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CIVIL DISTURBANCE CONTROL SYSTEM ENGINEERING DEVELOPMENT PROGRAM

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General Motors Corporation

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CIVIL DISTURBANCE CONTROL SYSTEM ENGINEERING DEVELOPMENT PROGRAM

Final Report

by
R S Peterson and D H Chabot
Fire Control Engineering Department

October 1975

DELCO ELECTRONICS DIVISION
GENERAL MOTORS CORPORATION
Santa Barbara Operations
Santa Barbara, California 93017

CONTRACT DAAA15-74-C-0262
Including Modifications P00001 thru P00007
Project/Task1W664608D566

DEPARTMENT OF THE ARMY
Headquarters, Edgewood Arsenal
Aberdeen Proving Ground, Maryland 21010

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Non-lethal weapons to control civil disturbances have had inherent limitations in their attempt to be non-lethal. A ringed air foil rubber projectile combines the benefits of a large effective impact area with good flight characteristics at relatively low velocity over an extended range. Such a projectile was used as a basis for an operational system that would provide a non-lethal weapon for control of civil disturbances or riots. The final system met all requirements that were initially established except for launcher cycle life. The life of the non-metallic keys that are fastened to the launcher cup to provide projectile rotation fell 30% short of the required 500 cycles. The investigations

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FOREWORD

The work described in this report was authorized under Contract No. DAAA 15-74-C-0262, Project/Task IW664608D566, Sting Ring Airfoil Grenade (Sting RAG) System. The work described covers the period from July 1974 to September 1975.

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The Contract Project Officer was A. Flatau; the Alternate Contract Project Officer was R. Belden. In addition Messrs. Miller, Olson, and Arbogast, Weapons Systems Concepts Office, Development and Engineering Dicrectorate, Edgewood Arsenal provided able technical assistance in support of this contract.

DIGEST

The purpose of this investigation was to finalize the design of the Civil Disturbance Control System. Experimental test firings were used to evaluate, improve, and finalize the design requirements of the launcher and projectile. The final system met all requirements initially established, except for launcher cycle life. The life of the non-metallic keys that are fastened to the launcher cup to provide projectile rotation fell 30% short of the required 500 cycles.

The Civil Disturbance Control System consists of the XM234 launchers that adapt to the M16 rifle and a carrier assembly that packages six XM743 projectiles and six XM 755 blank cartridges. The projectiles, of soft rubber with a ring airfoil shape, are launched at a nominal velocity of 200 ft/sec to impart a stinging, but non-lethal, blow to a human target.

The investigations included a launcher buffer system, projectile banding requirements, material for rotation of a launcher cup, a method of carrying and loading projectiles, and a system for stopping a bullet within the launcher.

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SECTION I
INTRODUCTION

Delco Electronics Division, Santa Barbara Operations, General Motors Corporation, sponsored by Weapons Systems Concepts Office of Edgewood Arsenal, Maryland, conducted an Engineering Development Program for the Sting Ring Airfoil Civil Distribution Control System. The system is based on the Exploratory Development Program completed under Contract DAAA15-72-C-0016. The system, consisting of a 64mm projectile launcher, projectile, cartridge and loading device for use on an M16 rifle, is designed to impart a non-lethal stinging blow. The launcher/cartridge shall launch a 35 gram projectile at 200 ft/sec and spin rate of 5000 rpm with accuracy at up to 80 meters range.

The program consisted of the following major tasks:

1. Refine the launcher design to improve handling, loading, reliability, producibility, accuracy, and safety.
2. Refine the Sting Ring Airfoil Projectile to improve its impact characteristics and flight characteristics and modify the design for interchangeability with the Soft RAG Ring Airfoil Projectile.
3. Prepare drawings to Form 1, requirements of MIL-D-1000 and MIL-STD-100.
4. Conduct a test and evaluation program to verify the adequacy of the design.
5. Fabricate for delivery 64 launchers, 6 cutaways, 8000 projectiles, and 10,000 cartridges in addition to material required to support program development and test requirements.
6. Conduct a RAM-D program including a reliability demonstration to assure meeting program requirements.
7. Perform a producibility engineering and planning (PEP) study.

Modifications to the basic contract consisted of:

Contract Modification P00001

This modification, effective 5 Deptember 1974, revised projectile delivery requirements.

Contract Modification P00002

This modification, 12 November 1974. added scope to the contract. This included performing tests to demonstrate the ability of the Sting RAG System to meet Reliability, Availability, and Maintainability (RAM) requirements; to perform a Producibility Engineering and Planning (PEP) study; and to increase the delivery requirements for launcher/adapters from 24 to 64.

Contract Modification P00003

This modification, effective 23 December 1974, further modified projectile delivery schedules.

Contract Modification P00004

This modification, effective 5 February 1975, revised design and performance requirements and limited extent of firings in RAM testing to 2 launchers/adapters firing 1000 projectiles each or until system failure. The design change revised the launcher sight from an adjustable sighting system to a fixed sighting system having an incremental arrangement for 40, 60, and 80 meters. In addition, velocity requirements were changed from "between 200 and 250 feet per second" to read "velocity between 180 and 220 feet per second."

Contract Modification P00005

This modification, effective 1 May 1975, provided interim funding to cover additional testing of the launcher/projectile interface.

Contract Modification P00006

This modification, effective 23 June 1975, amended the contract to provide for an additional iteration of the Sting-RAG Projectile (Sting-RAG VI), including specific tests to evaluate various projectile configurations and conducting pre-RAM-D tests with the redesigned projectile.

Contract Modification P00007

This modification, effective 30 June 1975, increased contract amounts and allotted funding.

At the conclusion of the contractual effort, a final design for a Civil Disturbance Control System had been achieved and complete systems delivered. Concurrent with development of launcher performance, a high degree of producibility and functional simplicity had been incorporated in the system. The only performance objective not completely satisfied was launcher life which achieved 70% of design goal of 500 firings before replacement of parts. Figure 1 is a photograph of the launcher and Figure 2 depicts the carrier assembly used to package, carry, and load the projectiles.

Table I is a summary of system requirements. Performance data is from the results of RAM-D testing. The one requirement not met resulted from excessive wear of the plastic key riveted to the launcher cup as shown in Figure 3. Contract schedule and funding requirements did not permit complete evaluation of alternate candidate materials for this part. However, sufficient life was achieved which along with the ease of replacement of the cup assure a viable system.

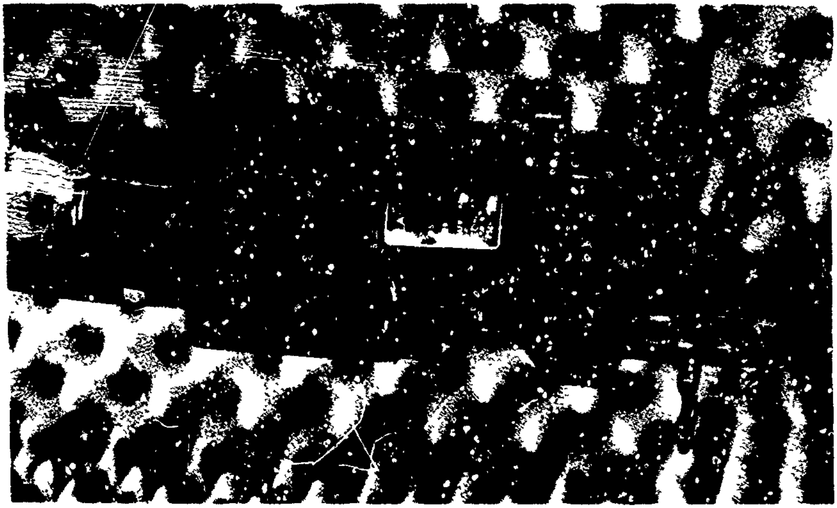

Figure 1. Launcher

Figure 2. Carrier Assembly

Table I

System Requirements Summary

Feature	Requirement	Met	Not Met	Remarks
Attachment to Rifle	No tools	x		Knurled nut, hand tightened
Disassembly	No tools	x		Complete disassembly of critical parts with removal of one retainer wire.
Projectile Loading	One hand while holding weapon	x		Uses disposable projectile loading device.
Rate of Fire	4 rounds/minute	x		
Life without adjustment or replacement of parts	500 firings		x	70% of requirement met.
Buffer	One piece	x		Butyl rubber.
Weight	2.0 pounds	x		2.0 pounds.
Live Round	Safe	x		Ball is captured in launcher.
Accuracy	18" W x 72" H Target 80% probability	x		82.8% measured.
Velocity	190 - 220 ft/sec	x		195.4 ft/sec - average 1412 firings. 2.96 ft/sec standard deviation

