120mm Mortar Ignition Cartridge Design Improvement and Black Powder Replacement

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30 March 2006

National Defense Industrial Association

41st Annual Armament Systems: Gun and Missile Systems Conference & Exhibition

Background

- Black powder is still an important energetic used in military applications.
  Over 90 military components distributed by JMC require BP.
  Certain limiting characteristics make it highly desirable to replace BP.
  - ✓ Moisture absorption
  - ✓ Safety during its production
  - ✓ Reproducibility – lot to lot and charcoal variations
  - ✓ High cost
  - ✓ Domestic sole source

- All mortar ignition cartridges use black powder as an intermediary charge. The hygroscopic nature of black powder and unrobustness of the current ignition cartridge sealing method and flash tube assembly have resulted in erratic performance of 120mm mortar systems: M931 Full Range Practice, XM930 Visible Light Illuminating and M929 WP Smoke Cartridges.

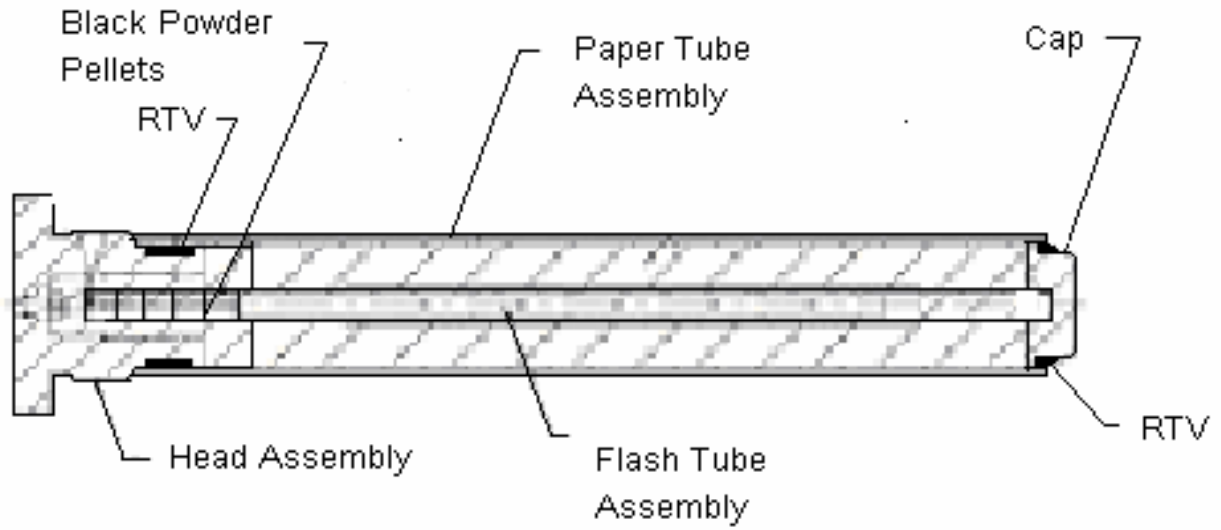
120 mm Mortar Ignition Cartridge Materiel Change Program Objectives

M1020 Ignition Cartridge

- Develop a robust sealing method and reliable flash tube assembly:
  - Eliminate the existing RTV seal and replace it with a mechanical seal
  - Eliminated the existing Mylar tape and replace it with a shrink tube
  - Improve flash tube assembly design
- Evaluate a non-hygroscopic alternate composition to black powder.
- Improve M48 web size to minimize pressure differential between fin blades.

Current Design of M1020 Ignition Cartridge

- An aluminum head assembly that contains a firing pin and percussion primer
- An aluminum flash tube assembly that contains five black powder ignition pellets
- A paper tube assembly (paper tube + Mylar tape) that fits over the head and contains a propellant
- A cap that fits on top of the flash tube and inside of the paper tube
- RTV seal on head and end cap



Improved Design with Crimp Seal

- The ring for the head is a simple band while the ring for the end cap is a rolled-over band. The crimp seal design vs standard design is illustrated below.

