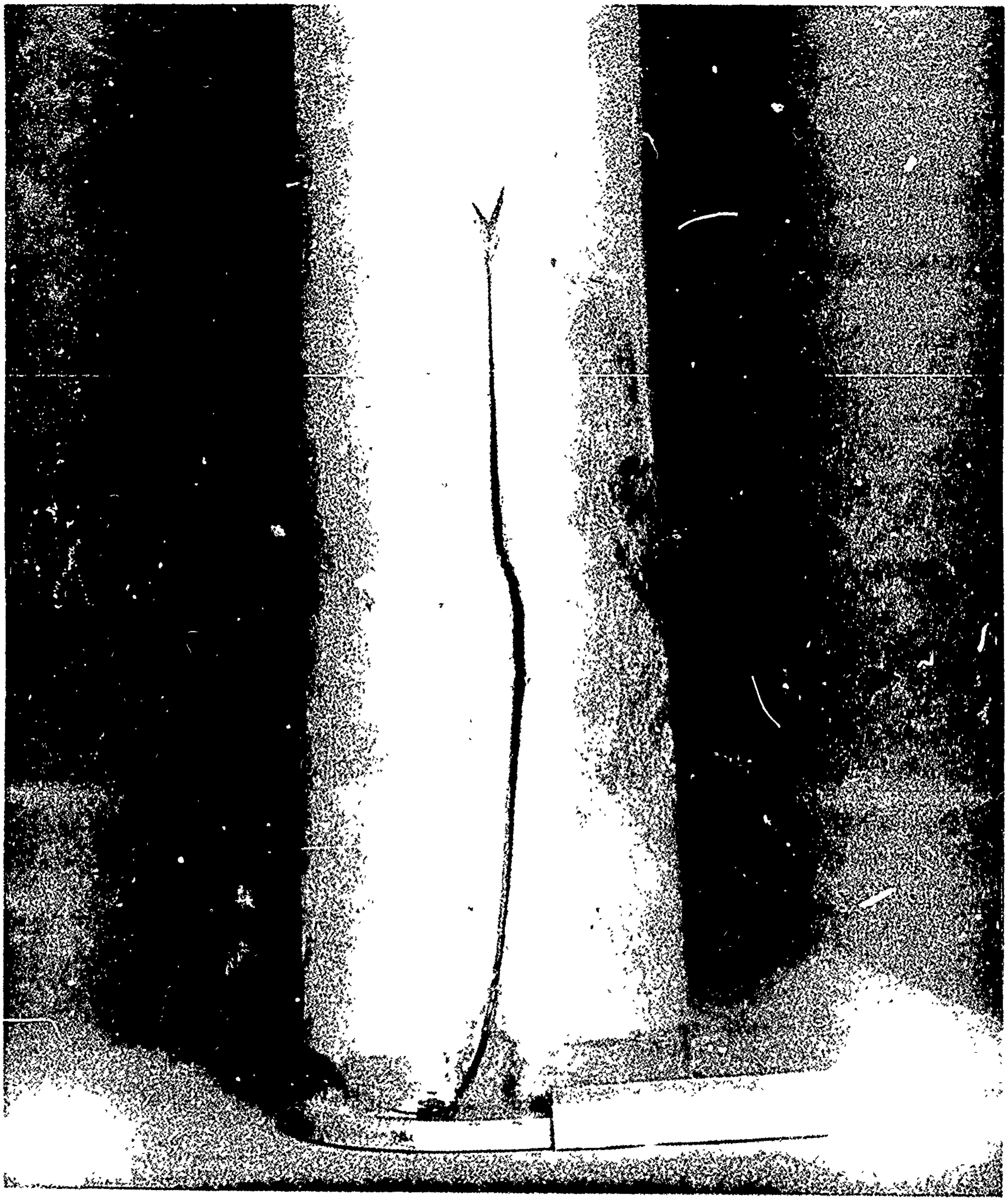
Strain gauge failure during the firing on liner FCA-101 caused the right extraction data to be either suspect or non-existent. New gauges were installed prior to this test when previously installed gauges were found to be nonfunctional. Initial firings on the new gauges showed the right extractor traces to be extremely erratic, and were not reported. Gauge failure also occurred on the left extractor at the start of the fourth burst fired from liner FCA-101.