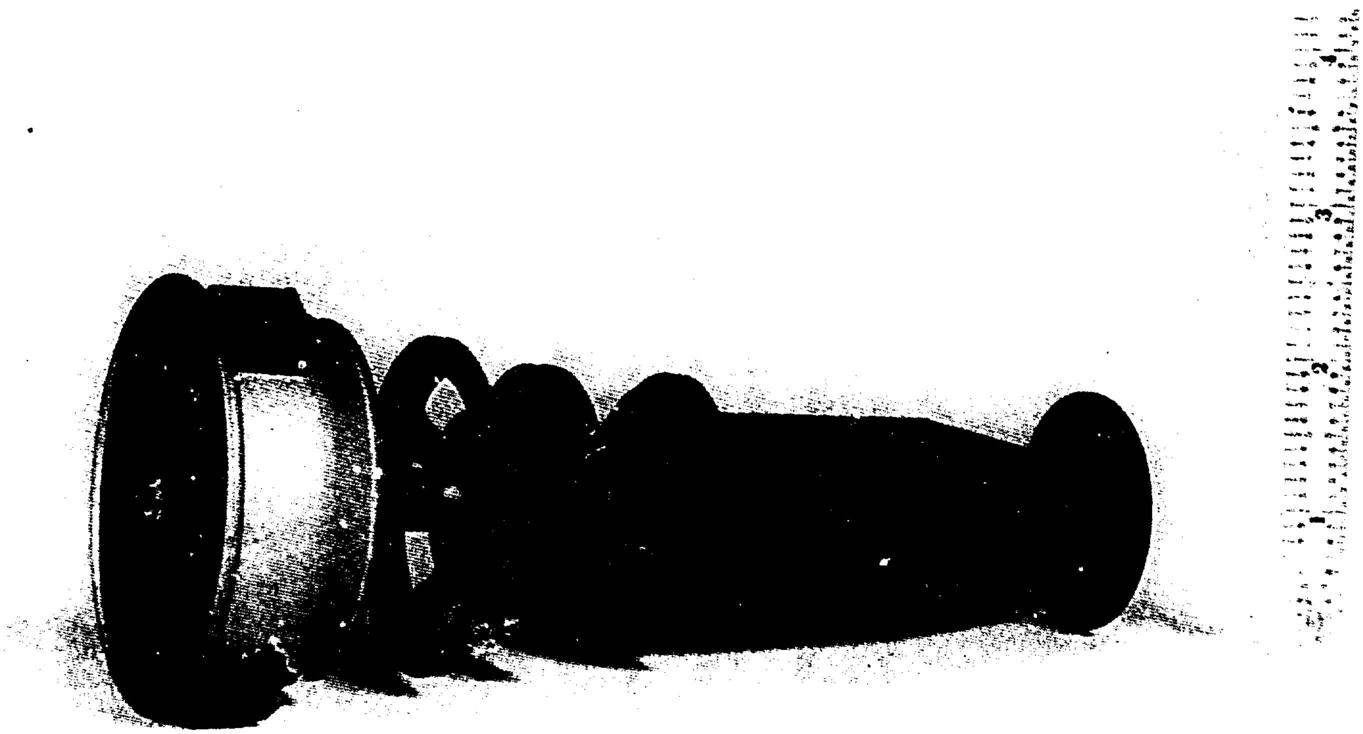

Figure 3. Launcher Cup Assembly

SECTION II
TECHNICAL DISCUSSION

DESCRIPTION OF COMPONENTS

The Civil Disturbance Control System consists of two basic assemblies: the XM234 Launcher and the Carrier Assembly. The Carrier assembly contains six XM743 64mm projectiles and six XM755 5.56mm blank cartridges. When the Launcher is fitted to the muzzle of an M16-A1 rifle the system is operational.

The XM234 Launcher, drawing E122-3-30 (see Appendix A), consists of an attachment system to adapt it to the rifle, a fixed sight, a launcher cup assembly, a buffer assembly, a manifold, and an assembly wire. These parts are assembled into an aluminum body that serves as the basic launcher structure.

The attachment system consists of a rear locating lug that fits into the bayonet lug, an anti-rotation arm that fits between the front sight shields of the rifle, and a quick attachment device that locks the launcher to the rifle. The attachment device consists of two levers on each side of the muzzle port of the launcher and a locking nut. With the locking nut backed out, the two levers are spring loaded to permit insertion of the flash hider into the launcher port. The levers are then pushed closed when properly shaped arms engage the backside of the flash hider on the rifle muzzle. The nut is then screwed in tight behind the arms, securely fastening the launcher to the rifle. An inertia lock ring assures tight engagement of the nut.

The launcher sight consists of a stepped front sight and an open rear sight on a cross bar. The rear sight on a cross bar provides an open view of the target area. The stepped front sight gives three aiming distances, 40, 60, and 80 meters (see Figure 4). Guards on the sides protect the sight from damage. Both front and rear sights are heat-treated spring steel.

The launcher cup assembly (Figure 3) provides support for the projectile during launch and consists of a cup assembly, a tube and nut assembly, and three plastic keys that mate with spiral female grooves in the launcher barrel and are fastened to the outside surface of the cup. The cup itself is a single piece formed to provide a conical inner support and an outer surface that conforms to the outside of the projectile, except for controlled interference to obtain a friction interference between the cup and the projectile. This cup is fastened to a shaft by means of a diaphragm formed into the shape of a catenoid for proper load distribution of the shaft buffer forces to the cup. The threaded end of the shaft accepts the buffer plate where the deceleration loads are developed.

The buffer is a molded butyl cylinder retained by a washer fitted into a groove in the buffer at one end. The free end is shaped to control the initial deceleration forces developed in stopping the cup assembly after the projectile is launched.

The manifold is a ported and grooved structure that serves to collect the gas from the muzzle port for launching the projectile and controlling buffer housing pressure needed to shape cup deceleration forces.

The manifold, cup assembly, and buffer are assembled together in one subassembly that is inserted into the launcher from the barrel and retained by a wire ring. This one assembly contains the functional parts of the launcher and is readily removed for cleaning or replacement of parts.

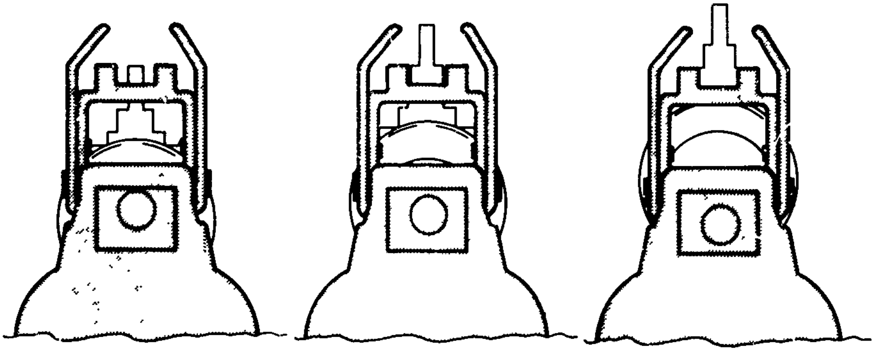

Figure 4. Gun Sight Aiming Positions

The body of the launcher is an aluminum investment casting designed to minimize machining operations and provide the internal gas channel from around the flash hider to the manifold. A small but significant feature of the body is the alloy steel deflector in the muzzle port. This deflector absorbs the particles from the propellant gas. Also, if a ball round is inadvertently fired in the rifle it will contain the ball without fragmentation of the launcher.

The carrier assembly, drawing D122-3-60 (see Appendix A) contains six projectiles and six blank cartridges in a tubular housing. This housing has a belt clip for fastening to the gunner's belt. The six cartridges are contained in a foam cushion at the cap end of the container. A foam cushion is also provided at the other end to secure the contents during handling. The projectiles are individually packaged in a plastic holder and ejector assembly. With the carrier fastened at the belt and with the open end of the carrier down, the projectiles are gravity fed to the bottom where they are retained by an internal ring in the container and are accessible for one-hand loading into the barrel of the launcher. Once the projectile is in the barrel, the ejector pushes it into the cup. A stop on the ejector bottoms against the inner cone of the cup controlling the pressure used to position the projectile in the cup as well as forcing the cup into the firing position.

The projectile, drawing D122-3-75 (see Appendix A) is a design based on extensive development work by Edgewood Arsenal. It consists of a molded rubber ring airfoil which by control of the rubber density can be used also for the Soft RAG Projectile. It is spiral wrapped with a continuous paper strip and secured by a carefully controlled adhesive to maintain the projectile shape during flight and proper impact characteristics.

The cartridge, drawing C122-3-43 (see Appendix A), is a standard 5.56mm primed cartridge case loaded with 12 grains of Dupont 700X gun powder. The nose is crimped and sealed after loading.

DEVELOPMENT EFFORTS

There were three essentially independent development efforts during the program: the launcher, the carrier assembly, and the projectile.

The projectile design was a result of a continuing Edgewood Arsenal development effort. Refinement and evaluation of the projectile was closely coordinated with the Arsenal where all critical testing such as biophysics was conducted and will not be part of this report.

The carrier assembly evolved from concept to final design with only minimal iterations during the evaluation and development. There was only one problem of any significance. This problem concerned establishing the retention detent for the projectile in an open carrier hung from the belt. A reasonable balance between extraction force and retention force had to be met to preclude ejection of projectiles via acceleration forces from body movements. While no qualitative data was developed, the final design required an abnormal body jolt to accidently eject a projectile and its holder/ejector assembly.

The launcher concept and initial design remained essentially unchanged except for details during the program with a great deal of the design effort free to concentrate on evolving a producible design. However, arriving at these details changes involved a significant development effort in two areas: the buffer system and development of the keys on the cup to impart spin to the projectile. The buffer system was especially critical since it established the critical loads that would be imposed on the functional parts of the launcher. The development effort in these two areas will therefore constitute the major part of this technical discussion.

