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Adaptation of Existing Fuze Technology to Increase the Capability of the Navy's 2.75-Inch Rocket System

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Agenda

- Background
- Design Description
- Expulsion Analysis and Testing
- Ballistic Testing
- Current Status
- Conclusions

BACKGROUND

Background

The 2.75-Inch Rocket System is a tri-service area suppression weapon system.

- Uses multiple warheads
  - HE
  - Smoke
  - Flare
  - Flechette
  - Sub-Munitions
  - Practice
- Used on multiple Rotary Wing and Fixed Wing platforms

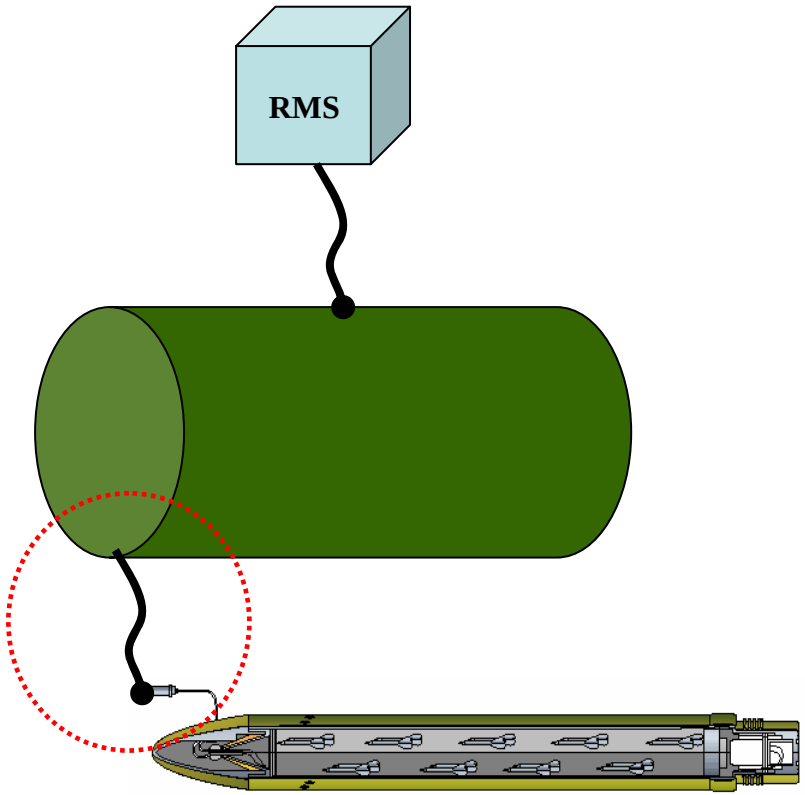
Background

The Navy/MC has identified a need for a 2.75-inch flechette warhead.

- Current Navy Flechette Warhead, WDU-4A/A, has been out of production for 20 years.
- Current Navy Launchers do not allow the use of the Army's M255A1 Flechette.
- Navy/MC wanted the capability of the M255A1 but with the ability to function from Navy launchers like the WDU-4A/A.

Background

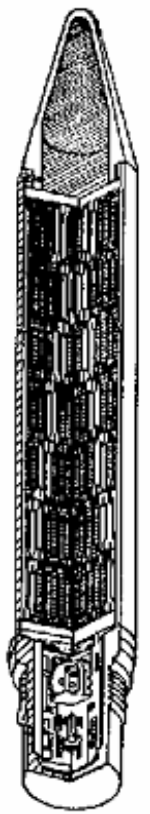
The current M255A1 Flechette Warhead configuration is not compatible with the existing Navy 2.75-Inch Rocket System.



- Uses M439 electronic variable time delay fuze
  - time delay is remotely set from cockpit
  - does not contain internal battery; energy is supplied by aircraft setter
- RMS communicates with M439 fuze via umbilical cable that connects warhead to launcher
  - Sets delay time
  - Provides fuze power

Background

The WDU-4A/A and the M255A1 Flechette Warhead have different physical characteristics and propellant charges.