Range and dispersion data gathered are shown in Table D-1. Figure D-2 shows a schematic of the target board with impact locations plotted. Analysis of these data will be given in separate reports.

Conclusions:

a. The steel cartridge case is structurally able to withstand firing at service conditions from the MARK 75 gun mount.

b. The steel cartridge case is compatible with the MARK 75 gun mount in that forces induced in the mount by firing are equivalent to or lower than those induced by brass-cased ammunition.



PHD-1722-7-75 FIGURE D-1 June 1975

View of longitudinal split in a 76mm steel cartridge case. Split occurred during a rapid fire test from the MARK 75 MOD 0 gun mount.

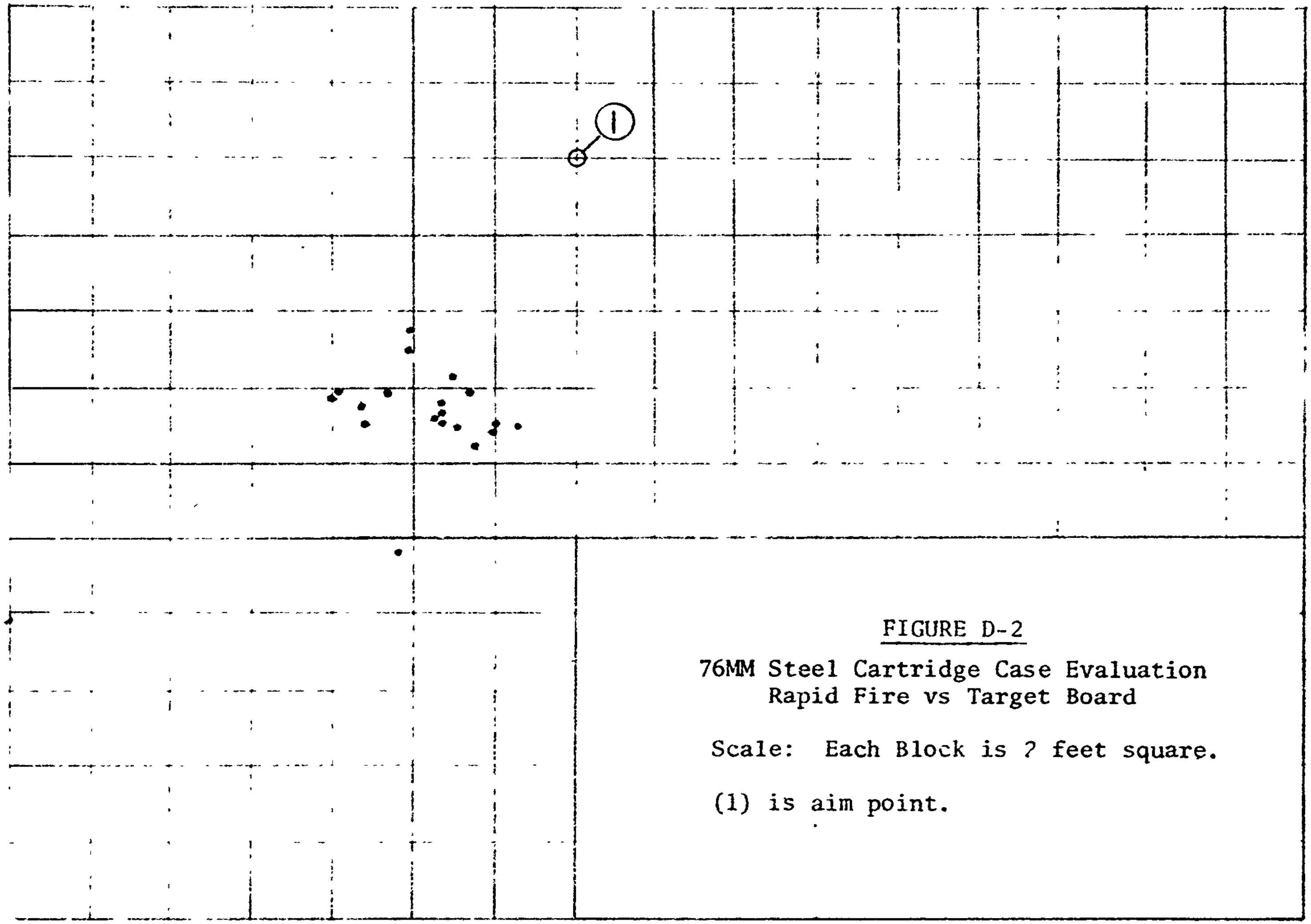



FIGURE D-2

76MM Steel Cartridge Case Evaluation
Rapid Fire vs Target Board

Scale: Each Block is ? feet square.

(1) is aim point.

## TABLE D-1

## 76MM STEEL CARTRIDGE CASE EVALUATION

### Rapid Fire-Service

Conditioning Temperature 90°F    Mount: MARK 75 MOD 0.    Q.E. 15°.