Launcher Buffer System

With reference to Figure 5, which shows the major functional parts of the launcher - the launcher cup, buffer nut, buffer, and manifold, the launch cycle can be described. The propellant gases are collected at the manifold and discharged behind the cup which contains the projectile. These gases accelerate the cup to launch velocity. After one inch of travel, a vent position in the barrel is reached where the gases start to vent to atmosphere. After 1-3/8 inches of travel the buffer nut on the end of the cup shaft contacts the buffer and the projectile starts leaving the cup. After 2-3/4 inches of travel, the stroke is completed and the cup rebounds back into the barrel, cushioned on rebound by residual gases in the barrel.

This cycle is further illustrated in Figure 6. The curve is based on analysis of high speed photography of the launcher firing a projectile. The initial displacements and velocities were obtained by converting cup rotation, given the lead angle of the barrel grooves, to displacement. A side camera angle of another firing gave displacement after reaching the vent position. The displacement curve shows that maximum energy transfer to the elastic projectile has occurred at or before the vent position, while peak velocity of the cup apparently occurs at time of contact with the buffer. However, velocity is tending to level off at this point.

Both of these points were established by experimental testing to minimize buffer loads without compromising velocity of the projectile. An early vent position was desired to assure a minimum velocity of the cup upon contact with the buffer and to permit the installation of the longest buffer possible to reduce material stresses in the buffer.

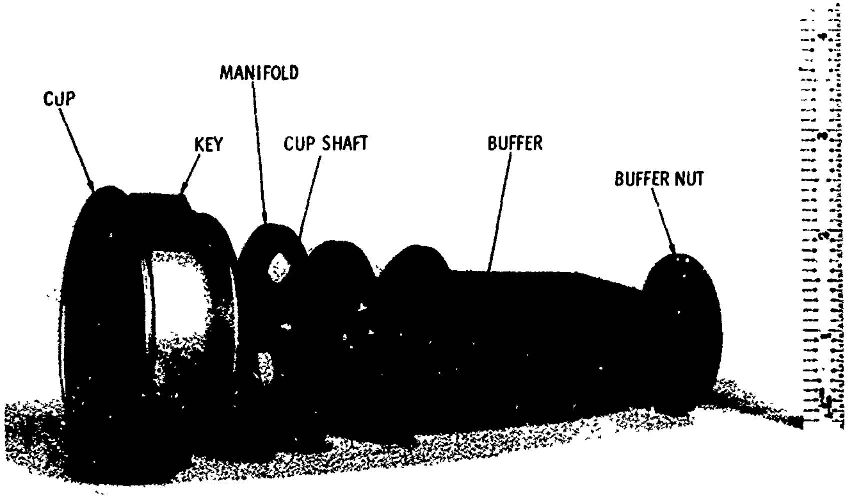

Figure 5. Components of Launcher Cup Assembly

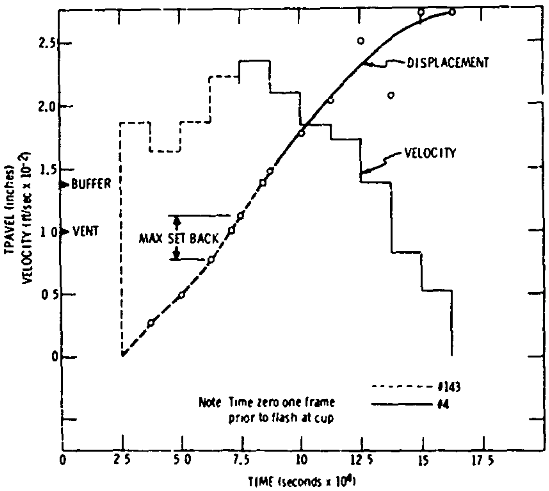

Figure 6. XM234 Launcher Cup Performance

The development of the buffer was carried through in the following steps:

- Establish the buffer volume
- Evaluate the material
- Establish the configuration
- Modify the system to shape the force curve.

The establishment of rubber volume, and even the feasibility of a one-piece buffer which was a contract requirement, was based on published data by Phillip Barkson and M. F. Sirkin on the "Impact Behavior of Elastomers." (1) This paper explored the following areas of the buffer impact problem:

1. Duration of impact
2. Energy dissipated, or the rebound velocity of mass following impact
3. Peak nominal stress, or force produced by impact.

While the data was not directly applicable, since it assumed an unbounded cylinder and a specific material, it paralleled the launcher problem close enough to be used for checking feasibility.

Two parameters were determined as governing factors:

$$\frac{W v_o^2}{2g\,AL} \quad \text{and} \quad \frac{WL}{A}$$

where:

W	=	Weight of impacting body, lb
v_o	=	Velocity at impact, in./sec
g	=	Acceleration of gravity, in./sec^2
A	=	Cross sectioned area, in.^{2}
L	=	Unstrained length, in.

The first term is the specific energy of the system and the second term represents a grouping of functions which appear in the expression for the natural frequency of a simple mass-spring system.

For a buffer that would fit the launcher, where A = 1.539 in.^{2}, L = 2.75 in., and the impact mass is 0.11 lb:

$$\frac{W v_o^2}{2g\,L} = 187$$

and

$$\frac{WL}{A} = 0.190$$

By using the referenced curves, one can determine that the impact period would be 0.5 ms, the kinetic energy returned would be 0.2, and the maximum normal stress would be 2,000 psi.

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(1) Machine Design, Vol. 35, Issue 4, p. 172, 14 Feb 1963.

For the short life required by the system, 2,000 psi was a reasonable level to work with, and the fact that the returned energy would be only in the order of 20% assured that the rebound problem would be minimal.

Four elastomers were selected for evaluation, Butyl, EPDM, natural rubber, and silicone (RTV). Their static characteristics are plotted in Figure 7. In general the curve indicates a higher spring rate than the RTV buffer previously tested (not shown). This is consistent with the difference in hardness – 43 shore versus 33 shore for the RTV. The hysteresis was greatest for the butyl with natural rubber having the least. This verification of the higher "damping" characteristics make it the first choice for the buffer.

Dynamic tests in a launcher with strain gage load measurement at the end of the shaft were made with identical configurations of approximately 40 durometer and fired under the same conditions, giving the following results:

Material	Average Peak Load (lb)	Average Velocity (ft/sec)
Natural Rubber	4000	175
EPDM	2800	166
RTV	2800	-
Butyl	2375	173

This data further confirmed the desirability of Butyl and it was therefore selected as the buffer material.

The energy to be absorbed by the buffer is approximately 80 ft-lb. Ideally, for 0.1 ft of travel the energy should be absorbed with a peak force of 800 pounds. As can be seen in Figure 7, under static conditions, the buffer does not approach this force until travel exceeds 1.0 inch. Under impact, however, the inertial resistance is very high and to minimize initial contact forces the buffer is designed with a conical nose to give a small initial contact area and inertia mass. A variety of sizes and shapes were evaluated to assure that initial loads were minimized. The final design, drawing 122-3-29 (see Appendix A), kept these initial loads to approximately 1200 pounds. However, peak loads of 2400 pounds or higher were experienced despite experimentation in configuration and hardness.

The problem resolved down to a reduction of buffer resistance to essentially that which would be experienced under static conditions after the initial inertia effects. This can be seen in the strain gage trace, Figure 8, where a dip in the buffer force after initial contact is apparent. To further optimize this load curve, pneumatic buffing was added to the system and resulted in a nearly optimum square wave shape for the force curve, as shown in Figure 9. The system cut buffer loads in half to an average of less than 1200 pounds, significantly reducing loads on related structural elements.

The addition of pneumatic buffing was accomplished by opening up the clearance between the cup shaft and the buffer and manifold. This permits some of the propulsion gas to leak back into the buffer chamber where the buffer nut acts as a piston. The pressure on the piston provides the additional force required to shape the curve.

Launcher Deflector

An unknown factor in the launcher was the consequences of firing a live round. Initial evaluation of this problem used a simulated muzzle port of the launcher that included

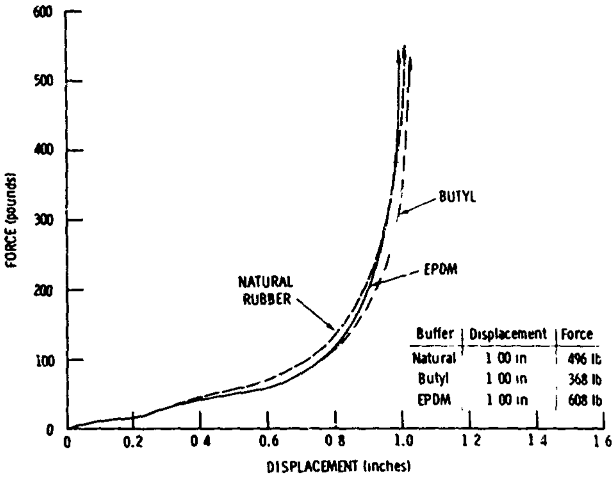
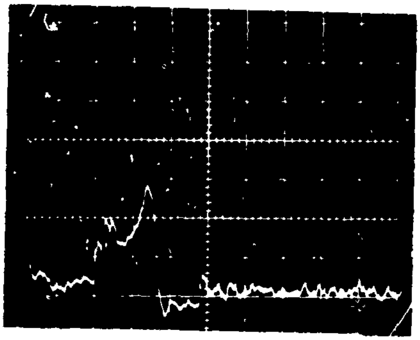
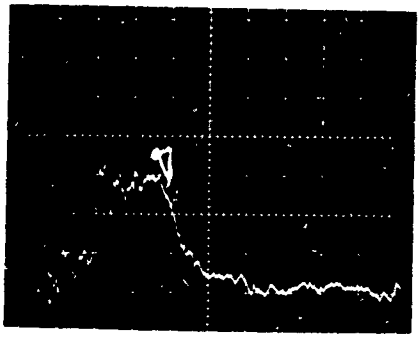


