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Technical Report ARFSD-TR-94021

# M864 CARGO EXPULSION FAILURE INVESTIGATION

Paul N. Rasmussen

March 1995

US ARMY
TANK AUTOMOTIVE AND
ARMAMENTS COMMAND
ARMAMENT RDE CENTER

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

Fire Support Armaments Center

**Picatinny Arsenal, New Jersey**

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# REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
March 1995

3. REPORT TYPE AND DATES COVERED
1991 to 1994

4. TITLE AND SUBTITLE
M864 CARGO EXPULSION FAILURE INVESTIGATION

5. FUNDING NUMBERS

6. AUTHOR(S)
Paul N. Rasmussen

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSES(S)
ARDEC, FSAC
Artillery Armaments Division (AMSTA-AR-FSA-MS)
Picatinny Arsenal, NJ 07806-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S)
ARDEC, IMD,
Information Research Center (AMSTA-AR-IMC)
Picatinny Arsenal, 07806-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Technical Report
ARFSD-TR-94021

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 engineering investigation surrounding the cargo expulsion failures of the M864 dual purpose improved conventional munition artillery projectile. The investigation examined the specific causes of the failure mechanism and identify four solutions to the problem. The investigation was terminated before final testing was concluded.

14. SUBJECT TERMS
M864
Expulsion charge
Cargo expulsion
Expulsion

15. NUMBER OF PAGES
23

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT
SAR

NSN 7540-01 280-5500
Prescribed by ANSI Std. Z39-18
298-102

Standard Form 298 (Rev. 2-89)

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# INTRODUCTION

## Purpose

A two phase investigation was initiated to determine a set of solutions for the M864 cargo expulsion failures. Phase I was to develop an immediate solution which would allow the loading of the 320,000 sets of body-ogive metal parts which had been produced. Phase II was to develop a rework procedure for the 70,000 M864 projectiles which had been loaded.

## Background

The M864 is a 155 mm extended range dual purpose improved conventional munition cargo carrying projectile. The cargo consists of 72 M42/M46 antiarmor/ antipersonnel grenades. The projectile's time fuze is preset to initiate at a predetermined time during the projectile's flight trajectory. The fuze detonates the expelling charge, which pressurizes the ogive volume, forcing the forward plate rearward moving the cargo against the base. The base threads are sheared and the base is ejected. The cargo continues moving rearward and is expelled from the projectile. A plastic grommet is assembled to the rear of the projectile for protection during transportation. The projectile was type classified (TC) for low rate initial production (LRIP) in May 1987, with TC-standard following in December 1987. Initial safety (60 rounds) and sequential safety (120 rounds) tests were conducted in accordance with ITOP 4-5-504, "Safety Testing of Field Artillery Ammunition," during this period. While conducting the 7 ft drop phase of the initial safety test, a base separation occurred. The failure occurred after a base down drop followed by a 45 deg nose down drop. Submunitions were exposed, but remained within the projectile. The testing was repeated during the sequential safety phase and did not recur. The failure was treated as an isolated incident.

Initial production testing was conducted at Yuma Proving Ground (YPG) from February through June of 1989. Two projectiles exhibited gaps in the base-body joint following the 45 deg nose down portion of the 7 ft drop test. Analysis indicated that a design deficiency existed which had been previously unnoticed. At this time, the LRIP quantity of metal parts had been fabricated and load, assemble, and pack (LAP) of the base burner assembly (P/N 9381130) was continuing. Production was halted for the LAP of both the base burner and the complete projectile.

The investigation revealed that the M864 projectile, as designed at that time, could fail the 7 ft drop test at 45 deg nose down attitude, provided the plastic grommet was not present. These plastic grommets are damaged and often fall off the projectile during the loose cargo vibration test. During the developmental test, new grommets were placed on the projectiles for transportation to the drop test area and were mistakenly left in place for the drop test. The initial safety test performs the 7 ft drop without a loose cargo test, so the grommets are always in place.