Crimp Rings for End Cap and Head

Crimp Ring for Sealing Paper Tube and Cap

Crimp Ring for Sealing Paper Tube and Head

Crimp Seal Design **Standard Design**

Improved Design with Shrink Tube

- A study was conducted to determine the use of shrink tubing with the developed crimp seal design to eliminate the wrinkling and buckling problem and also improve the moisture barrier. Each cartridge sample was loaded with 52 grams of inert farina for a 5-day exposure to moisture. The weights of each sample prior to testing and at day 3 and day 5 were measured.

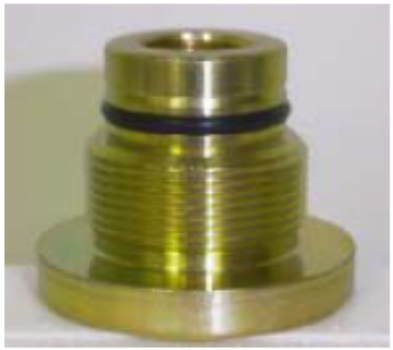
- The results indicate that the crimp seal design with Mylar tape and RTV sealant absorbed as much moisture as the standard design. The crimp seal design with polyolefin shrink tubing had a significant improvement in moisture barrier.

Test Sample		Initial	Day 3	Day 5
Mylar Tape+RTV - Standard Design (Current)	W, g	151.58	152.05	152.18
	ΔW, g	-	0.9%	1.2%
Crimp Crimp+Mylar Tape+RTV	W, g	153.86	154.38	154.51
	ΔW, g	-	1.0%	1.2%
Crimp+ Shrink Tubing+RTV-	W, g	156.42	156.51	156.58
	ΔW,g	-	0.2%	0.3%

Improved Design with O-ring

- An effort to completely eliminate RTV sealant (for cartridge with shrink tube). The head and end cap were modified to include a groove for O-ring sealing.
  - Improvement made the crimp design more producible by eliminating need for RTV sealant and the accompanying costs of curing, clean-up, etc.
  - Eliminated the wrinkling and broken seam problems of the Mylar paper tube assemblies.

O-ring in Head Groove

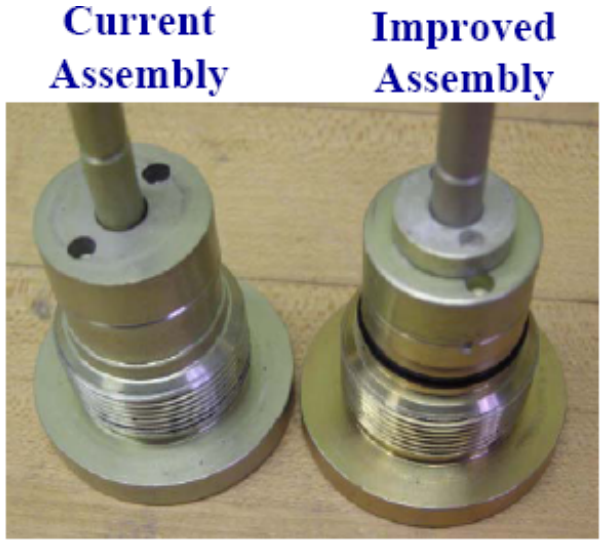


O-Ring in End Cap Groove

Without O-ring | With O-ring

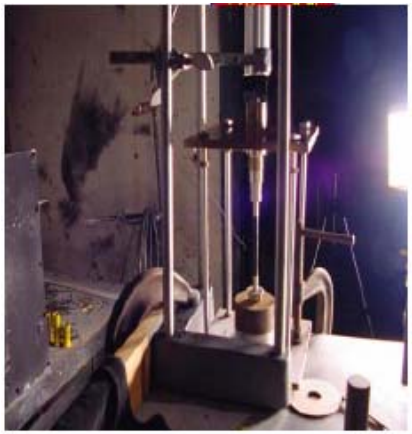
Improved Flash Tube Assembly

- **Current design**
  - The flash tube is loosely assembled to the head assembly body
  - This loose fit design has caused ignition blow-bypass and moisture intrusion from propellant and paper tube, thus reducing the effectiveness of black powder.
- **Improved design**
  - The interior of body (connected to the head assembly) was modified to incorporate an O-ring in a groove and threaded for connecting an adaptor.
  - The flash tube was securely held in place by the O-ring to prevent ignition blow-bypass and moisture infiltration.