Figure 7. Buffer Static Characteristics



XM 234-1 BUTYL BUFFER
800 lb/Div - .5 Ms/Div
Maximum Load - 2380 lbs
Velocity - 208.2 ft/sec

Figure 8. Strain Gage Trace - Butyl Buffer



XM 234-1 BUTYL + PNEUMATIC BUFFER
400 lb/Div - .5 Ms/Div
Maximum Load - 1275 lbs
Velocity - 200.0 ft/sec

Figure 9. Strain Gage Trace - Butyl and Pneumatic Buffer

the deflector. While firing a live round, the deflector as originally designed broke up and the bullet exited the test device as two pieces, creating aluminum fragments. For the second shot, a deflector with approximately twice the mass was installed and tested. This deflector caught the bullet and retained it in the test device. In both of these tests the locking nut holding the device to the gun barrel was retained with 1-1/2 to 2 threads. Although the threads were damaged the test part did not separate from the barrel under the impact. A third shot was fired with a deflector that simulated the final design. This deflector also stopped the bullet as shown in Figure 10. (Device has been cut in two for examination.) As an alternate design, a ceramic ball was installed as a deflector and it also very effectively contained the bullet. This series of tests effectively determined two methods of stopping the bullet completely in the launcher without external fragmentation.

The test was repeated in an actual launcher and as expected no external fragmentation resulted. The launcher was damaged as shown in Figures 11 and 12. Fracturing and displacement of the metal housing occurred as the deflector was displaced forward approximately 0.04 inch. The bullet was vaporized by the impact, and while cratered, the deflector retained its structural integrity. The flash hider on the rifle, Figure 13, was enlarged by the impact and considerable force was required to remove it. The cup retained its structural shape and there was no indication of excessive gas pressure in the housing.

Launcher Key Configurations

Another critical area in the launcher design was the cup-key/barrel-groove interface. The problem was aggravated by the increase in helix angle from 14.6 degrees, previously used in the development launcher, to 16.3 degrees required to meet the spin requirement of 5000 rpm at the lower velocity of 200 ft/sec. In addition, design requirements that emphasized producibility and simplicity restricted solutions of the design problem to those that could be evaluated in a short period.

Two different metal key configurations in combination with three types of barrel finishes were initially evaluated. This was followed by evaluation of basically six different plastic key materials in two configurations.

The metal keys were lightweight metal stampings spot-welded to the outside surface of the cup. They were tested in a tapered-sided and a straight-sided, or square, groove configuration. The aluminum barrel surface finishes used with these keys were plain anodize, hard anodize, and nickel. Cycle life with these keys was as short as 30 shots against a plain anodized barrel, and while the harder surface finishes extended this life, barrel groove wear was excessive. Correcting for these deficiencies did not appear attractive so an alternate solution using plastic keys riveted to the cup was investigated.

Five basic materials were evaluated in two configurations. The results are summarized in Table II.

The 230-cycle life achieved with plain nylon keys, with no apparent wear damage to the lower barrel, led to the decision to fabricate molded keys from plastic for the final design. The molded keys would be 50% longer to reduce bearing pressures. The addition of glass fiber, based on available data and experience, was expected to result in a significant reduction in wear. However, tests with keys machined from such material did not result in the expected reduction in wear.

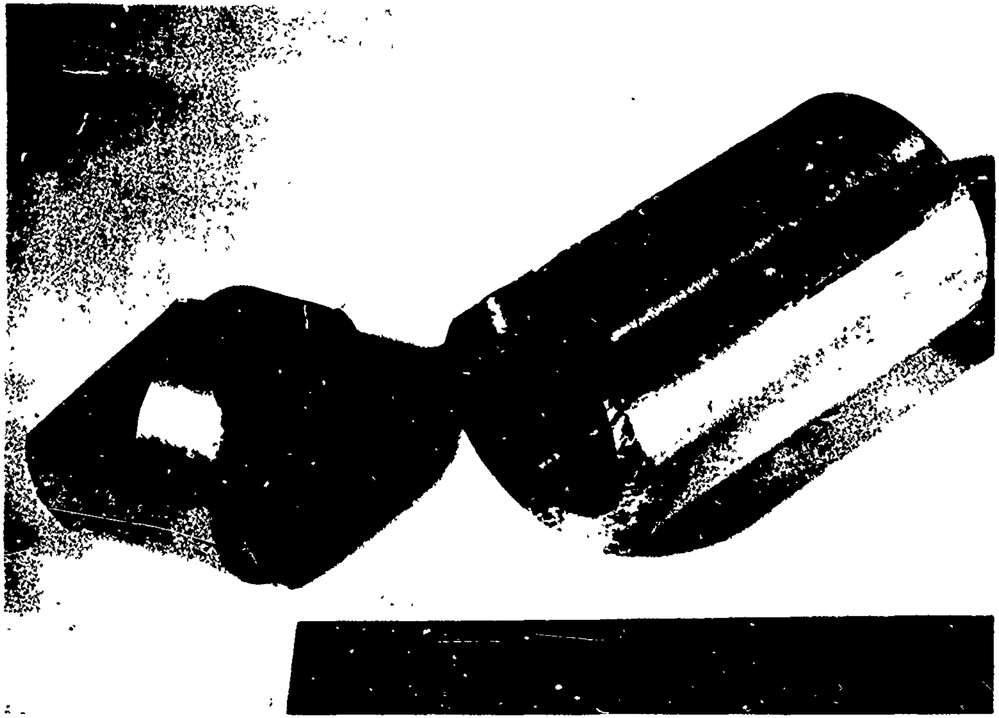


Figure 10. Test Device – Deflector (Revised, larger steel deflector contained live round).

Figure 11. Post Live Round Test – Launcher, Exterior View

Figure 12. Post Live Round Test – Launcher, Interior View

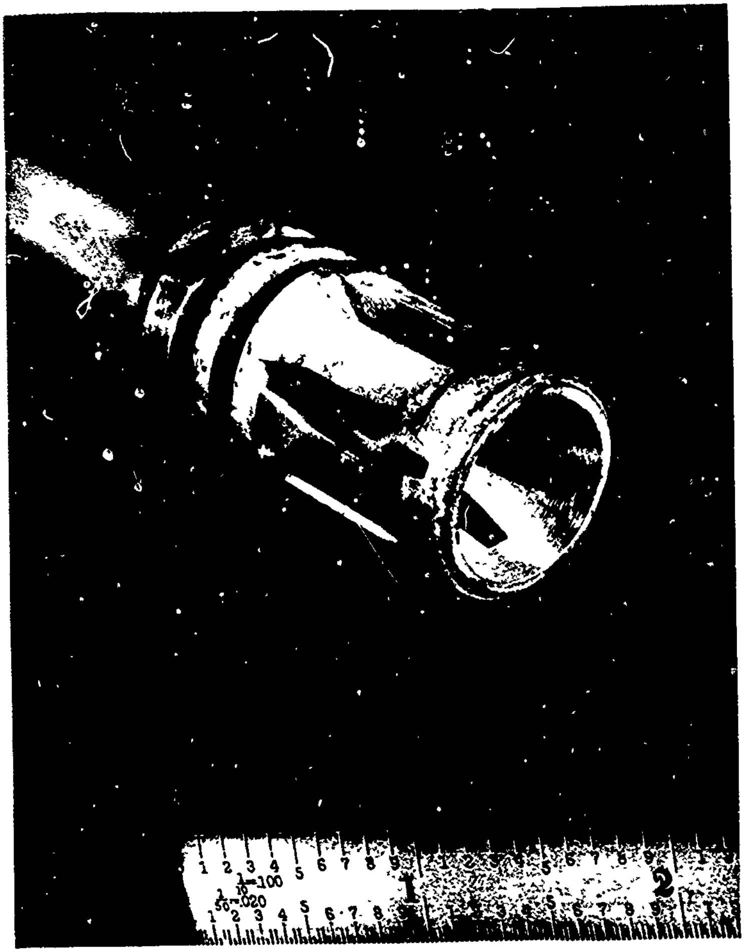


Figure 13. Post Live Round Test – Flash Hider

Table II

Key Evaluation

	Material	Configuration(1)	Results
1.	Acetal	Short	Limited Life
2.	Nylon 6/6	Short	230 Cycles
3.	Nylon 6/6, 30% Glass	Long	325 - 447 cycles
4.	Nylon 6/6, 30% Glass 5% Molydenum Disulfide	Long	Brittle
5.	Nylon 6/6, 30% Glass 15% Teflon	Long	Short Life

(1) Short key was 0.32 inch long, long key 0.47 inch.