To eliminate the drop test failure, a design modification was made to strengthen the base-body joint. During early lot acceptance testing (LAT), a low rate of expulsion failures was experienced. However, there was no immediate evidence suggesting that the 97% reliability requirement was no longer being achieved. An investigation determined that replacing the existing v-thread ogive-body joint with a buttress joint, and increasing the expulsion charge from 95 g to 105 g, would not only strengthen the joint enough to eliminate all of the failures, it would also increase the expulsion force. It was decided by AMCCOM that retooling for the buttress thread would occur with the next production contract. The current contract continued with the v-thread design. However, during the LAT for the seventh production lot (MA91-G022-007), an abnormal failure rate was evident and production was immediately halted. Approximately 70,000 projectiles with this configuration had been fully loaded. An additional 320,000 sets of body-ogive metal parts had been manufactured and were ready for loading.

## PHASE I

### Data Collection

The first step of the investigation was to collect data to determine the failure mechanism for the expulsion event. It was initially believed that the lampblack, which is added to the LAT samples to aid in observation, was inhibiting expulsion. Lampblack had always been used during developmental testing and in other Improved conventional munitions cargo ejecting projectiles and was believed to have no effect upon expulsion. Testing was conducted with varying expulsion charge sizes as well as varying amounts of lampblack. The results indicated that the lampblack aids the expulsion event by decreasing the volume of the ogive. With lampblack in place, cargo expulsion rates approximated those of a charge 5% higher without the lampblack; static testing later showed the correlation was due to increased peak pressures.

The next aspect that was investigated concerned the effect of the interior finish of the projectile body. A rougher interior surface finish would increase the friction between the cargo and projectile body, thereby increasing the force necessary for expulsion. A series of projectile bodies were examined prior to loading and categorized according to the smoothness of the interior finish. The rough group consisted of projectiles with surface finishes in excess of √200; they were loaded in the normal manner. The smoother group was polished before loading; measurements after polishing showed the surface finishes to be between √25 and √60. Test data showed no statistical difference between the expulsion rates of the different finishes. The rough group tested 28/29 successes and the smooth group had 27/29 successes.

Examination of recovered test hardware revealed that two different expulsion failure modes were occurring. A non-expulsion would occur when smaller expulsion charges were used. The ignition of the charge would not shear the base threads and the entire round would stay intact with the expulsion gasses venting out through the fuze. A blown ogive would occur at larger expulsion charge sizes, sometimes resulting in a partial expulsion where only a portion of the cargo would be expelled. At expulsion charge sizes of 95 to 97 g, both failure modes were observed. In all cases, it was noted that expulsion charge gasses erode through the fuze creating a hole of approximately 1/4 in. diameter.

Stress analysis of the body/ogive joint area showed that the expulsion gasses generated enough force to radially open the body, provided the gasses could reach beyond the initial starting position of the forward plate. Once partially opened, the gasses would then exit through the threaded joint, completely separating the two parts. A test was designed to prevent the gasses from reaching the joint before the base threads were sheared. A 60 durometer Shore A urethane rubber was poured 1 in. deep into the ogive cavity of a sample of the lot 7 production items. After the first 1/4 in. of travel, the base threads were sheared and the cargo ejection had started. Tests indicated a point estimate of 96.6% reliability.

At this point, AMCCOM directed ARDEC to institute a parallel program using all of the prospective solutions. Four possible solutions were identified and simultaneously examined: an ethylenepropylenediene (EPDM) rubber boot bonded to the forward plate, welding of the threaded joint, riveting of the threaded joint, and using threaded pins in place of rivets.

### Ethylenepropylenediene Boot

An EPDM rubber boot was designed to be vulcanized to the forward face of the forward plate. This boot would seal the body-ogive joint from the expulsion gasses. This seal would remain attached to the plate and would continue to protect the joint until the base assembly separates from the body and the grenade cargo is accelerating out of the body. This assembly was tested locally and at YPG.

### Welded Joint

Welding the interior surface of the joint is a permanent solution to strengthening and sealing the area, but requires several steps. First, the body-ogive is baked to destroy the loctite and then they are separated. Both parts are cleaned, and welded together along the faying surface. The weld is then dressed to meet dimensional requirements. Refinishing of the painted surfaces is also required. Testing of the weld was conducted locally and at YPG. This solution is incompatible with loaded projectiles unless first downloaded.