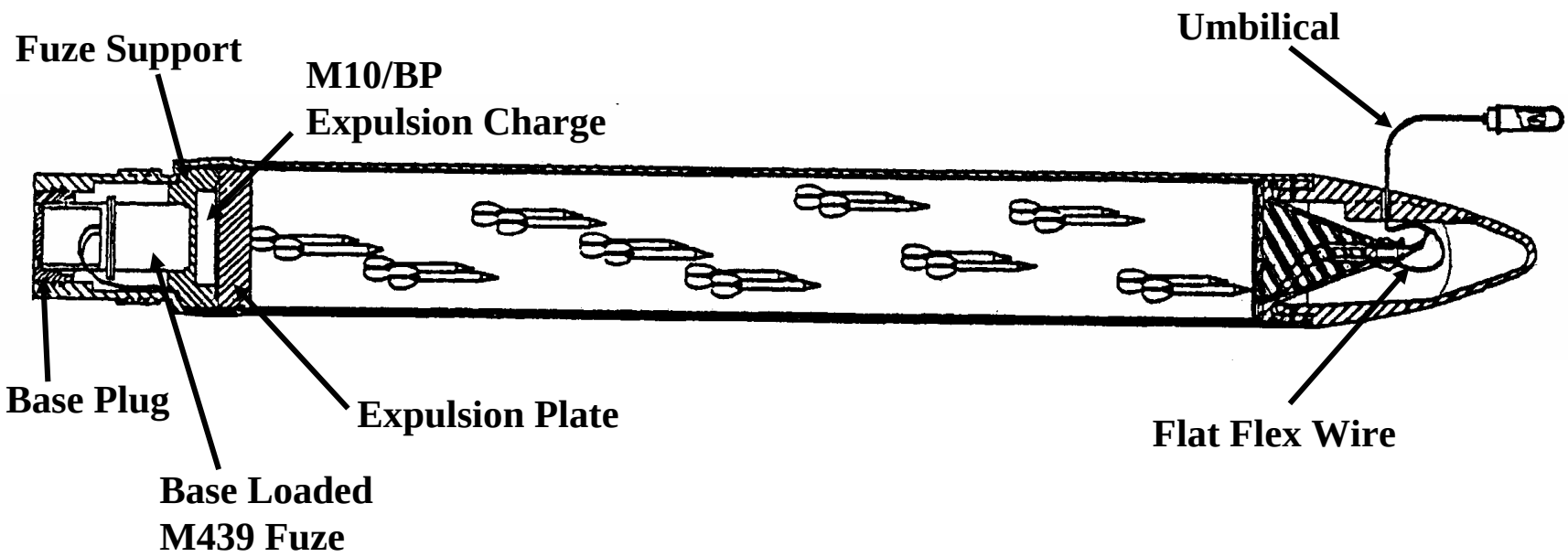


WDU-4A/A		M255A1
---	**LENGTH**	---
17.76	Total (in.)	26.93
---	**WEIGHT**	---
9.3	Total (lbs)	13.9
6.7	Payload (lbs)	10.5
---	**CHARGE**	---
M9	Type	M10/BP
3.0	Weight (g)	4.0/1.0
---	**FLECHETTE**	---
2205	Total Number	1179
20	Weight (grains)	60

DESIGN DESCRIPTION

Design Approach

Cutaway of the current M255A1 Flechette Warhead.