Variation in glass fill from 15% to 50% did prove a significant parameter, with the increase in life apparently only due to increased bearing area. It was obvious that the "wear" mechanism being experienced was the result of instantaneous high surface temperatures exceeding the melting temperature of nylon (495°F). An alternate material with higher temperature capability (Torlon - Amoco Chemical) proved too brittle to withstand the impact loads. (Testing and evaluation of Torlon keys was conducted by Edgewood Arsenal.) At the end of the development effort, keys molded from 6/6 nylon with 30% carbon fill were procured but launcher design was finalized before they were available.

This nylon, carbon-fill material was selected on the basis of its higher thermal conductivity which exceeds the glass filled material by over 100%. This material would still have the basic resiliency of nylon to absorb the impact loads and the increased thermal conductivity should improve cycle life considerably.

It should be noted that total wear in excess of 0.060 inch can be tolerated on the nylon keys without affecting launcher accuracy and velocity significantly and that this level of wear is only attained after an excess of 500 cycles. However, after approximately 0.015 inch of wear, impact loads as a result of the increased clearance are high enough to cause structural failure of the key at the rivet, thus reducing the reliable life cycle of the cup assembly. Increased rivet edge distance on the key and possible bonding of the key to the cup are other design changes that could add to the life cycle capability of the launcher.

The lives of other parts of the launcher are shown in Table III. It is reasonable to expect that eventually a 1000-cycle life could be achieved with this launcher. Use of the nylon carbon-fill key material alone should improve the cycle life of the cup the 30% required to achieve 500 cycles, and with further refinement of the overall launcher design the 1000-cycle figure appears attainable.

Table III

Component Life

Component	Cycles	Remarks
Cup Assembly	379 avg.	Key failure
Buffer Assembly	715	No failure
Buffer Nut	715	No failure
Clip Assembly	523	No failure
Gun attachment	523	No failure

Projectile

The XM743 Sting RAG Projectile development was based on the XM742 Soft RAG Projectile developed by Remington Arms Company, Incorporated, for Edgewood Arsenal. It was designed to be fabricated by using the same tooling that would be used to fabricate the Soft RAG. Remington Arms Company was therefore placed under subcontract by Delco Electronics to develop the XM743 Sting RAG Projectile. This development effort is covered in Final Report AB 75-3, September 1975 by Remington Arms and included as Appendix B of this report.

SYSTEM PERFORMANCE

During RAM-D tests, the nominal velocity of the round was averaging 8 to 10 ft/sec less than that which had originally been obtained with earlier projectiles and launchers. (Projectile velocity was measured by three screens, five feet apart, with the first screen located 31.5 inches from the launcher muzzle.) It also must be noted that the projectiles containing the PEG additive weighed a nominal 1 gram over the specified nominal value of 34.5 grams. In an effort to determine the cause of the velocity degradation, several steps were undertaken. The first was to weigh projectiles: it appeared that nominally a 35.5 gram projectile was being fired. The second assessment was to break open a number of loaded cartridges from various lots and weigh the charges. The nominal value of the charge weight was 11.9. Therefore, an analysis was made to determine the effect of charge and projectile weight variations. This analysis is as follows:

During the original charge weight selection, 12 grains of propellant gave a nominal velocity of 203 ft/sec with a 34.5 gram nominal weight projectile. Therefore, given

$$KE = (1/2)\ MV^2 \qquad (1)$$

and substituting the values stated above,

$$KE = 1/2\ \frac{34.5\ (203)^2}{(454)\ \ 32.2} = 48.6\ \text{ft/lb} \qquad (2)$$

To determine the effect of charge weight variation, the following velocity relationship was used:

$$V = 344.11\sqrt{\frac{CW}{PW}}$$

where CW is the charge weight and PW the projectile weight. The results are shown in Table IV.

Table IV
Charge Weight and Projectile - Effects on Velocity

Projectile Weight (grams)	Velocity (Ft/Sec) at 11.8 Grain Charge	Velocity (Ft/Sec) at 12 Grain Charge	Velocity (Ft/Sec) at 12.2 Grain Charge
33.5	204.2	205.0	207.7
34.0	202.7	204.4	206.0
34.5	201.0	202.9	204.6
35.0	199.8	201.5	203.1
35.5	198.4	200.1	201.7
36.0	197.0	198.7	200.3
36.5	195.7	197.3	198.9

It can be seen from this calculation that charge weight has a minor effect as compared to projectile weight – Figure 14 shows velocity plotted versus projectile weight.

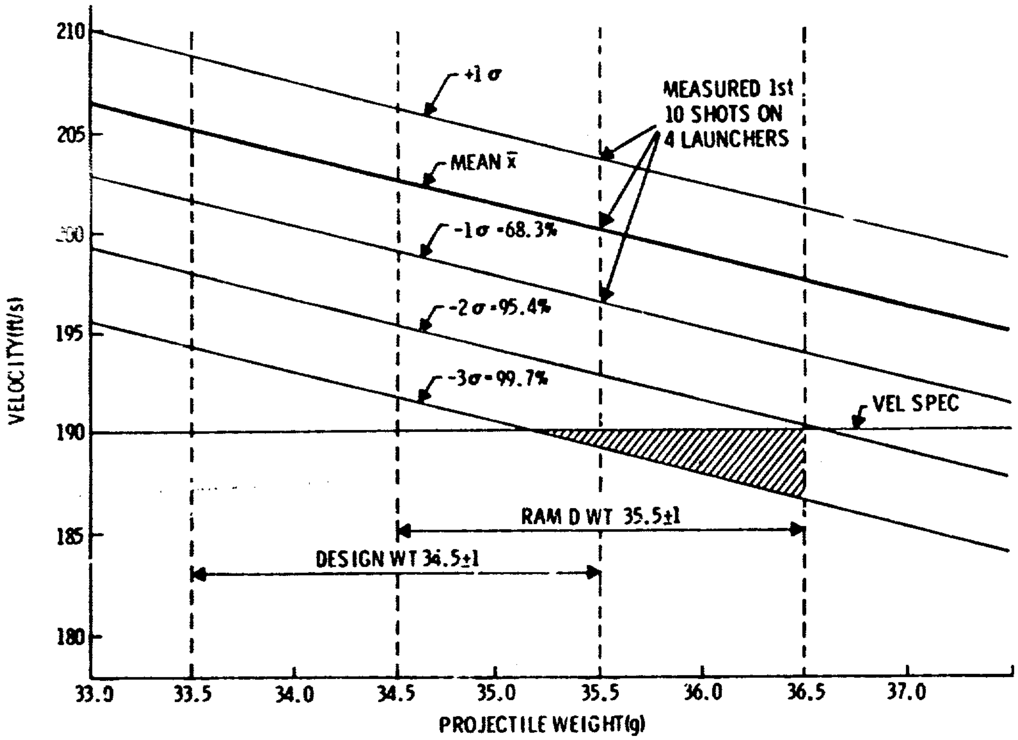


Figure 14. Start Test Velocity Estimate

The four launchers used during the RAM-D test exhibited the following standard deviation around the mean velocity ($\bar{x}$):

				Velocity ($\bar{x}$)
Launcher	Serial # 011	1 σ	3.65	195.5
Launcher	015	1 σ	4.024	196.8
Launcher	016	1 σ	4.314	194.2
Launcher	019	1 σ	2.767	195.7

Velocity degradation with these launchers is shown in Table V.

Table V

Velocity Degradation

	Serial No.	Velocity Degradation Trend
Launcher	011	0.023 ft/s per shot
Launcher	015	0.011 ft/s per shot
Launcher	016	0.009 ft/s per shot
Launcher	019	0.010 ft/s per shot
This shows an average trend of 0.01325 ft/s. Assuming 365 shots, the expected degradation would be 4.8 ft/s.		

The mean velocity and the standard deviation are calculated for the four launchers used in RAM-D.

$$\bar{X} = 1/N \sum_{m=1}^{M} N_m \bar{X}_m \qquad (4)$$

$$\sigma^2 = \frac{1}{N-1}\left[\sum_{m=1}^{M} (N_m - 1)\,O_m^{\;2} + \sum_{m=1}^{M} N_m \bar{X}^2 = N\bar{X}^2\right] \qquad (5)$$

This calculation yields an average velocity ($\bar{X}$) = 195.4 ft/sec. On the total of 1,462 rounds fired in RAM-D, the estimated trend of velocity versus projectile weight is shown in Figure 14, as well as 1σ value. This plot is for the start of the test. This graph shows that the mean velocity at the start of tests assuming a 35.5 grain projectile would be about 200 ft/sec. As a cross-check the first ten rounds from each of the four launchers were used to calculate actual experience (Table VI). Note that the mean velocity $\bar{X}$ = 199.53 ft/sec and is indicated by the plot. There is a possibility that some round would fall below 190 ft/sec. As indicated in Table VI, there is one round out-of-specification.

The total number of rounds on the four launchers was 1,462 rounds and shows an indicated average of 365-round capability for a given group of launchers. A velocity degradation trend of 4.8 ft/sec (for all the launchers) was calculated. The 4.8 ft/sec shift in mean velocity is shown in Figure 15, again with a -3σ bounds. By definition 1σ = 68.3%; 2σ = 95.4%; and 3σ = 99.7% of the population. The interpretation of these plots is that in the initial firings less than 1% of the shots would be out-of-specification, and, after an average life of 360 rounds, less than 5% would be out-of-tolerance. A cross-check on ordering of 1,083 rounds on three of the launchers which lasted at least 360 rounds is given in Table VII. As can be seen from that ordering, 3.7% of the rounds are out-of-tolerance. The conclusion, therefore, is that with an in-specification weight projectile, less than 1% of the velocities would be out-of-specification with a launcher, assuming an average life of 350 rounds.