### Riveted Joint

Six holes were drilled radially, equidistant around the body-ogive joint.Rivets were assembled to the body-ogive joint. The rivets will provide increased shear strength and some increase in radial strength. Only rivet diameters of $^5/_{16}$ in. to $^3/_8$ in. were locally tested.

### Pinned Joint

A variation of the rivet design was tried; pins, threaded pins and a bolt design were tested. Two locking methods were used to seal the pins: loctite and Teflon tape.

## Interfacial Seal

After the welded seal testing, a secondary issue was raised regarding cost and producibility. From a strictly technical viewpoint a solution was found, but doubts remained as to its validity because of the implementation cost. Estimates were received from the LAP facilities which indicated that the per unit cost of welding the stockpile of metal parts would be between $40 (FY92) and $60 (FY92), resulting in a total cost in excess of $16 million. Although a successful solution to the problem existed, it was desirable to locate a more cost efficient application.

An interfacial seal (fig.1) was formed by applying Loctite's Ultrablue 587 to the interior surface of the body-ogive joint. This sealant adds no radial strength to the joint, but does seal the joint from the expulsion gasses. The ultrablue was selected because it is used on the weatherseal assembly in the base burner assembly. The sealant must be allowed to cure for 24 hrs before final assembly is initiated. The cost of the interfacial seal was estimated to be between $4 (FY92) and $5 (FY92) per unit.

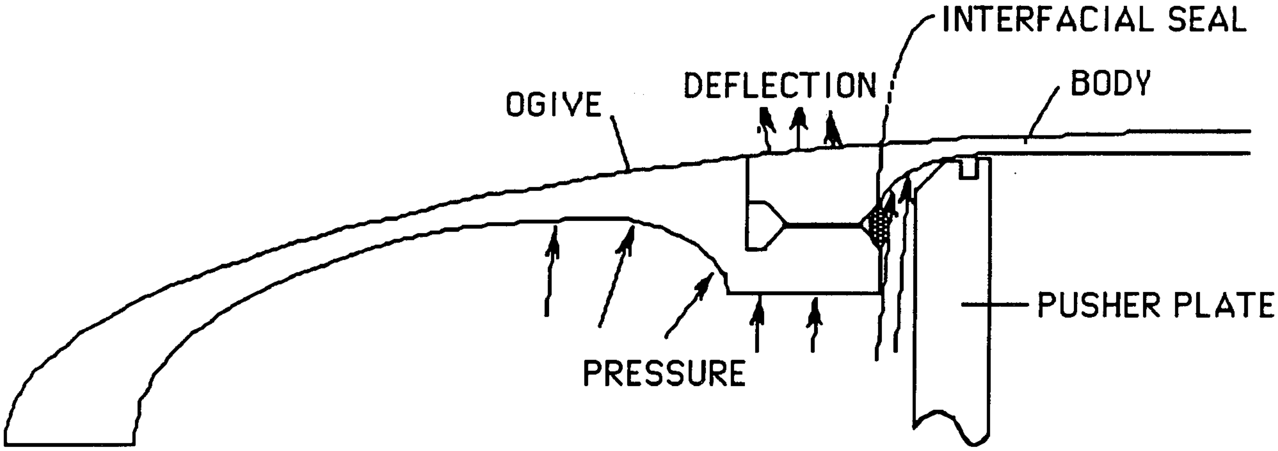

Figure 1. Interfacial seal

## DESIGN TESTING

Static ogive tests were conducted at ARDEC in the Energetic's Test Range. An ogive was attached to a holding fixture representing the starting forward plate position. The ogive was loaded with an expulsion charge and a modified M577 fuze. The fuze was initiated electronically while pressure measurements were recorded inside the ogive cavity. Later tests were also conducted with nonstandard fixtures representing the cargo position after 4 in. of travel. Note that the local tests were static in relation to movement of the cargo so that pressure-time curve measurements represent the peak pressure for the position at which the fixture is configured and not necessarily those of a projectile with moving cargo.