| Barrel Number | Test Unit No. | Case Serial Number | Velocity (ft/sec) | Extraction Forces (lbs) Left | Extraction Forces (lbs) Right | CFK to Ejection (sec) | Uncorrected Range (yds) | Deflection (yds) |
|---|---|---|---|---|---|---|---|---|
| Liner 8 | CS-156 | 139 | 2962 | 2310 | 2590 | .082 | ----- | --- |
| Liner 8 | CS-157 | 309 | 2982 | 2440 | 2750 | .087 | ----- | --- |
| Liner 8 | CS-158 | 303 | 2988 | 2370 | 2430 | .092 | ----- | --- |
| Liner 8 | CS-159 | 306 | 2981 | 2690 | 3680 | .083 | ----- | --- |
| Liner 8 | CS-160 | 301 | 3004 | 2620 | 6490 | .088 | ----- | --- |
| Liner 8 | CS-161 | 308 | 3008 | 2240 | 4010 | .088 | ----- | --- |
| Liner 8 | CS-162 | 304 | 2999 | 2280 | 4160 | .086 | ----- | --- |
| Liner 8 | CS-163 | 305 | 2999 | 2140 | 4930 | .109 | ----- | --- |
| Liner 8 | CS-164 | 302 | 2998 | 2650 | 6440 | .094 | ----- | --- |
| Liner 8 | CS-165 | 229 | 2998 | 2300 | 4160 | .093 | ----- | --- |
| Liner 8 | CS-166 | 232 | 3007 | 1710 | 4790 | .098 | ----- | --- |
| Liner 8 | CS-167 | 207 | 3004 | 3020 | 3160 | .096 | ----- | --- |
| Liner 8 | CS-168 | 237 | 3010 | 2950 | 6050 | .097 | ----- | --- |
| Liner 8 | CS-169 | 231 | 3001 | 2490 | 6410 | .100 | ----- | --- |
| Liner 8 | CS-170 | 236 | 3010 | 2750 | 5650 | .092 | ----- | --- |
| Liner 8 | CS-171 | 230 | 3022 | 2510 | 6020 | .106 | ----- | --- |
| Liner 8 | CS-172 | 234 | 3008 | 2300 | 5260 | .109 | ----- | --- |
| Liner 8 | CS-173 | 233 | 3014 | 2100 | 4870 | .108 | ----- | --- |
| Liner 8 | CS-174 | 211 | 3015 | 1710 | 4870 | .090 | ----- | --- |
| Liner 8 | CS-175 | 288 | 3006 | 1900 | 5030 | .087 | ----- | --- |
| FCA-101 | (1) | --- | 3152 | 3660 | (2) | .081 | ----- | --- |
| FCA-101 | (1) | --- | 2983 | 2020 | (2) | .090 | ----- | --- |
| FCA-101 | CS-176 | 291 | 2964 | 3360 | (2) | .088 | 12277 | 0 |
| FCA-101 | CS-177 | 285 | 2945 | 2520 | (2) | .088 | 12265 | -24 |
| FCA-101 | CS-178 | 290 | 2948 | 1630 | (2) | .101 | (2) | (2) |
| FCA-101 | CS-179 | 284 | 2953 | 1760 | (2) | .091 | 12243 | -17 |
| FCA-101 | CS-180 | 289 | 2968 | 1830 | (2) | .097 | 12125 | -8 |
| FCA-101 | CS-181 | 287 | 2955 | 1870 | (2) | .094 | 12352 | -21 |