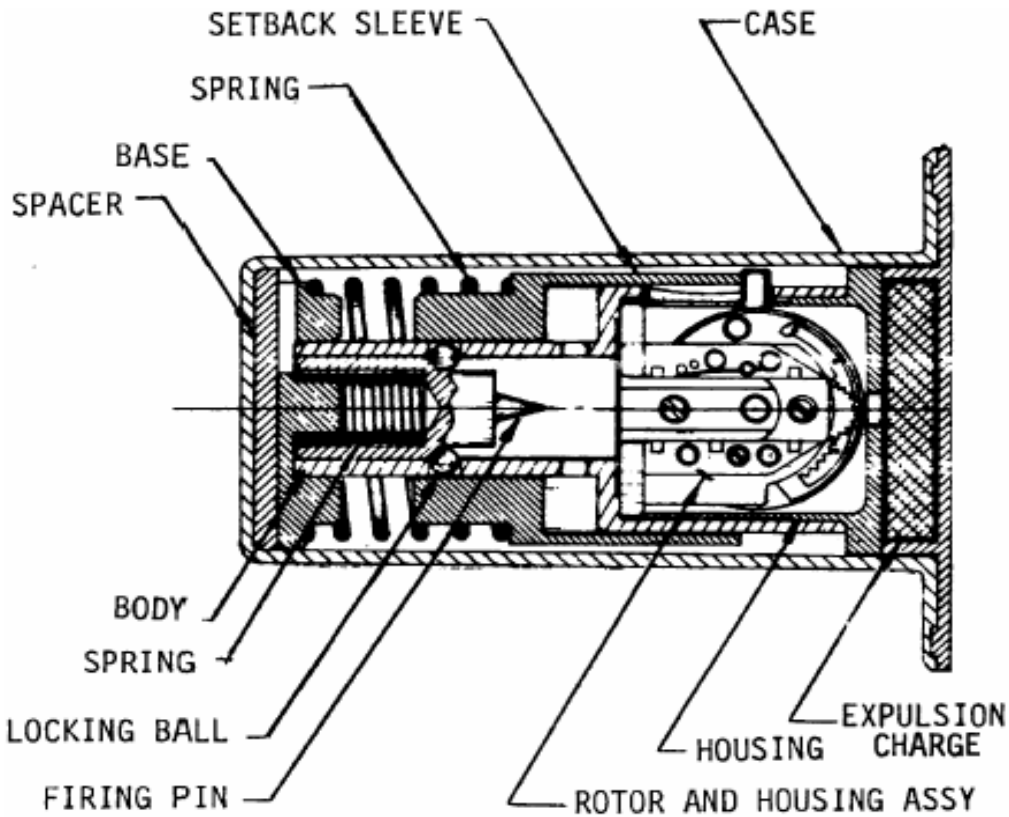
Design Approach

The approach was to replace the M439 fuze in the M255A1 warhead with an existing mechanical fuze to minimize risk.

- Use existing WDU-4A/A Flechette fuze
  - Already fielded
    - Proven safety record
    - Proven to withstand life cycle
- Functions at a fixed time (motor burnout)
- Low technical and safety risk

WDU-4A/A Fuze Description

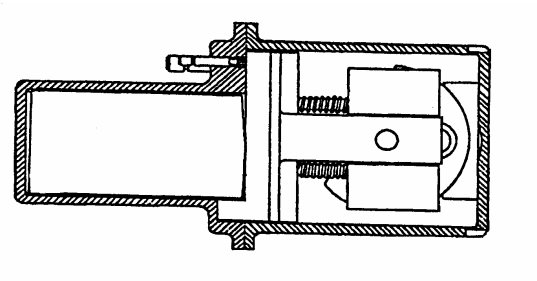
The WDU-4A/A Fuze functions at deceleration and ignites an M9 Expulsion Charge via a PA515 Stab Detonator.



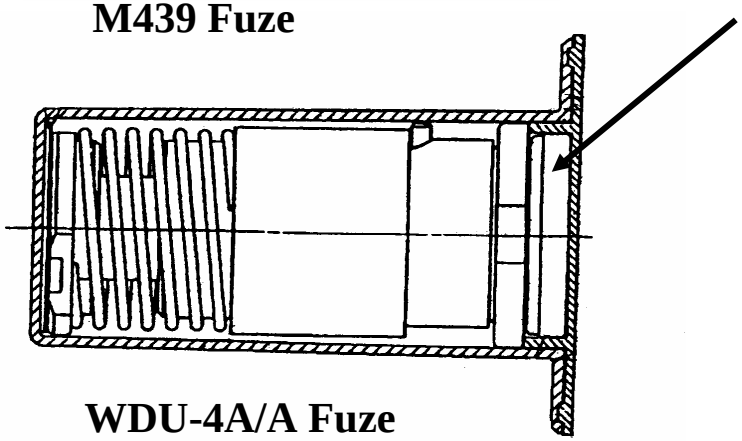
Design Approach

There were fuze differences that need to be accounted for in the warhead design.

- The WDU-4A/A fuze is larger than the M439 fuze, but it contains its own expulsion charge