Tests at YPG were conducted for expulsion effects as stated in the projectile specification for the LAT. The projectiles were fired with the M203A1 propelling charge and the M577A1 mechanical time superquick fuze. The firing data and determination of successful cargo expulsion was collected. The failure mode was determined by recovering and examining the hardware.

## TEST RESULTS

### ARDEC Tests

#### Ethylenepropylenediene Boot

A standard test fixture was used. Five tests were conducted with charge sizes of 94 g and 97 g. The average peak pressures of the two charge sizes tested in this smaller ogive volume are presented in table 1. These were used to determine starting expulsion charge weights for testing at YPG.

#### Welded, Riveted, and Pinned Joint Designs

Prior to local testing of the mechanical designs, an overtest was designed to determine an always fail charge weight. The purpose of the overtest was to allow for the difference in burning characteristics of the expulsion charge between the static stand and the spin of flight. The difference is not empirically known, but deduced from the difference in the failure rates between the static tests and the flight tests. It was found that at 110 g the static test always fails, thus any modification made which improves from this failure rate would represent a possible solution worthy of further investigation. The test data for the various designs is represented in table 2.

## Yuma Proving Ground Tests

### Ethylenepropylenediene Boot

There were two phases of YPG testing with the EPDM Boot, the first was to establish a proper expulsion charge size and the second to qualify the fix. The data from the expulsion charge sizing test is presented in table 3. Numbers in parentheses represent additional test rounds which were fired, but did not have a proper primary fuze action (NFA) which is a no-test condition. On the basis of the test results it was decided to qualify an expulsion charge of 111.5 g with a known safety window between 110.5 and 113 g.

During the qualification tests, the boot performed with a 92.7% reliability (51/55 fully successful expulsions), all failures were partial expulsions of cargo (table 4).

### Welded Joint

An expulsion charge sizing test was conducted for the welded seal which was then followed by a qualification test. All test projectiles functioned properly during both phases except for several NFAs. The qualification test was performed with an expulsion charge of 105 g with a known window of 99 g to 111 g. The results are collected in tables 5 and 6.

### Interfacial Seal

The interfacial seal was recognized as a method to seal the joint from the expulsion charge gasses without adding any additional strength to the joint. Initial testing determined that this seal would fail at the 105 g charge proven by the welded seal. A new charge weight of 100 g was selected and successfully qualified with a final test of 117/117 with two NFAs. Test results are tabulated in table 7.

# EVALUATION OF TEST RESULTS

## ARDEC Tests

### Ethylenepropylenediene Boot

The evaluation of the peak pressures demonstrated that an expulsion charge weight of 97 g was comparable to expulsion pressures of the 105 g charge, which ranged from 10.4 ksi to 10.7 ksi. It was decided that testing would begin at 94 g so that a window of tolerance would exist.

### Welded, Riveted, and Pinned Joint Designs

The only joint design which passed any of the local tests was the welded seal, all others failed at the ogive-fixture joint. Testing at YPG was scheduled to prove out a charge size window with 99 g and 111 gas the starting boundaries.

## Yuma Proving Ground Tests

### Ethylenepropylenediene Boot

The boot sealed the joint area as desired, but also reduced the surface area available for the piston action of the forward plate by approximately 20%. This resulted in a necessary increase in expulsion charge weight to 111 g. At this higher charge weight the lip of the boot, which sealed the thread from the gasses, began to experience shear failures that allowed the gasses to reach the joint. This resulted in several delayed body-ogive separations which occurred after the cargo started to exit the projectile, but before it was fully ejected. The EPDM boot decreased the exposed surface of the pusher plate and the effects were greater than anticipated. The reliability of the boot was 88% at 80% confidence, 97% reliability at 80% confidence is required.

### Welded Seal

The welded seal was qualified at a 105 g charge weight with a known safety margin existing from 99 g to 111 g. The reliability of the welded seal was 97% at 95% confidence (99% confidence if all 160 test points are used). The actual limits of the seal are unknown because a failure never occurred.