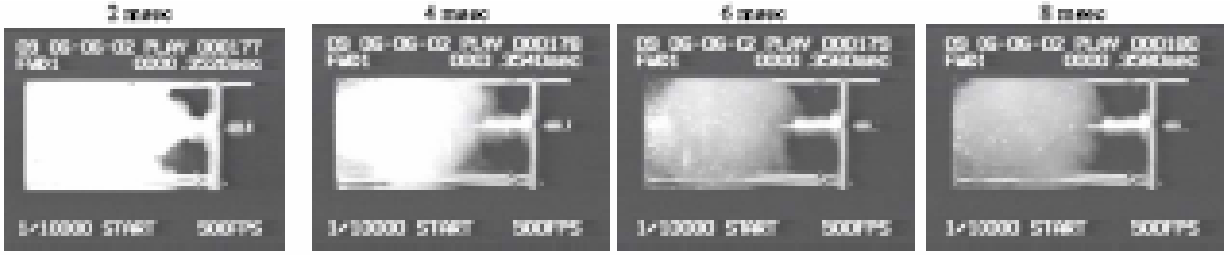


BP Performance
at Various Moisture Levels

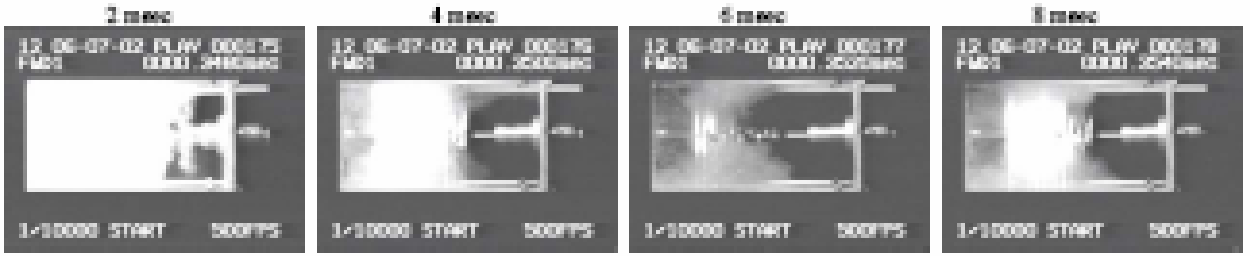
- **An experiment was conducted to evaluate the impact of moisture on black powder (BP) performance in the current flash tube assembly.**
  - **BP pellets were conditioned to various moisture levels (0.6%, 1.6%, 2.5%, and 3.2%) for open ignition (without propellant loaded) in a test fixture. The images captured with a Kodax 500 FPS Motion Corder Analyzer.**
  - **Results indicated that the BP performance degraded progressively with increased amount of moisture.**