M439 Fuze

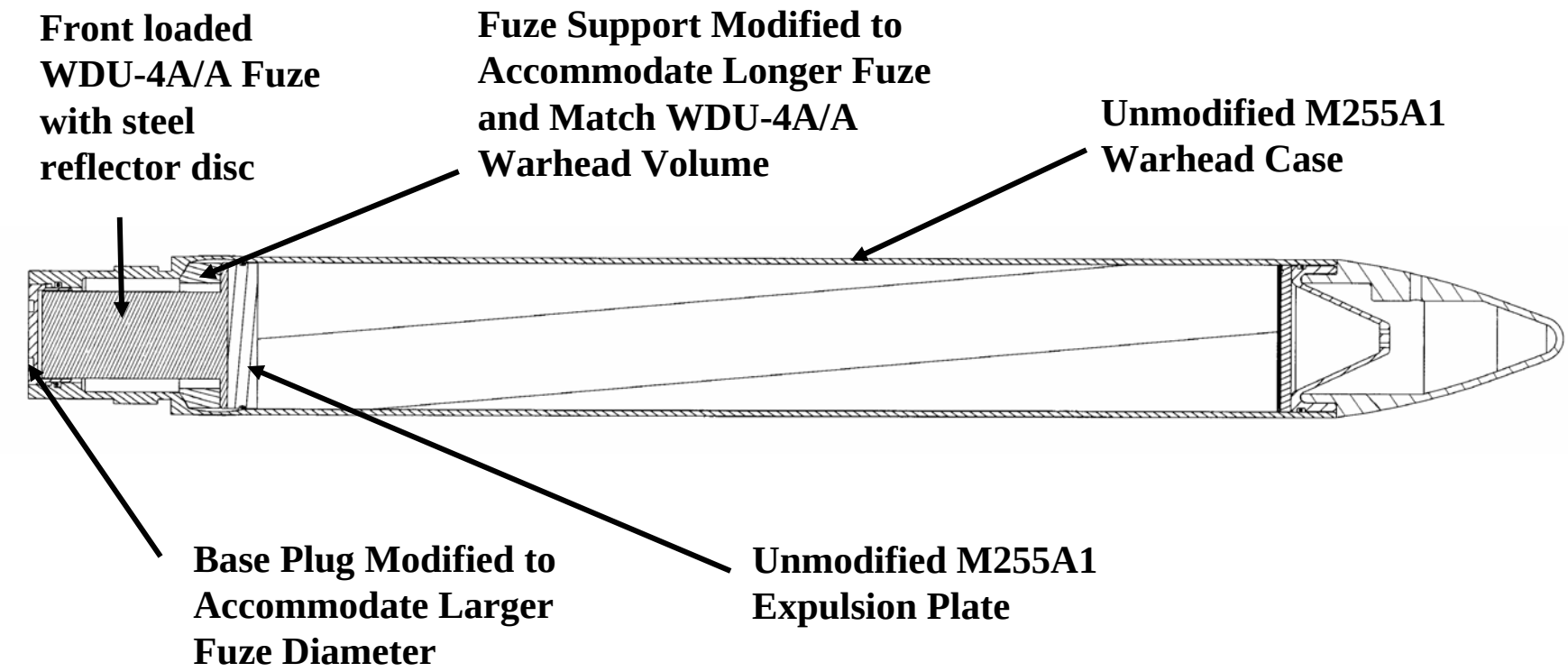


WDU-4A/A Fuze

Fuze	Max Length (inches	Max Diameter (inches)	Length increase over M439 (inches)
M439	2.785	1.500 @ mid-section	Baseline
WDU-4A/A	3.28	2.55	0.495

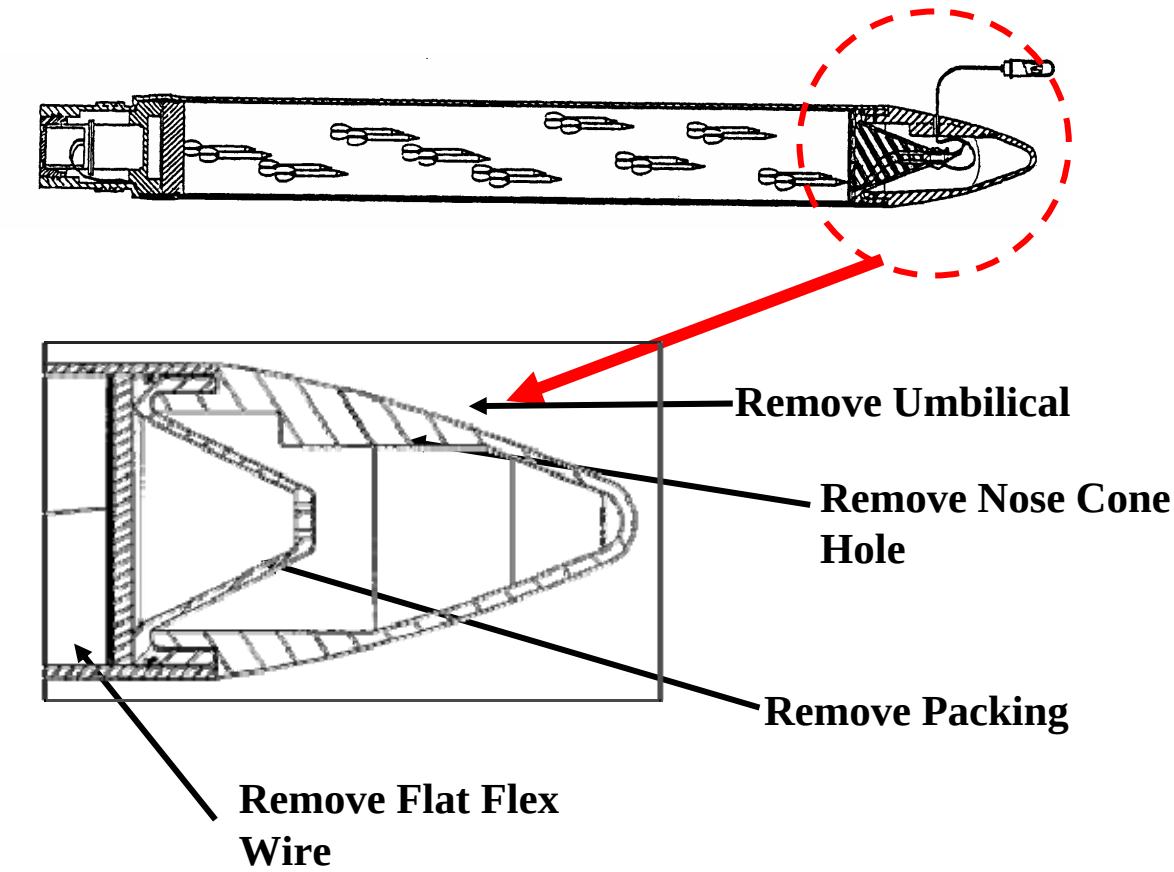
Mk 149 Design

Changes were made to the aft end of the warhead to accommodate the WDU-4A/A Fuze.