### Interfacial Seal

The interfacial seal test produced a reliability 97% with a 97% confidence. These results provided a low-cost solution to the expulsion problem. An added benefit was that the interfacial seal could be implemented in 4 months as opposed to the10 to 12 months required for the welded seal.

# PHASE II

## Rework Designs

The interfacial seal did not lend itself easily to a rework procedure for the previously loaded projectiles. Other methods of sealing the joint were researched with two processes being pursued. The molded seal (fig.2) is a modification of the EPDM boot. Grease/mold release is applied to the pusher plate's front surface. A circular mold is placed into the ogive and held and positioned with a press tool. A force of 3 tons is applied to crush the rubber pad behind the pusher plate. When the fast-cure urethane rubber is poured into the area, it flows into the area between the joint and the pusher plate thus forming a rubber seal. By allowing the seal to bond to the ogive surfaces and not the pusher plate, the expulsion gasses hold the seal in place.

Figure 2. Molded seal

The fluidic seal (fig.3) is a mixture of Dow Corning (DC) 111 valve lubricant with glass beads. The DC 111 is a very high viscosity lubricant used primarily in the refrigeration industry; it has a working temperature range of -50°F to 400°F. The glass beads are added to guarantee that a gap exists between the pusher plate and the rear surface of the ogive. The components can be added to the ogive separately (glass beads first is recommended) without any mixing required. During setback in the gun tube, the fluidic seal will form a buffer region between the joint and the interior of the ogive. During the expulsion event the joint is protected from the gasses.

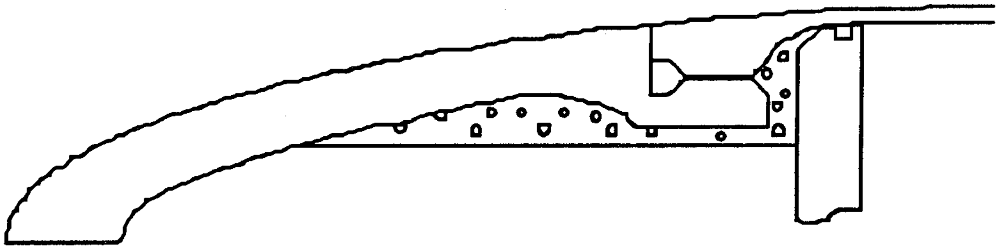

Figure 3. Fluidic seal

Static ogive tests determined target expulsion charge sizes of 100 g for these two solutions.

## Interlude

Production was restarted with the interfacial seal and ran smoothly for the first eight lots. Coincidentally, the load plant was using up the small sized projectile metal parts lots during the startup of the interfacial seal. These lots were the metal parts produced by Scranton (AAP). When the loading facility, Milan AAP, started to use the Louisiana AAP (LAAP) produced metal parts, expulsion failures occurred. The first lot to experience a failure was the second production lot using the LAAP parts (MA93-C024-010). Loading of M864 projectiles was immediately halted and the investigation was reopened.

## Data Collection

Production was halted during the fifth lot (MA93-C024-013) of LAAP parts. Acceptance testing was concluded for the in-process lots. Lot 9 was the first lot to use the LAAP parts, it was retested to determine if its initial acceptance was a mischance. The same lot of Laap produced metal parts was used to load lots 9 and 10, thus the direction of the investigation hinged on the results of the lot 9 retest. Lot 9 failed during the retest, so a broad scope for the investigation was prepared. Also, all of the later assembled LAAP lots failed LAT. Since failures coincided with startup of the second LAP line at Milan AAP, it was postulated that the increased interfacial seal application rate may have caused incomplete sealing of the joint. To test the hypothesis, a set of 20 projectiles were loaded with double the normal amount of material for the interfacial seal. When tested for cargo expulsion at YPG, this group had four blown ogive failures. The search for the cause of the new failures was shifted to the projectile metal parts.