| FCA-101 | CS-182 | 283 | 2968 | 2250 | (2) | .101 | 12387 | -7 |
| FCA-101 | CS-183 | 339 | 2971 | 1910 | (2) | .096 | 12128 | -20 |
| FCA-101 | CS-184 | 337 | 2980 | 2240 | (2) | .089 | (2) | (2) |
| FCA-101 | CS-185 | 338 | 2972 | 2520 | (2) | .097 | 12090 | -18 |
| FCA-101 | CS-186 | 342 | 2979 | 2470 | (2) | .103 | (2) | 3 |
| FCA-101 | CS-187 | 341 | 2967 | 3520 | (2) | .094 | 11964 | -30 |
| FCA-101 | CS-188 | 204 | 2967 | 1630 | (2) | .109 | 12345 | -19 |
| FCA-101 | CS-189 | 345 | 2966 | 3170 | (2) | .092 | 12021 | -10 |
| FCA-101 | CS-190 | 343 | 2987 | 2740 | (2) | .095 | 12355 | -11 |
| FCA-101 | CS-191 | 344 | 2993 | 2240 | (2) | .101 | 12090 | -18 |
| FCA-101 | CS-192 | 262 | 2988 | 2240 | (2) | .099 | 11938 | -15 |
| FCA-101 | CS-193 | 264 | 2962 | 2750 | (2) | .101 | 12025 | -35 |
| FCA-101 | CS-194 | 263 | 2981 | 3140 | (2) | .096 | 12227 | -17 |
| FCA-101 | CS-195 | 261 | 2981 | 3360 | (2) | .102 | 11909 | -23 |
| FCA-101 | CS-196 | 314 | 2975 | 2300 | (2) | .093 | 12220 | 4 |
| FCA-101 | CS-197 | 315 | 2944 | 3070 | (2) | .090 | 12027 | -26 |
| FCA-101 | CS-198 | 258 | 2965 | 2040 | (2) | .096 | 12131 | -11 |
| FCA-101 | CS-199 | 311 | 2950 | 2750 | (2) | .094 | 12057 | -8 |
| FCA-101 | CS-200 | 313 | 2964 | 2020 | (2) | .089 | 12272 | -14 |
| FCA-101 | CS-201 | 318 | 2950 | 2410 | (2) | .101 | 11972 | -15 |
| FCA-101 | CS-202 | 335 | 2971 | 2520 | (2) | .092 | 12106 | -23 |
| FCA-101 | CS-203 | 336 | 2981 | 3410 | (2) | .098 | 12051 | -2 |
| FCA-101 | CS-204 | 312 | 2962 | 3030 | (2) | .098 | 12064 | -19 |
| FCA-101 | CS-205 | 223 | 2975 | 2920 | (2) | .097 | 12452 | -5 |
| FCA-101 | CS-206 | 331 | 2968 | 2920 | (2) | .091 | 11787 | -43 |
| FCA-101 | CS-207 | 279 | 2975 | 2800 | (2) | .098 | 11999 | -8 |
| FCA-101 | CS-208 | 227 | 2985 | 2070 | (2) | .101 | 11988 | 7 |
| FCA-101 | CS-209 | 254 | 2963 | 2240 | (2) | .093 | (2) | (2) |
| FCA-101 | CS-210 | 186 | 2978 | 3510 | (2) | .092 | 12129 | -21 |
| FCA-101 | CS-211 | 194 | 2969 | 1740 | (2) | .090 | 11892 | -48 |
| FCA-101 | CS-212 | 226 | 2993 | 2750 | (2) | .088 | 12147 | -3 |