Mk 149 Design

Changes were made to the nose end of the warhead to eliminate the umbilical (no longer needed).



Expulsion Analysis and Testing

Analysis

Two major technical issues had to be addressed when incorporating the WDU-4A/A fuze into the M255A1 flechette warhead.

1) Evaluate the structural integrity of the warhead base during the expulsion event due to reduced wall thickness.
2) Evaluate the effect on flechette expulsion performance due to the change in propellant charge.

Expulsion Analysis

An analysis was performed to determine if the WDU-4A/A fuze in the M255A1 configuration provides sufficient payload expulsion as compared to the baseline M255A1.

- Expulsion analysis assumptions
  - Free space volume is different between the two configurations (WDU-4A/A in M255A1 and M439 in M255A1)
  - Expulsion charge is different in type and amount
    - Different burn characteristics
  - Energy will be lost due to friction and heat (based on previous experience with gun barrel analysis)
  - Initial analysis performed at ambient temperature (70F)
  - Propellant burn rates will vary with pressure
  - Detonator output will be a factor in analysis
  - A minimum of 84 fps expulsion velocity is required to prevent the trailing rocket from impacting the payload
    - Based on historical data using high speed video of a WDU-4A/A

Expulsion Analysis Results

The simulated expulsion velocities produced by the M9 closely matches the velocities produced by the M10/BP.

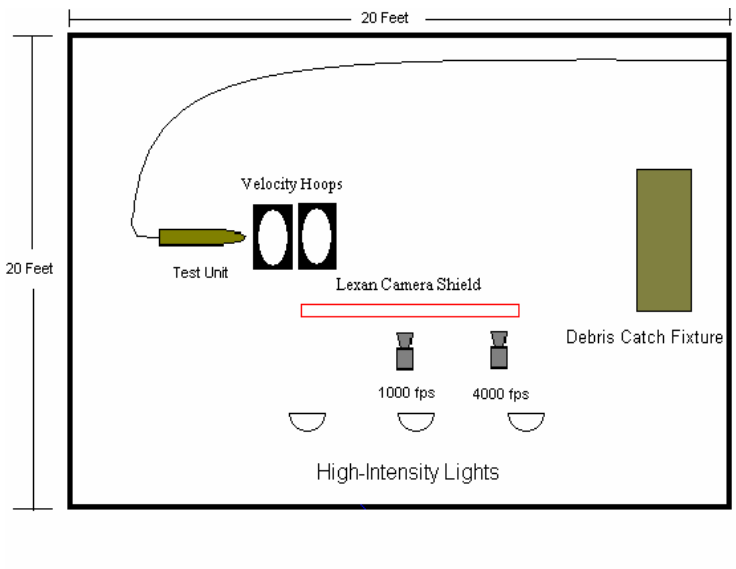
Single Motion: No Recoil

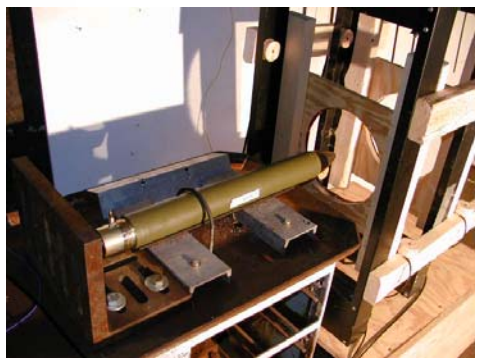
Charge	Stroke	Volume (in3)	Time of Release (s)	Expulsion Velocity (fps)
M10/BP	M255A1	4.648	0.0236	99.28
M9	M255A1	5.985	0.0263	111.57

- Simulated expulsion velocity was higher for M9 than M10/BP run under the same conditions
- M9 burns more efficiently than M10/BP, therefore utilizing more of the expulsion charge
  - M10/BP results in more unburned propellant
  - Expulsion time was slower for M9 than M10/BP
  - Expels payload ~5-6 ft further downrange
- Analysis results provided grounds to support a live fire expulsion test.