An analysis of ammunition data cards showed that the only manufacturing change timed with the failures was the change in body-ogive manufacturer. A sample of 38 projectiles from each of the failed lots (MA93-C024-009 through MA93-C024-013) were downloaded at Milan AAP and sent to ARDEC for analysis. The ARDEC analysis included separating the body-ogives and performing a dimensional study of the threads. It was found that some components failed to meet the technical data package requirements in several measurement areas. Approximately 55% of the body threads and 30% of the ogive threads were out of tolerance, and 56% of the bodies failed the minimum wall thickness requirement. In an attempt to definitively establish a primary cause of the failures, a series of controlled tests were established. This series was categorized into three areas: vent control, friction reduction, and workmanship.

To determine if controlling the fuze venting characteristics would eliminate/exacerbate the ogive failures, three tests were developed. First, a heavy steel washer was placed between the fuze and the expulsion charge. The hole in the washer was 0.3 in. diameter and would ensure that the gasses venting through the fuze would be limited to a known quantity. Second, a vented expulsion cup was designed and tested at ARDEC prior to flight tests. The vented cup allows the expulsion gasses to immediately enter the ogive without first having to burst the expulsion cup, creating a smoother buildup of pressure in the ogive with fewer shock waves. The third approach was to use the washer and the vented cup together. Thirty projectiles of each configuration were prepared for testing at YPG. Statistically, zero failures would show a significant improvement which would need to be pursued. None of the venting solutions passed the test. The results are tabulated in table 8.

Reducing the payload friction was accomplished by selecting a group of 24 body-ogives and repolishing the interior body surface finish to $\sqrt{60}$. These were fired against a control group without special treatment which had a surface finish of $\sqrt{125}$. Surface finish measurements were taken on all of the test and control samples. In addition, a group of 30 projectiles was fabricated eliminating the o-ring in the body-ogive joint. It was postulated that the o-ring was sealing the joint and causing an overstress in the area. The results of these tests are in table 9.

The downloaded metal parts were selectively reassembled into four known families. Group 1 consisted of parts which failed both the minimum wall thickness and the thread profile requirements, group 2 failed minimum wall but met the thread profile, group 3 met all requirements, and group 4 met the wall thickness but failed the thread profile. The results from testing these groups would determine which of these characteristics were critical. The results are in table 10 and demonstrated that neither the wall thickness nor the thread profile was critical over the range tested and that the current overall design had an inherent weakness.

A comparison of the differences between the manufacturing processes and physical characteristics of the parts from the two producers was performed to determine why the Scranton parts passed expulsion tests with the interfacial seal and the LAAP parts failed. It was found that there were many small differences between the manufacturing methods, but nothing that was of significance. The Scranton parts tended to have slightly higher strength (159 versus 153 ksi yield) and the mechanical measurements showed that the Scranton parts would qualify as being statistically in control, whereas the LAAP parts' used the full allowable dimensional range, and in some cases were beyond the tolerance requirement. A stress analysis of the joint was conducted under expulsion conditions. It showed that the joint normally created a gap of approximately 0.001 to 0.002 in. but because some of the LAAP parts were already less than the specified dimensional requirements, this gap would be greater.

The conclusion of this analysis was that the failures were being caused by a combination of the following factors: bad thread profiles, undersized wall thicknesses, weaker metal parts, and higher cargo friction. It was demonstrated that different combinations of these factors were occurring, and that it was not feasible to attempt to develop screening procedures for identifying acceptable parts.

## Engineering Thrust

After determining that screening procedures were inappropriate and that the interfacial seal could not solve the problem with the LAAP parts, qualification of a new rework procedure was required. The fluidic and molded seals were presented for immediate evaluation. A new version of the molded seal was developed for testing, which would allow for easier application on the load lines. The seal was premolded and then loaded into the projectile prior to the loading of the pusher plate. This solution was only useful for the projectiles which were not yet loaded, but it represented a great savings in cost and time for immediate testing and future production. The fluidic seal was hand-loaded into ammunition at YPG. The projectiles loaded were from the actual production lots which previously failed LAT.