BP Pellets at 0.6% Moisture

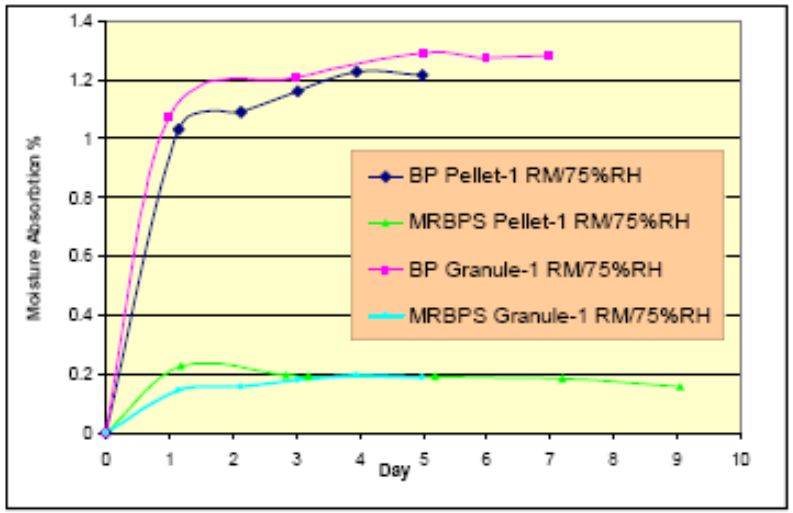


BP Pellets at 1.6% Moisture



Moisture Absorption

MRBPS vs BP

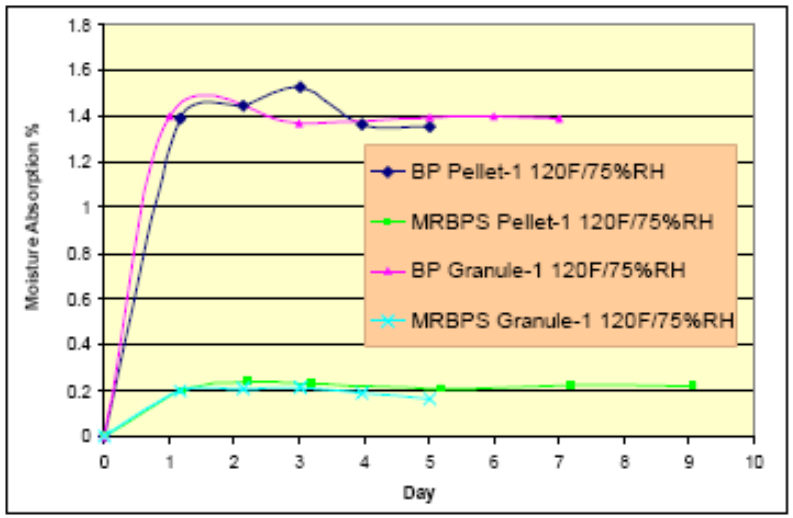


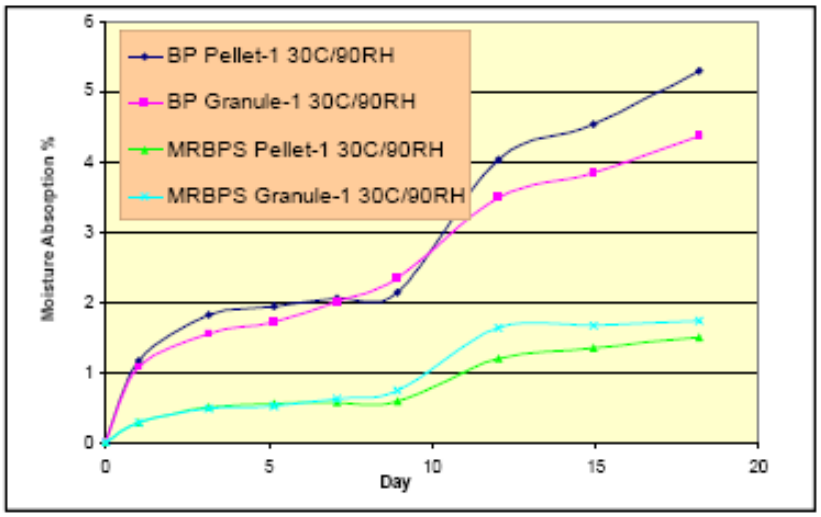
75% RH/Ambient Temperature & 120 F:

- Ambient temperature- BP and MRBPS reached equilibrium at 1.2% and 0.2% respectively after 3 days.
- 120 F- BP and MRBPS reached equilibrium at 1.4% and 0.2% respectively after 1 day.
- No significant difference in moisture absorption between pellets and granules.

90%RH/30C (Mil-STD-286 C, Part 503.1.3):