Expulsion Test Set-Up

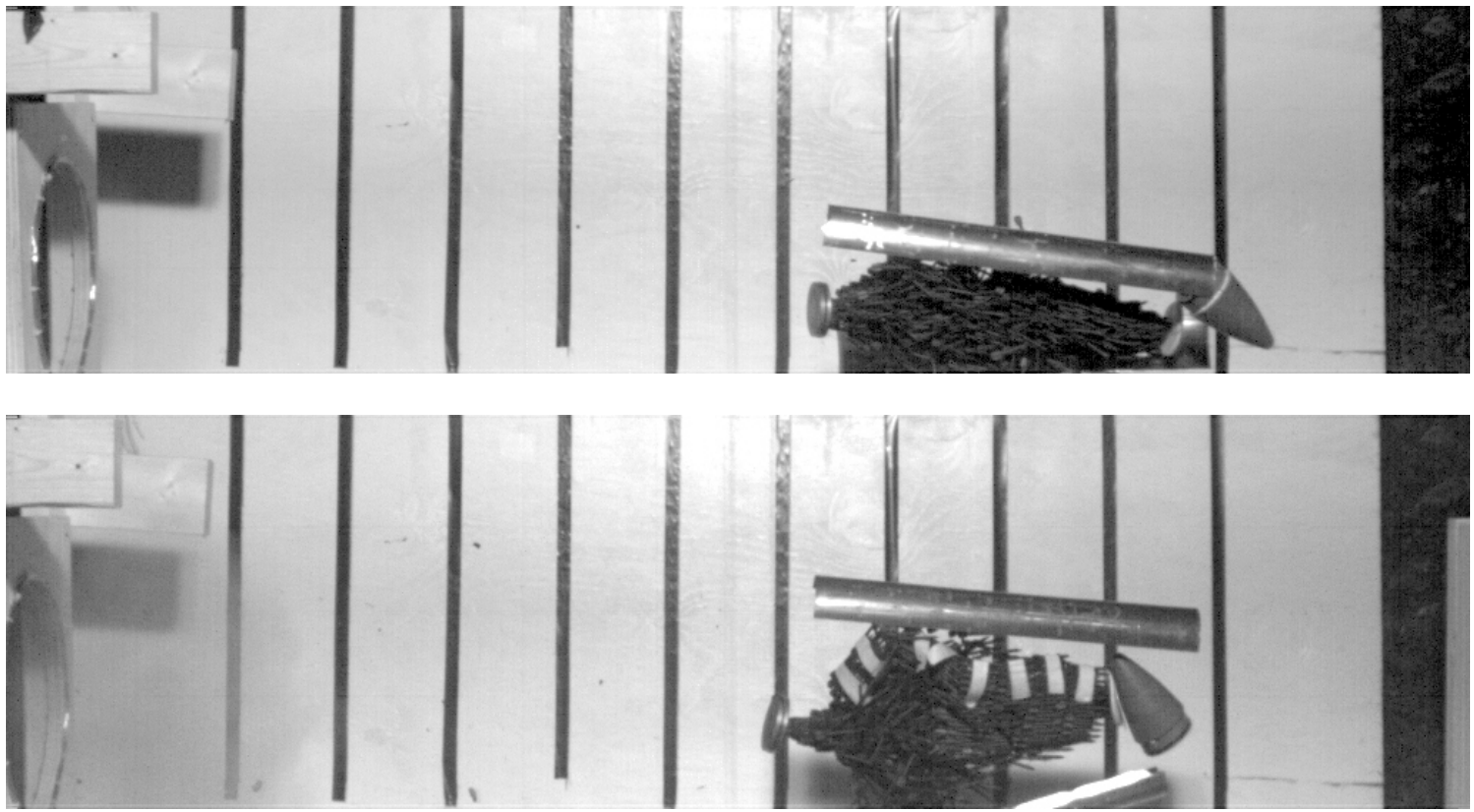
An expulsion test set-up was designed to capture the expulsion velocity and pressures.





Expulsion Test Set-Up

Screen shot of M9 and M10/BP expulsions.



Expulsion Test

The Expulsion Test confirmed that the M9 charge provides sufficient expulsion velocity.