Another solution which was proposed was called the expansion ring (fig.4). The expansion ring was a steel ring which was pressed into a body-ogive causing an interference fit inside the ogive at the joint. Stress analysis showed that this would decrease the radial displacement within the joint by up to 0.006 ins. thus strengthening the joint. Samples of each of the three solutions were prepared and ballistically tested at YPG. The results are tabulated in tables 11 through 13. One failure to expel was observed during a low expulsion charge test of the fluidic seal, but there were no blown ogives during any of the tests.

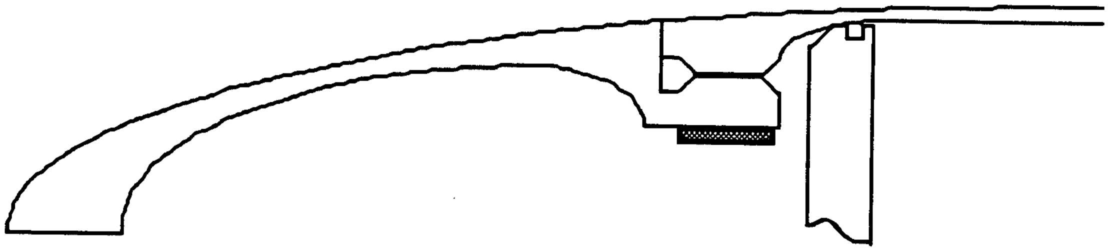

Figure 4. Expansion ring

## CONCLUSIONS

It was decided that there was no need to qualify all three fixes, so a down selection was made to the expansion ring and the fluidic seal. These were the most cost and time effective methods to introduce to production, costing between $4 (FY93) and $8 (FY93) per unit.

The molded seal was comparable in price if premolded units were used, but was significantly more expensive to use as a rework procedure for already loaded rounds. However, it was kept as a fall-back in case the fluidic seal failed.

Qualification of these solutions was never completed. The Deputy Chief of Staff for Ammunition at HQ, AMC, determined that the Army has no requirement for the 326,000 Louisiana Army Ammunition Plant v-thread rounds, and work was immediately halted. The projected inventory requirement for the M864 projectiles was reduced to a level that it would be met by buttress thread production.

This decision was made due to the changing needs of the U.S. military and the reductions in Army Acquisition objective.

Table 1. Static ogive tests - EPDM boot

| Charge size (g) | Peak pressure (KSI) |
|---|---|
| 94 | 9.7280 |
| 97 | 10.2912 |

Table 2. Static ogive tests - various fasteners

| Date/Test # | Design | Pass/Fail | Charge Weight (g) |
|---|---|---|---|
| 7 May/1 | Standard | Fail | 110 |
| 7 May/2 | Standard | Fail | 110 |
| 7 May/3 | Standard | Fail | 110 |
| 7 May/4 | Pinned (T-1) | Fail | 110 |
| 7 May/5 | Welded (T-11) | Pass | 110 |
| 7 May/6 | Welded (T-12) | Pass | 110 |
| 10 May/7 | 6x$^1/_4$ Rivets (T-6) | Fail | 110 |
| 10 May/8 | 6x$^1/_4$ Rivets (T-7) | Fail | 110 |
| 12 May/9 | Threaded Pin (Loctite) (T-8) | Fail | 110 |
| 12 May/10 | Threaded Pin (Teflon Tape) (T-9) | Fail | 110 |
| 3 Jun/1 | Welded | Pass | 110 |
| 3 Jun/2 | Welded | Pass | 110 g |
| 3 Jun/3 | Welded | Pass | 110 g |
| 24 Jun/a | Bolt w/ shoulder | Fail | 110 g |
| 24 Jun/b | 6x$^3/_8$ Rivet | Fail | 110 g |
| 24 Jun/c | 6x$^5/_{16}$ Rivet | Fail | 110 g |

Table 3. YPG expulsion tests - EPDM boot

| Charge Weight (g) | -50°F | 145°F |
|---|---|---|
| 113 | | 15/15 |
| 109 | 13/14(1) | |
| 107 | 4/10 | |
| 105 | 2/13(2) | 29/29(1) |
| 103(washer) | 0/5 | |
| 103 | 0/4 | |
| 101 | 1/6 | |
| 97 | 0/7 | 8/8(1) |
| 94 | 0/2 | |