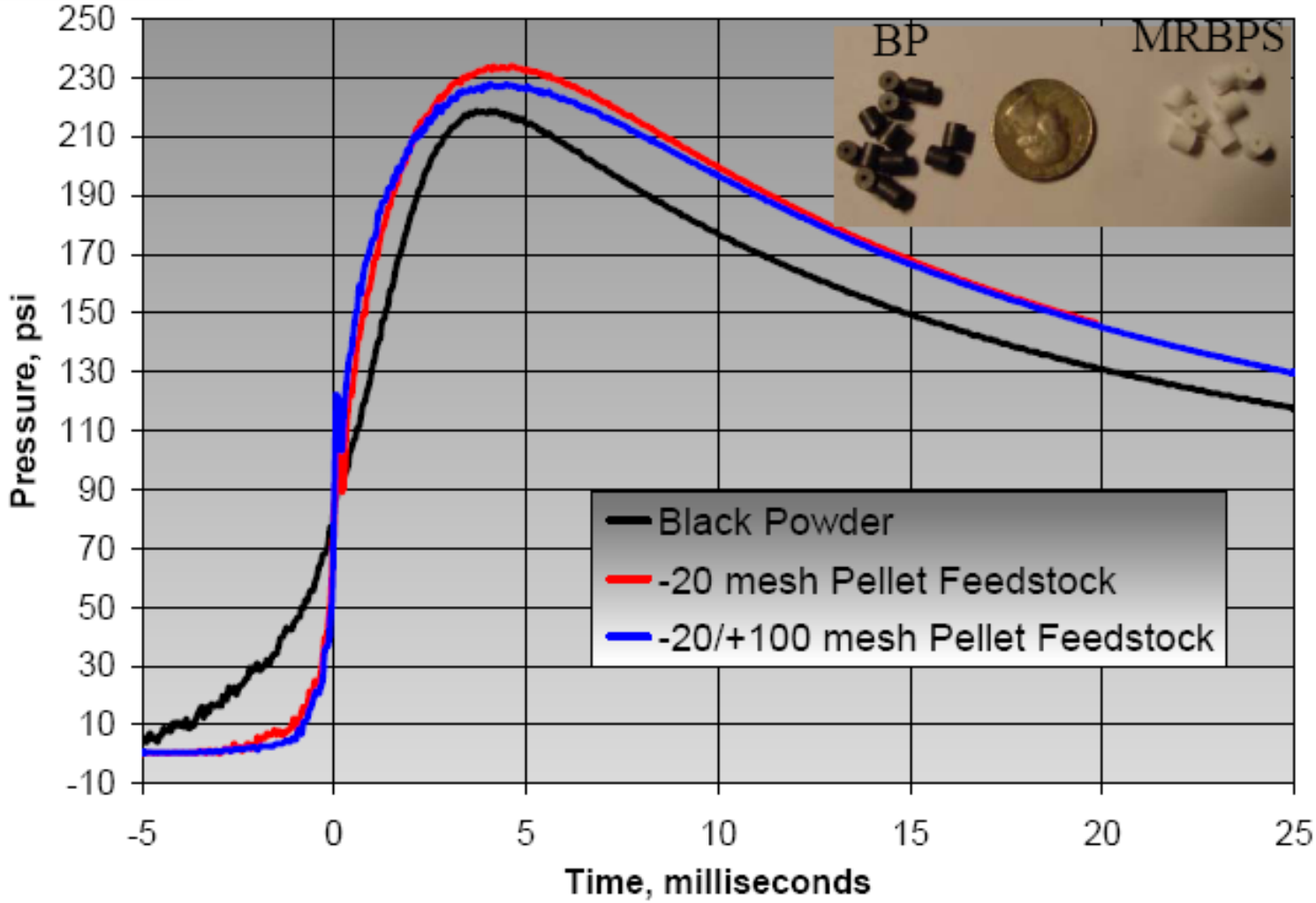
- BP and MRBPS pellets absorbed 5.3% and 1.5% moisture respectively after 18 days. Similar moisture absorption pattern occurred for granules.