Shot	Velocity	Internal Pressure
T4-M10	121 ft/sec	N/A
T1-M9	106 ft/sec	1209 psi
T5-M10	135 ft/sec	1015 psi
T2-M9	119 ft/sec	909 psi
T6-M10	128 ft/sec	1011 psi
T3-M9	128 ft/sec	>800 psi *

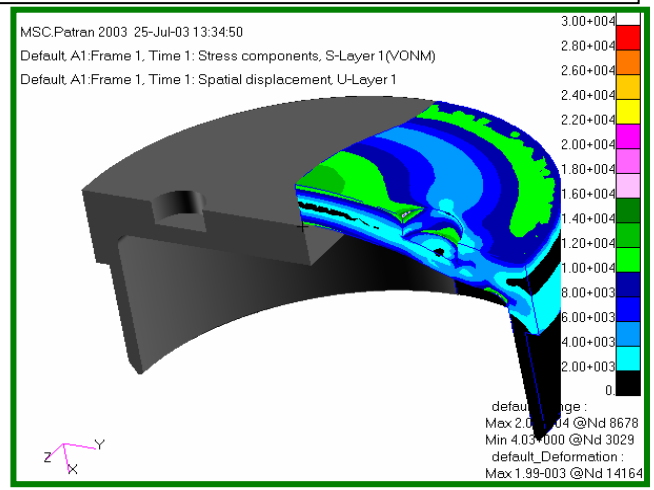
* The oscilloscope was not set to the correct scale and the internal pressure could not be read past 800psi

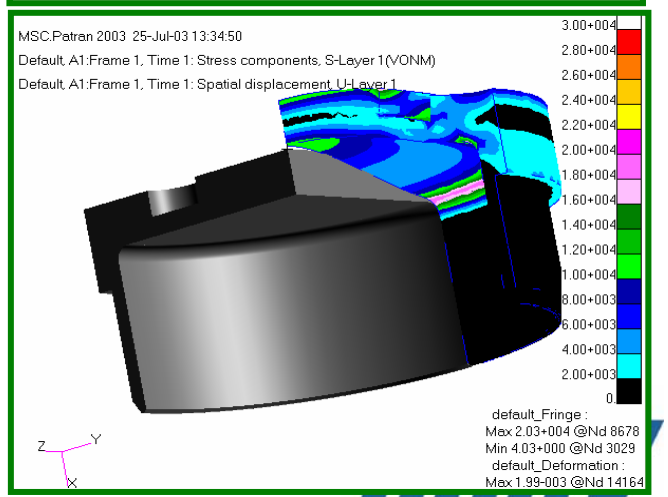
- The velocities of the two configurations overlapped, indicating that the M9 charge is an acceptable substitute for the M10/Black Powder charge.
  - Contribution from rocket motor velocity is the same for both configurations

Analysis Results

The Base Plug was found to be able to withstand the maximum internal pressures witnessed during the expulsion test.

- Primary location of failure for the base plug was determined to be at the bending perimeter of the plug face.
- Analysis determined that 20ksi of material yield strength will be needed to safely contain (without deformation) every 1,000psi of internal pressure.
- Base Plug is 6061-T6 Aluminum with a yield strength of 40ksi making the maximum internal pressure that the case can see without rupture about 2,000psi.
- Max pressure levels during expulsion testing fell well below calculated base plug failure limits providing an adequate factor of safety.





BALLISTIC TESTING

Qualification testing

Some reliability problems were encountered during Qualification.

- 21/23 cold rounds (-50F) functioned and 13/14 hot rounds (+150F) functioned during ground launch at Yuma Proving Ground.
- 2 cold rounds and 1 hot round failed to function
  - 82% reliability vs. desired 89.5%
- All three failed rounds were recovered and inspected
  - Inspection revealed that the M9 bag had a hole burned through the center from the PA515 detonation on one round.

M9 Expulsion Charge

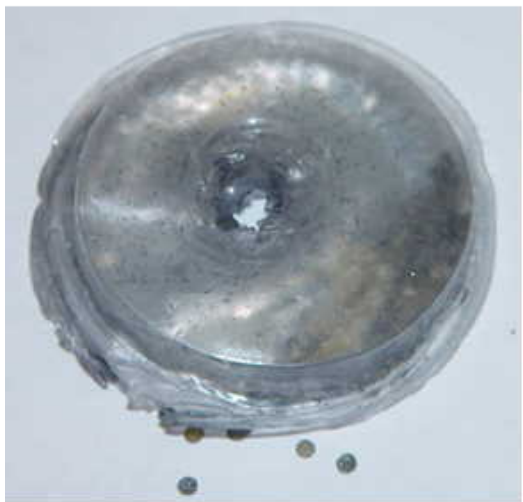
Historical expulsion cup design changes resulted in excess free space in the charge cup.