Table VI
Mean Velocities of First Ten Rounds from
Each of the Four Launchers

-3σ	-2σ	-1σ	Mean	$+1\sigma$	
187.970	188.288	192.036	195.783	199.530	203.278
		193.050	196.078	200.000	204.082
		193.050	196.850	200.000	204.082
		193.798	196.850	200.000	206.612
		194.553	196.850	200.803	
		195.313	197.628	200.803	
			198.413	200.803	
			198.413	200.803	
			198.413	200.803	
			198.413	200.803	
			199.203	201.613	
			199.203	201.613	
				201.613	
				201.613	
				202.429	
				202.429	
				203.252	
				203.252	
				203.252	
				203.252	
				203.252	

Table VII

Mean Velocities of 1,083 Rounds from Launchers that Launched at Least 360 Rounds

-3 SIGMA	-2 SIGMA	-1 SIGMA					MEAN				+1 SIGMA	+2 SIGMA	+3 SIGMA
171.821	185.068	188.652	192.236	193.050	194.553	195.313	195.828	196.078	197.628	198.413	199.405	202.989	206.573
179.211				193.050	194.553	195.313		196.078	197.628	198.413			
179.856	185.185	188.679	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	206.612
179.856	187.266	188.679	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	
18[illegible]	187.266	188.679	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	
181.159	187.266	188.679	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	
181.159	187.266	188.679	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	
18[illegible].482	187.266	189.494	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	
18[illegible].482	187.266	189.494	192.308	193.050	194.553	195.313	196.078	196.078	197.628	198.413	200.000	203.552	
18[illegible].150	187.266	189.494	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	203.552	
18[illegible]50	187.970	189.494	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	203.552	
18[illegible]24	187.970	189.494	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	203.552	
184.[illegible]02	187.[illegible]70	189.494	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	203.552	
184.[illegible]02	187.[illegible]70	189.494	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	203.552	
	187.970	189.494	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.082	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.082	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.082	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.082	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.082	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.082	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.418	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.418	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.418	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.418	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	204.418	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	205.[illegible]61	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000	205.[illegible]61	
		190.114	192.308	193.050	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.796	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		190.840	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		191.571	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		191.571	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		191.571	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		191.571	192.308	193.796	194.553	195.313	196.078	196.850	197.628	198.413	200.000		
		191.571	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.803		
		191.571	192.308	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	198.413	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
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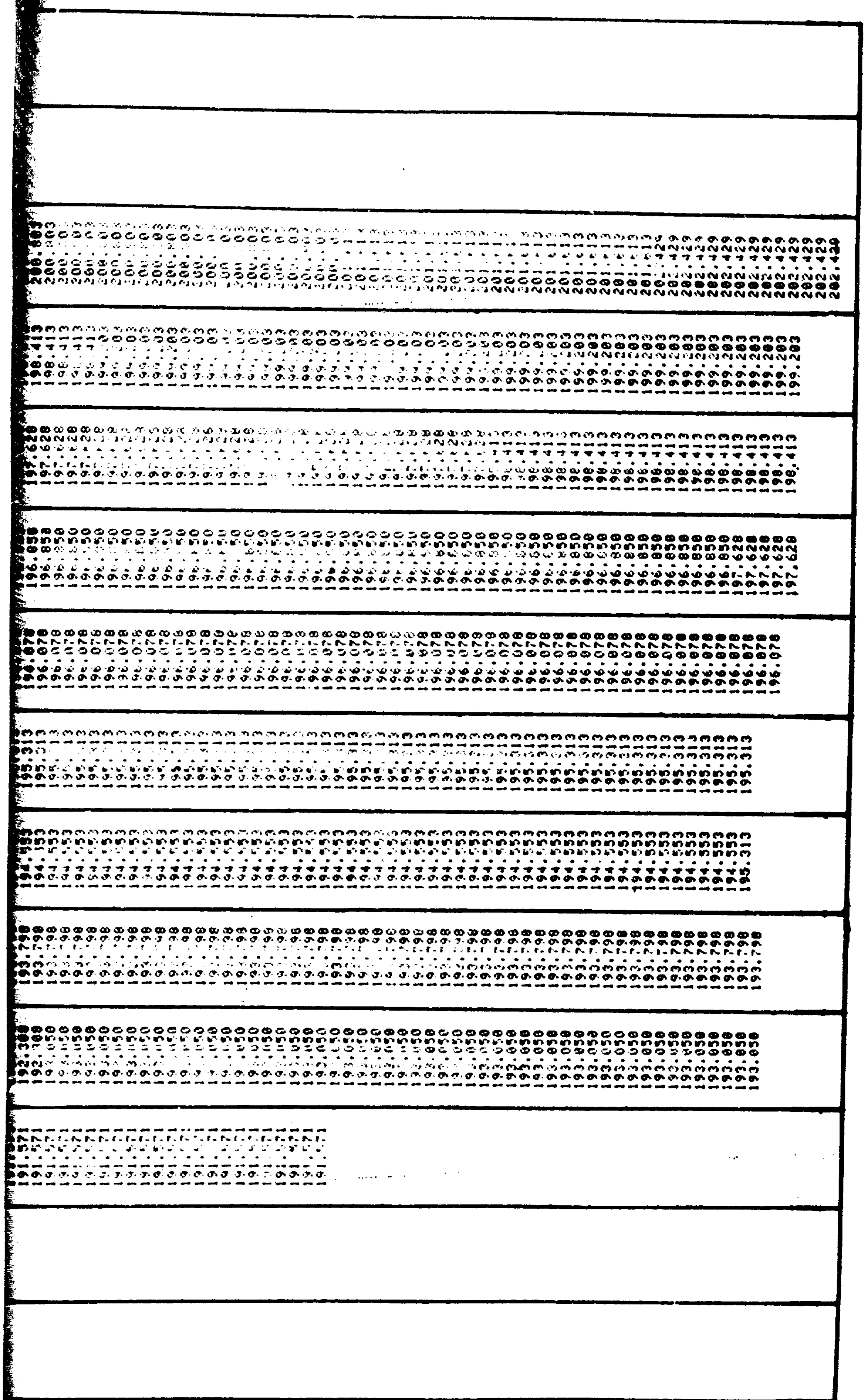
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.079	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		
		191.571	193.050	193.798	194.553	195.313	196.078	196.850	197.628	199.203	200.803		



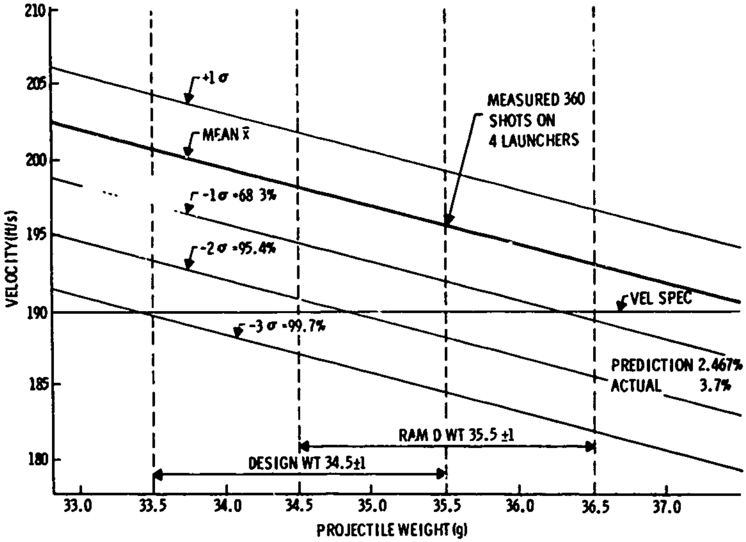


Figure 15. 360-Round Velocity Estimate

SECTION III
TESTING

A variety of individual component and assembly tests were performed during the contract period. Total recorded firings and demonstrations, excluding RAM-D tests, numbered slightly over sixty-six hundred, 6617. It should be noted that this number does not reflect Edgewood Arsenal testing, which during the additional projectile testing was significant.

Early development testing was completed by using old Mk III and IV parts. As the XM234 design solidified, a machined launcher was produced. Under careful observation, tests were planned which combined compatible piece part investigations. In December 1974, the first machined launcher castings were completed. Prior to this a total of 1109 test firings were performed by using Mk III, Mk IV, and the totally machined XM234 hardware. Critical design areas were investigated by using electromechanical instrumentation. Three types of instrumentation were used extensively: 1) velocity screens, 2) pressure transducers, and 3) strain gages.

Velocity screens were used in development as well as RAM testing. In development tests the screens were used as a baseline for analysis. As testing progressed, the screens were used to finalize propellant load. All of RAM testing was completed by using the screens to monitor the velocity criteria.