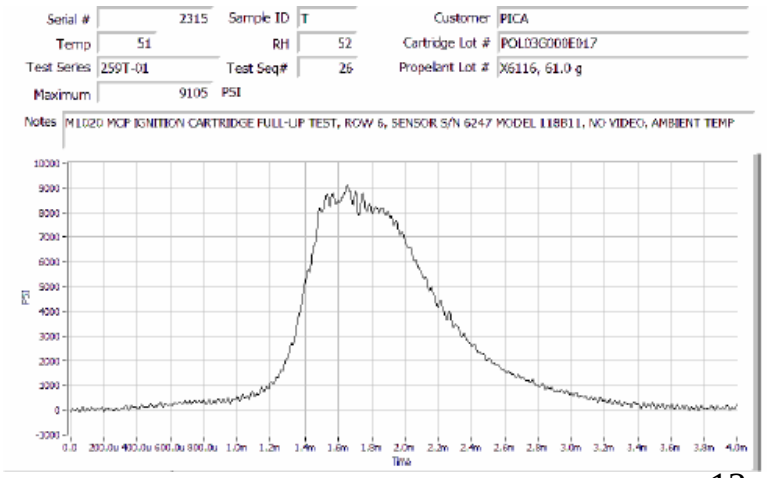
10K MRBPS Pellet Production Run

Primer Bomb Single Pellet Pressure Trace



M1020 Static Pressure Test
Test Platform

- To prove-out the ignition cartridge design changes and BP replacement with MRBPS, thirty (30) full-up improved M1020 were loaded (61 gram ball propellant) and assembled in production environment for testing in a static test platform as shown.
  - Identify maximum output pressure and standard deviation to determine compatibility with tail fin
  - Analyze pressure vs. time curve to define burning characteristics
- The cartridges were tested at ambient temperature (50-51 F) and 55% relative humidity.
- The resulting average static pressure (8,835 psi) and low standard deviation (446 psi) indicate a producible and consistent performance for the improved M1020 ignition cartridge.



M1020 Static Pressure Test

Maximum Output Pressure

Test Seq #	Serial #	Temp, F	Max PSI (Sensor 1)	Test Seq #	Serial #	Temp °F	Max PSI (Sensor 1)
1	**2,288**	50	9,550	**16**	**2,303**	51	9,271
2	**2,289**	50	8,690	**17**	**2,304**	51	8,791
3	**2,290**	50	9,865	**18**	**2,305**	51	8,573
4	**2,291**	50	8,690	**19**	**2,306**	51	9,027
5	**2,292**	51	9,027	**20**	**2,307**	51	9,016
6	**2,293**	51	9,803	**21**	**2,310**	51	8,539
7	**2,294**	51	8,420	**22**	**2,311**	51	8,802
8	**2,295**	51	9,327	**23**	**2,312**	51	8,921
9	**2,296**	51	9,137	**24**	**2,313**	51	8,713
10	**2,297**	51	8,664	**25**	**2,314**	51	8,054
11	**2,298**	51	8,392	**26**	**2,315**	51	9,105
12	**2,299**	51	8,849	**27**	**2,316**	51	8,643
13	**2,300**	51	9,027	**28**	**2,317**	51	8,450
14	**2,301**	51	8,492	**29**	**2,318**	51	8,128
15	**2,302**	51	8,927	**30**	**2,319**	51	8,147

Engineering Test on M931 at YPG

TEST	RESULTS
• **Strength of Design**	**pass**
• **12.2 Meter Drop (40ft)**	**pass**
• **Hot/Dry Cycle**	**pass**
• **Cold Soak**	**pass**
• **Sequential Rough Handling**	**pass**
• **Loose-cargo vibration**	**pass**
• **2.0 meter (6.5 ft) Bare Drop**	**pass**
• **Ammunition Adverse Environment**	**pass**
(a) 10-day temperature/humidity cycle	**“**
(b) 48- hour salt fog	**“**
(c) Water Immersion/blowing rain	**“**
(d) Bare Immersion test	**“**
• **Temperature Extreme and Accuracy**	**pass**
(a) Residue, Debris	

SUMMARY

- **A mechanical crimp seal to eliminate the current RTV seal in the 120mm mortar ignition cartridge has been developed and demonstrated.**
- **The crimp seal design has demonstrated to achieve excellent moisture barrier when using together with the polyolefin shrink tube.**
- **The flash tube assembly design was improved to eliminate pellet ignition blow-by and vulnerability to moisture infiltration caused by the current loose-fit design.**
- **The replacement of black powder pellets with moisture resistant black powder substitute (MRBPS) pellets provided further improvement in robustness and shelf-life of the 120mm ignition cartridge.**
- **The full-up M1020 120mm mortar ignition cartridges with the above improvements have been successfully produced in production environment and passed the static pressure and leak testing.**
- **The improved M1020 cartridge passed all safety certification testing on the M931 training and M929 smoke rounds.**
- **Preliminary data done on the firing tables testing on M931 training rounds showed promising results.**
- **The same design was implemented on the M299, M752& M702 cartridges for the 60 & 81 mm mortar rounds and the results were encouraging.**