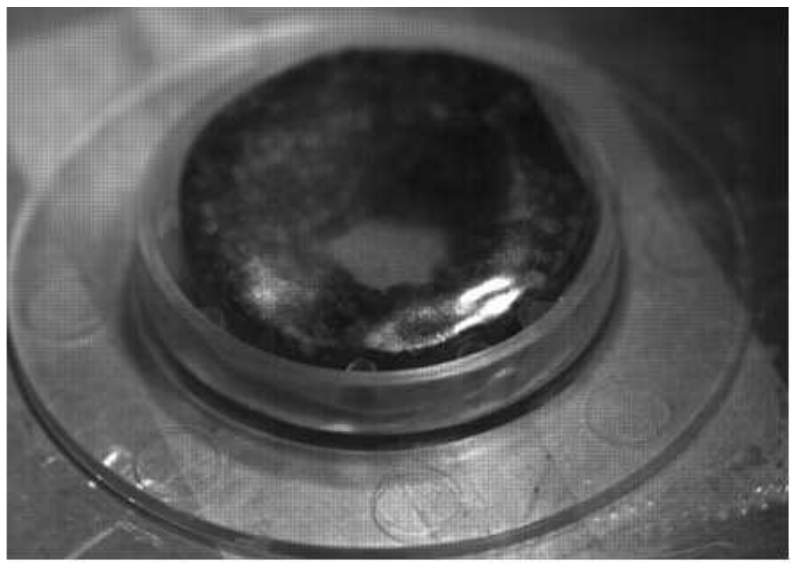
- In the early 80s, the expulsion charge in the WDU-4A/A Fuze was reduced from 5.9g to 3.0g and the composition of the charge was also changed from M9 and Black Powder to just M9. Although the mass of the charge changed, the cup size did not change.
- As a result of the decrease in propellant volume without a decrease in charge cup size, a significant amount of free space is now present in the Expulsion Charge Cup.

Spin Test Results

The excess free space in the charge cup creates a propellant free detonator path under rocket spin during flight.

- Pictures comparing the hole in the M9 charge from the PA515 (left) and what the PA515 would see when it fires during launch (right).

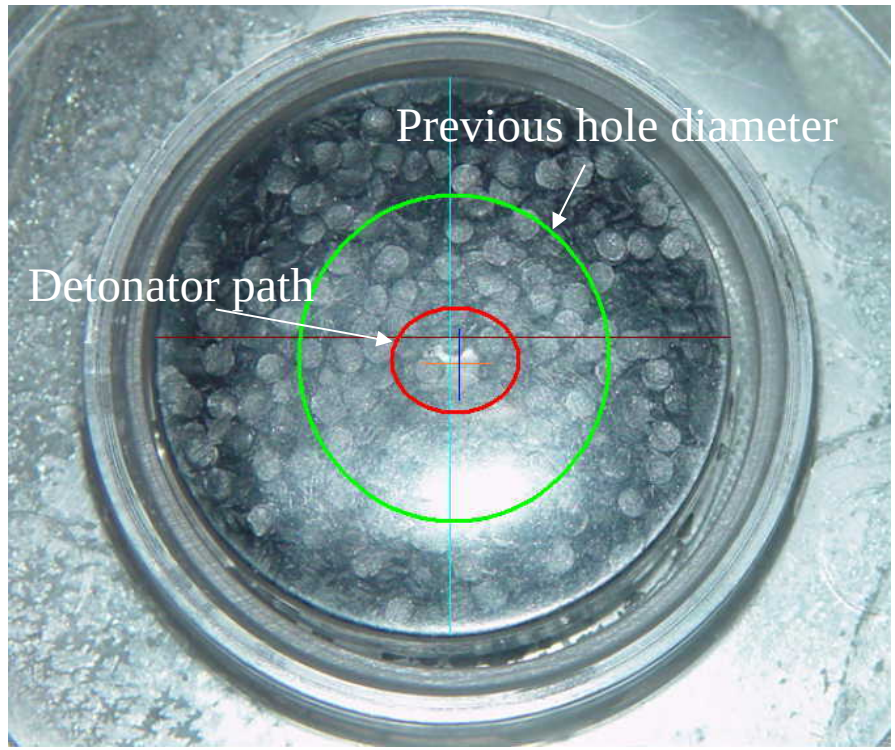




Reliability Improvements

Additional design changes were successful in eliminating the excess free space in the expulsion cup.

- The size of the charge cup was reduced.
- A compression ring was added around the cup to keep propellant in the center.
- The low end of the propellant charge weight was restricted.
- A spin test was performed and the size of the hole was significantly reduced.



Current Status

The modified Mk149 warhead is currently proceeding with Qualification.

- Qualification is continuing with the modified Mk149 Warhead.
- A reliability assessment will take place after functional testing.
  - Actual demonstrated reliability of currently fielded flechette warheads will be taken into account.
- Additional evaluation is being performed concurrently to improve the explosive train for future reliability improvements.
- The Mk149 warhead is scheduled to be fielded in FY08.

Conclusion

- A design was developed to meet urgent user requirements.
  - The design has proven to provide acceptable expulsion performance.
  - The design is currently undergoing qualification.
- Existing technology can be used to fill urgent capability gaps as interim solutions for legacy systems.