Table 4. YPG expulsion tests - EPDM boot

| Charge Weight (g) | Temperature | Results | Notes |
|---|---|---|---|
| 113 | 145°F | 15/15 | |
| 111.5 | 145°F | 20/20 | Three Blown Ogives with Partial Expulsion |
| 109 | -50°F | 20/20 | One Blown Ogive with Full Expulsion |

Table 5. YPG expulsion tests - welded seal

| Charge Weight (g) | Temperature | Results |
|---|---|---|
| 111 | 145°F | 29/29 |
| 99 | -50°F | 28/28 |

Table 6. YPG expulsion tests - welded seal

| Charge Weight (g) | Temperature | Results |
|---|---|---|
| 105 | 145°F | 33/33(2 NFA) |
| 105 | 70°F | 35/35 |
| 105 | -50°F | 35/35 |

Table 7. YPG expulsion tests - interfacial seal

| Charge Weight (g) | Temperature | Results |
|---|---|---|
| 105 | 145°F | 47/49 |
| 100 | 145°F | 38/38(1 NFA) |
| 100 | 70°F | 40/40 |
| 100 | -50°F | 39/39(1 NFA) |

Table 8. YPG expulsion tests - vent control

| Variation | Charge Weight (g) | Results |
|---|---|---|
| Washer | 100 | 17/18 |
| Vented Cup | 100 | 18/19 |
| Vented Cup and Washer | 100 | 15/16 |

Table 9. YPG expulsion tests - friction reduction and no O-ring

| Variation | Charge Weight (g) | Results |
|---|---|---|
| Surface Finish Control | 100 | 22/24 |
| Surface Finish Test | 100 | 23/24 |
| No O-Ring | 100 | 29/30 |

Table 10. YPG expulsion tests - selected assembly

| Variation | Charge Weight (g) | Results |
|---|---|---|
| Bad Wall/Bad Thread | 100 | 24/27 |
| Bad Wall/Good Thread | 100 | 27/27 |
| Good Wall/Good Thread | 100 | 15/17 |
| Good Wall/Bad Thread | 100 | 22/25 |

Table 11. YPG expulsion tests - expansion ring

| Charge Weight (g) | Results |
|---|---|
| 100 | 31/31 |
|  |  |

Table 12. YPG expulsion tests - fluidic seal

| Charge Weight (g) | Temperature | Results |
|---|---|---|
| 97 | 70°F | 3/4 |
| 100 | 70°F | 30/30 |
| 100 | -50°F | 4/4 |
| 101 | 145°F | 1/1 |
| 102 | 145°F | 4/4 |
| 103 | 145F | 3/3 |
| 104 | 145°F | 3/3 |
| 105 | 145°F | 3/3 |
| 106 | 145°F | 2/2 |

Table 13. YPG expulsion tests - molded seal

| Charge Weight (g) | Results |
|---|---|
| 100 | 28/28 (2NFA) |

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Aberdeen Proving Ground, MD 21005-5066

Commander
Chemical/Biological Defense Agency
U.S. Army Armament, Munitions and Chemical Command
ATTN: AMSCB-CII, Library
Aberdeen Proving Ground, MD 21010-5423

Director
U.S. Army Edgewood Research, Development and Engineering Center
ATTN: SCBRD-RTT (Aerodynamics Technical Team)
Aberdeen Proving Ground, MD 21010-5423

Director
U.S. Army Research Laboratory
ATTN: AMSRL-OP-CI-B, Technical Library
Aberdeen Proving Ground, MD 21005-5066

Chief
Benet Weapons Laboratory, CCAC
Armament Research, Development and Engineering Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-CCB-TL
Watervliet, NY 12189-5000

Director
U.S. Army TRADOC Analysis Command-WSMR
ATTN: ATRC-WSS-R
White Sands Missile Range, NM 88002