TABLE D-1 (Cont'd)

76MM STEEL CARTRIDGE CASE EVALUATION

Rapid Fire-Service

Conditioning Temperature 90°F  Mount: MARK 75 MOD 0.  Q.E. 15°

| Barrel Number | Test Unit No. | Case Serial Number | Velocity (ft/sec) | Extraction Forces (lbs) Left | Extraction Forces (lbs) Right | CFK to Ejection (sec) | Uncorrected Range (yds) | Deflection (yds) |
|---|---|---|---|---|---|---|---|---|
| FCA-101 | CS-213 | 247 | 2965 | 2970 | (2) | .100 | (2) | (2) |
| FCA-101 | CS-214 | 251 | 2970 | 2300 | (2) | .096 | 11929 | -49 |
| FCA-101 | CS-215 | 206 | 2958 | 1790 | (2) | .096 | 11829 | -56 |
| FCA-101 | CS-216 | 250 | 2975 | 2300 | (2) | .089 | 11942 | -11 |
| FCA-101 | CS-217 | 310 | 2947 | 2970 | (2) | .089 | 12256 | -6 |
| FCA-101 | CS-218 | 316 | 2964 | 2400 | (2) | .099 | 12239 | -6 |
| FCA-101 | CS-219 | 269 | 2952 | 2240 | (2) | .093 | 12215 | -15 |
| FCA-101 | CS-220 | 271 | 2963 | 3310 | (2) | .091 | 11987 | -28 |
| FCA-101 | CS-221 | 259 | 2972 | 3250 | (2) | .100 | 12322 | 4 |
| FCA-101 | CS-222 | 267 | 2980 | 3030 | (2) | .103 | 12327 | 4 |
| FCA-101 | CS-223 | 265 | 2964 | 3330 | (2) | .092 | 12084 | 4 |
| FCA-101 | CS-224 | 266 | 2960 | 3200 | (2) | .092 | 11976 | -16 |
| FCA-101 | CS-225 | 187 | 2970 | 3480 | (2) | .098 | 12282 | 17 |
| FCA-101 | CS-226 | 329 | 2986 | 3290 | (2) | .099 | 12014 | -34 |
| FCA-101 | CS-227 | 330 | 2980 | 3360 | (2) | .096 | 12386 | -11 |
| FCA-101 | CS-228 | 332 | 2978 | 3430 | (2) | .102 | 12092 | -28 |
| FCA-101 | CS-229 | 282 | 2970 | (2) | (2) | .099 | (2) | (2) |
| FCA-101 | CS-230 | 268 | 2969 | (2) | (2) | .102 | 11855 | -26 |
| FCA-101 | CS-231 | 281 | 2980 | (2) | (2) | .099 | 12169 | 11 |
| FCA-101 | CS-232 | 200 | 2951 | (2) | (2) | .088 | 12009 | -25 |
| FCA-101 | CS-233 | 280 | 2975 | (2) | (2) | .094 | 11818 | -37 |
| FCA-101 | CS-234 | 220 | 2981 | (2) | (2) | .099 | 11916 | -7 |
| FCA-101 | CS-235 | 277 | 2969 | (2) | (2) | .101 | (2) | (2) |
| FCA-101 | CS-236 | 188 | 2964 | (2) | (2) | .090 | (2) | (2) |
| FCA-101 | CS-237 | 249 | 2958 | (2) | (2) | .090 | 12060 | 2 |
| FCA-101 | CS-238 | 253 | 2953 | (2) | (2) | .089 | 11935 | 2 |
| FCA-101 | CS-239 | 274 | 2965 | (2) | (2) | .096 | 12142 | -3 |
| FCA-101 | CS-240 | 252 | 2967 | (2) | (2) | .101 | 11953 | -15 |
| FCA-101 | CS-241 | 272 | 2961 | (2) | (2) | .089 | (2) | (2) |
| FCA-101 | CS-242 | 273 | 2960 | (2) | (2) | .097 | 12190 | -4 |
| FCA-101 | CS-243 | 328 | 2972 | (2) | (2) | .100 | 11972 | -13 |
| FCA-101 | CS-244 | 334 | 2965 | (2) | (2) | .093 | 11869 | -13 |
| FCA-101 | CS-245 | 257 | 2978 | (2) | (2) | .095 | 11879 | -30 |
| FCA-101 | CS-246 | 225 | 2970 | (2) | (2) | .098 | 11934 | 8 |
| FCA-101 | CS-247 | 260 | 2977 | (2) | (2) | .090 | 11989 | 8 |
| FCA-101 | CS-248 | 221 | 2973 | (2) | (2) | .098 | 12095 | 14 |
| FCA-101 | CS-249 | 228 | 2967 | (2) | (2) | .102 | 11880 | -32 |
| FCA-101 | CS-250 | 224 | 2967 | (2) | (2) | .093 | 12075 | -19 |
| FCA-101 | CS-251 | 270 | 2963 | (2) | (2) | .096 | 11819 | -19 |
| FCA-101 | CS-252 | 222 | 2981 | (2) | (2) | .107 | 12002 | -9 |
| FCA-101 | CS-253 | 275 | 2965 | (2) | (2) | .095 | 11891 | -57 |
| FCA-101 | CS-254 | 278 | 2957 | (2) | (2) | .096 | 12007 | 18 |
| FCA-101 | CS-255 | 253 | 2963 | (2) | (2) | .097 | 11961 | 4[illegible] |

(1) Spotting cartridges (round 1 Italian depot round, round 2 steel-cased cartridge (5.30 lb charge weight)).
(2) Data suspect; not recorded.

APPENDIX E

REFERENCES

1. Technical Evaluation of 76mm/62 (OTO Melara) MARK 75 MOD 0 Mount; NWL Technical Report TR-2996 of August 1973 (Unclassified).

2. Limited Technical Evaluation of 76mm/62 Gun Mount MARK 75 MOD 1; NSWC/DL Technical Report TR-3281 of April 1975 (Unclassified).

3. Technical Evaluation of 76mm/62 Caliber Ammunition for the MARK 75 Gun Mount; NSWC/DL Technical Report TR-3355, Publication Pending (Confidential).

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5. 76mm/62 Caliber Ammunition Reliability Assessment Report; NSWC/DL Technical Report, Publication Pending (Unclassified).

6. 76mm/62 Caliber Ammunition Engineering Evaluation Report; NSWC/DL Technical Report, Publication Pending (Confidential).

7. MARK 75 MOD 0 Gun Malfunction Report; NSWC/DL Technical Report, Publication Pending (Confidential)

8. 76mm/62 Caliber Accuracy Assessment; NSWC/DL Technical Report TR-3278, Publication Pending (Unclassified).

9. NOS/IH Memo 5032T:JOR 8032/1 of 21 Jan 1975.

10. NAVSURFWPNCEN/DL Memo DT-41:RCR:ges 8010/1-21 of 10 Sep 1975.

APPENDIX F

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| Structural Overtests | Rapid Fire Service Test |
| Structural Integrity and Compatibility | Smoke-Puff Round |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of tests were performed to evaluate the suitability of a steel cartridge case as a replacement to the brass cartridge case used in the 76mm/62 caliber family of ammunition. The scope of the test program conducted was limited to cartridge case integrity at service and proof conditions, and compatibility with the 76mm MARK 75 gun mount. Tests performed included cartridge case integrity and compatibility tests in the MARK 75 gun mount, and structural overtests (proof firings) in a single fire mount. One

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20. ABSTRACT (Continued)

cartridge case out of 205 cases tested was found to have failed structurally upon firing. After examination of the cartridge case by the Naval Ordnance Station/Indian Head, Maryland, it was determined that the cause of the failure was the presence of a manufacturing defect in the case wall. As a result of the test program and analysis conducted, it is concluded that the steel cartridge case is a suitable replacement for the 76mm brass cartridge with respect to structural integrity and compatibility with the MARK 75 gun mount.