Pressure transducers were used to obtain data for formal launcher and projectile analysis. With pressure transducers located in the buffer chamber, in the plenum chamber below the flash hider, on the top of the plenum chamber, and behind the launcher cup, pressure traces were obtained. The pressure data obtained is shown in Figure 16. By modifying the transducer positions to receive pressure profiles in specific chambers, data was received for acceleration analysis during projectile development. Transducers were located as shown in Figure 17. The pressure traces received during the projectile development revealed an almost optimum acceleration profile. Further Edgewood Arsenal analysis confirmed this data.

Early advances in strain gage mounting techniques which increased the gage life made it an extremely useful tool. Gages mounted in the shaft of the launcher cup help to identify and trace high stress areas. For example, with the strain gage as a direct readout of buffer performance, rubber materials and configurations were evaluated. After the optimization of the buffer design, testing continued by using strain gages to optimize other design requirements in areas such as the launcher cup assembly.

A significant amount of development testing was performed at Edgewood Arsenal, most of which can be classified in two areas. The first area is biophysics tests which were performed solely at the Arsenal. Their tests indicated that the projectile when fired within the velocity limitations, 205 ± 15 ft/sec, is not lethal. The second area was that of projectile development.

On 21 November 1974, a projectile status review and test was conducted at Delco Electronics. Edgewood and Remington representatives were present and based on this review and preliminary biophysics testing the projectile design was frozen. The interface December 1974 monthly drawing R022869, Rev. D appears in Appendix A.

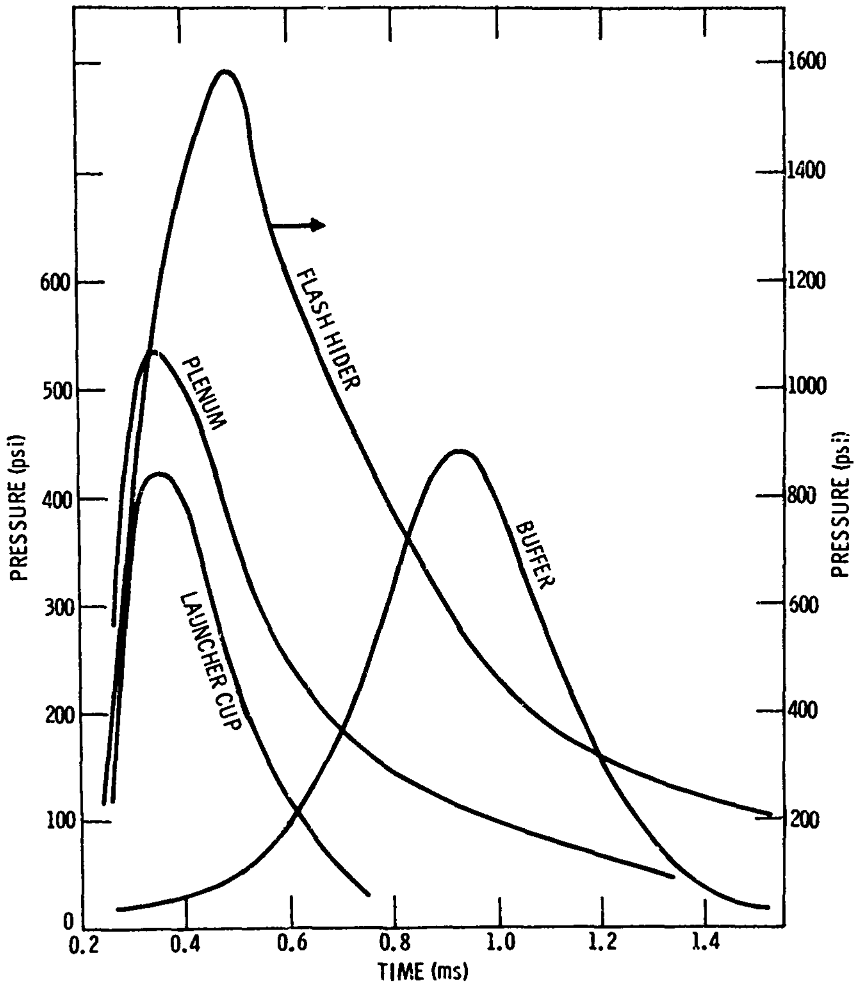


Figure 16. Results of XM234 System Pressure Tests

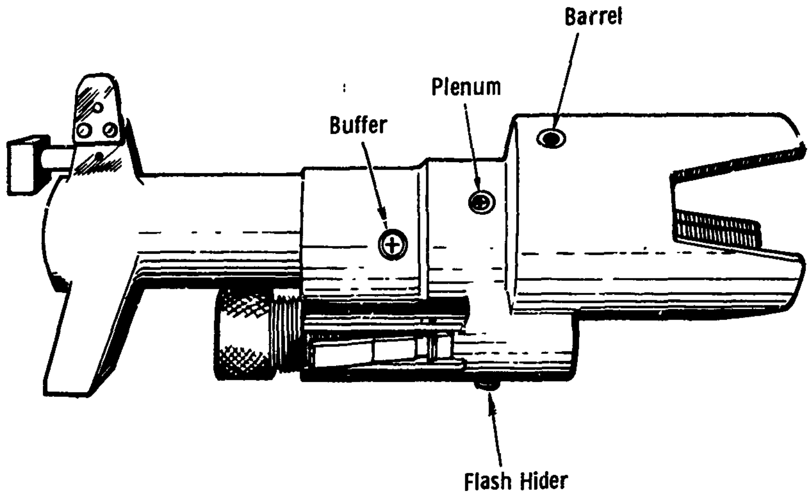


Figure 17. Pressure Transducer Chamber Locations on Test Launcher

On 29 and 30 January, a projectile specification meeting was held at Edgewood Arsenal. At this meeting, high-speed films were taken of the projectile fired from the XM234 launcher which disclosed a problem of projectile wrapping breakage on launch. This problem previously has gone unnoticed because breakage of the 20 wraps/inch projectiles, as received and used exclusively in preliminary RAM-D tests, had not deterred flight and did not appear significant. A quick check of the approved RAM-D projectiles, as received at Delco Electronics (17 wraps/inch), revealed band breakage on every launch and severe deterioration of accuracy.

Extensive projectile tests were scheduled and performed to resolve the projectile band breaking problem. The majority of the firing tests were conducted at Edgewood. In addition, the following objectives were outlined:

- Remington Arms would conduct an engineering investigation to evaluate: 1) a band wrap with moisture-resistant properties and specific strain characteristics, and 2) an alternate projectile material to attain the minimum launch stresses and strains.
- Delco Electronics would develop and test launcher alterations that would minimize launcher acceleration and projectile stresses and strains.

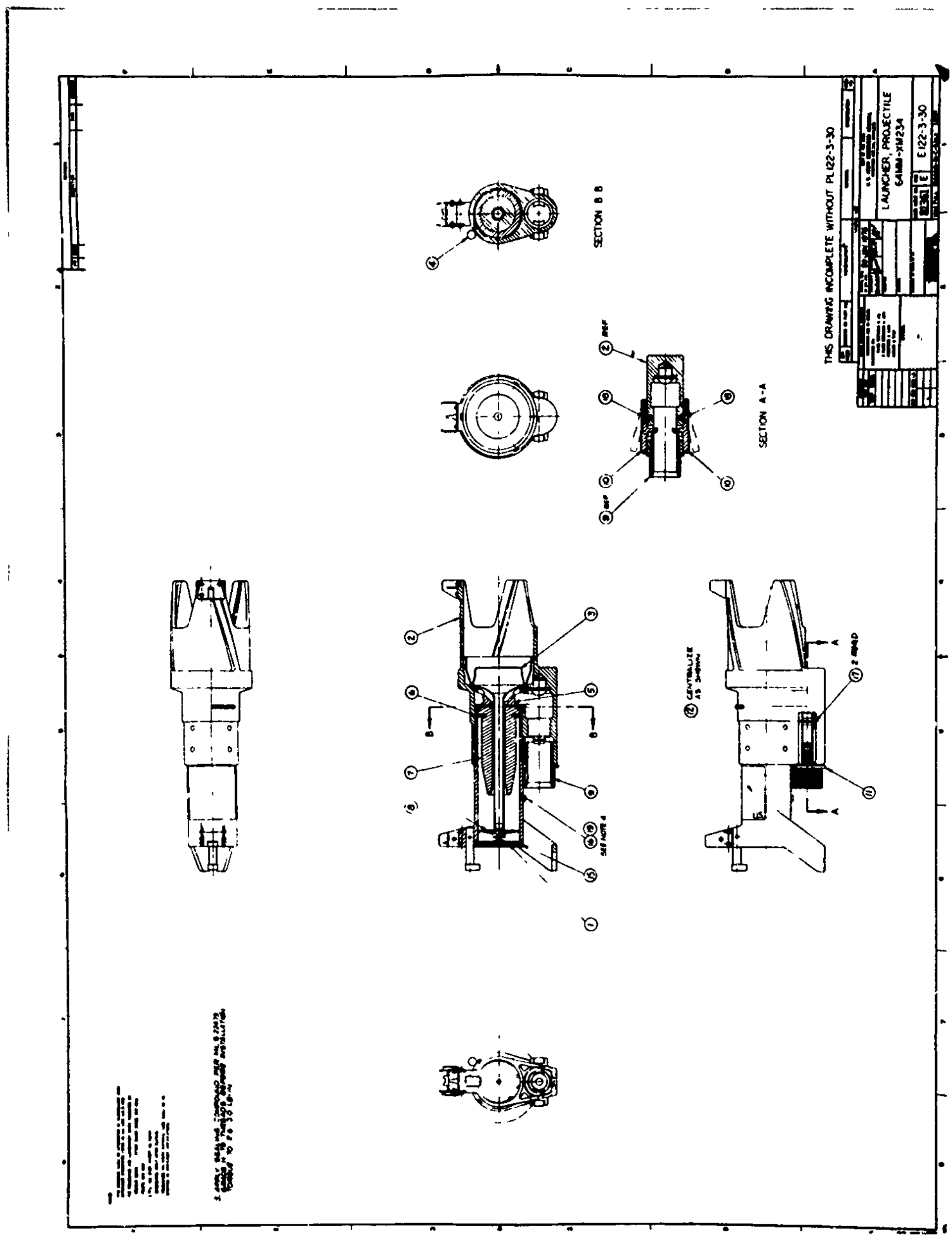
In support of the Edgewood-requested effort, Delco initiated investigations in the following areas:

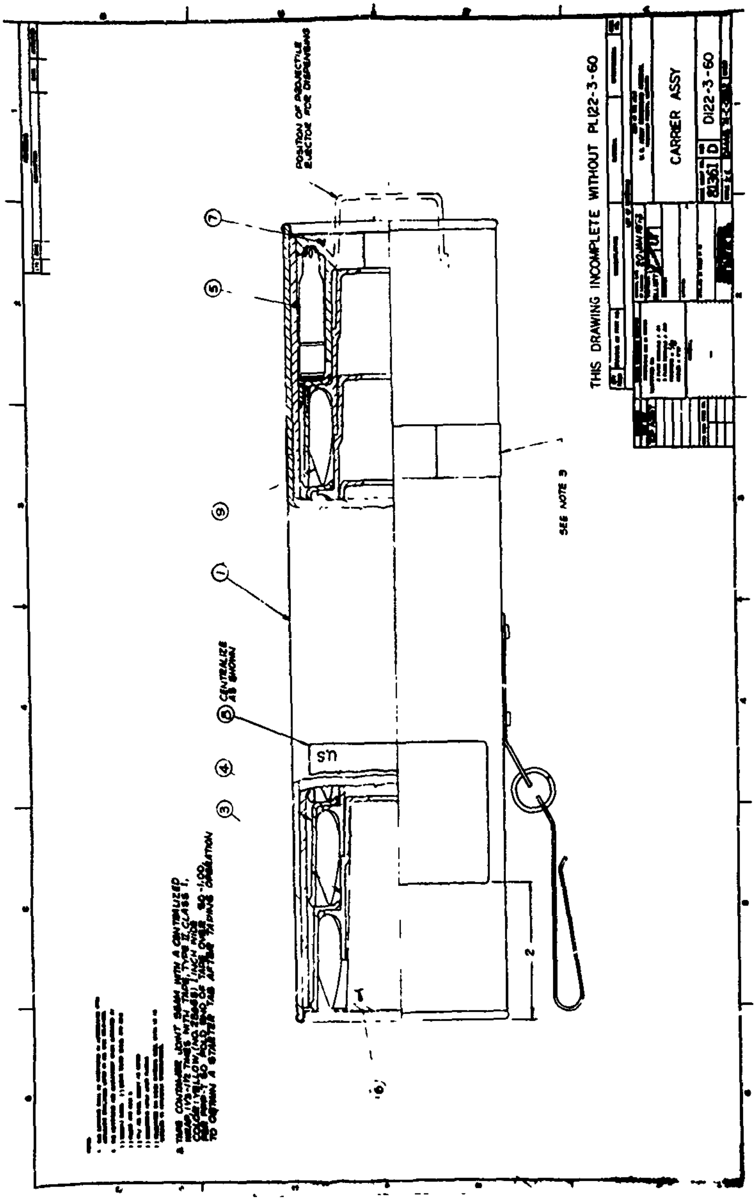
- Launcher sealing to reduce propellant load
- Flow modifications to receive softer launch
- Projectile spin rate reduction to 4,000 revolutions/minute
- Additional cup support of the projectile.

As reflected in the current projectile design (see Appendix A), projectile modification was selected as the solution to the banding breaking problem. The final evaluation testing was conducted at Edgewood Arsenal on 5 and 6 June 1975. At the conclusion of the test program, agreement was reached by Edgewood, Delco, and Remington on the process and materials to be used in completing the fabrication of the Sting projectile. These requirements are also reflected in the attached drawing.

From 27 June 1975 through 14 July 1975 Delco conducted a reliability test, demonstration, and evaluation of the Sting RAG VI Civil Disturbance Control System. The test program was witnessed in total or in part by representatives from Aberdeen Proving Ground, Edgewood Arsenal, and Fort McClellan. Test results and analysis were completed and distributed as stipulated in Mod P00002 of the contract.

APPENDIXES


THIS DRAWING INCOMPLETE WITHOUT PL122-3-30
LAUNCHER, PROJECTILE
64MM-XM234
E122-3-30
SECTION B-B
SECTION A-A
CENTRALIZE AS SHOWN
SEE NOTE 4


THIS DRAWING INCOMPLETE WITHOUT PL122-3-60
CARRIER ASSY
81361
D
D122-3-60
POSITION OF PROJECTILE EJECTOR FOR DISPENSING
SEE NOTE 3
CENTRALIZE AS SHOWN
U.S
1
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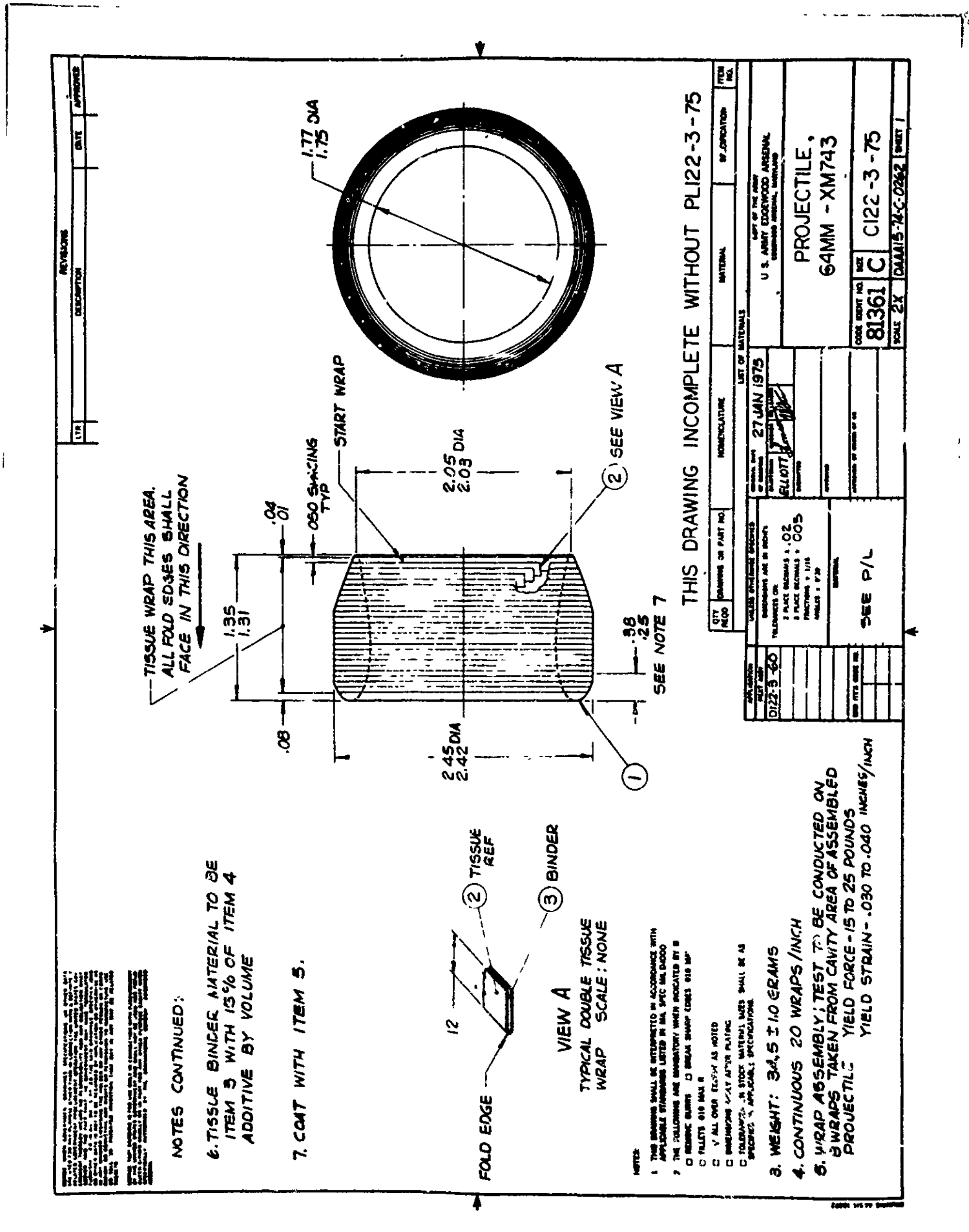
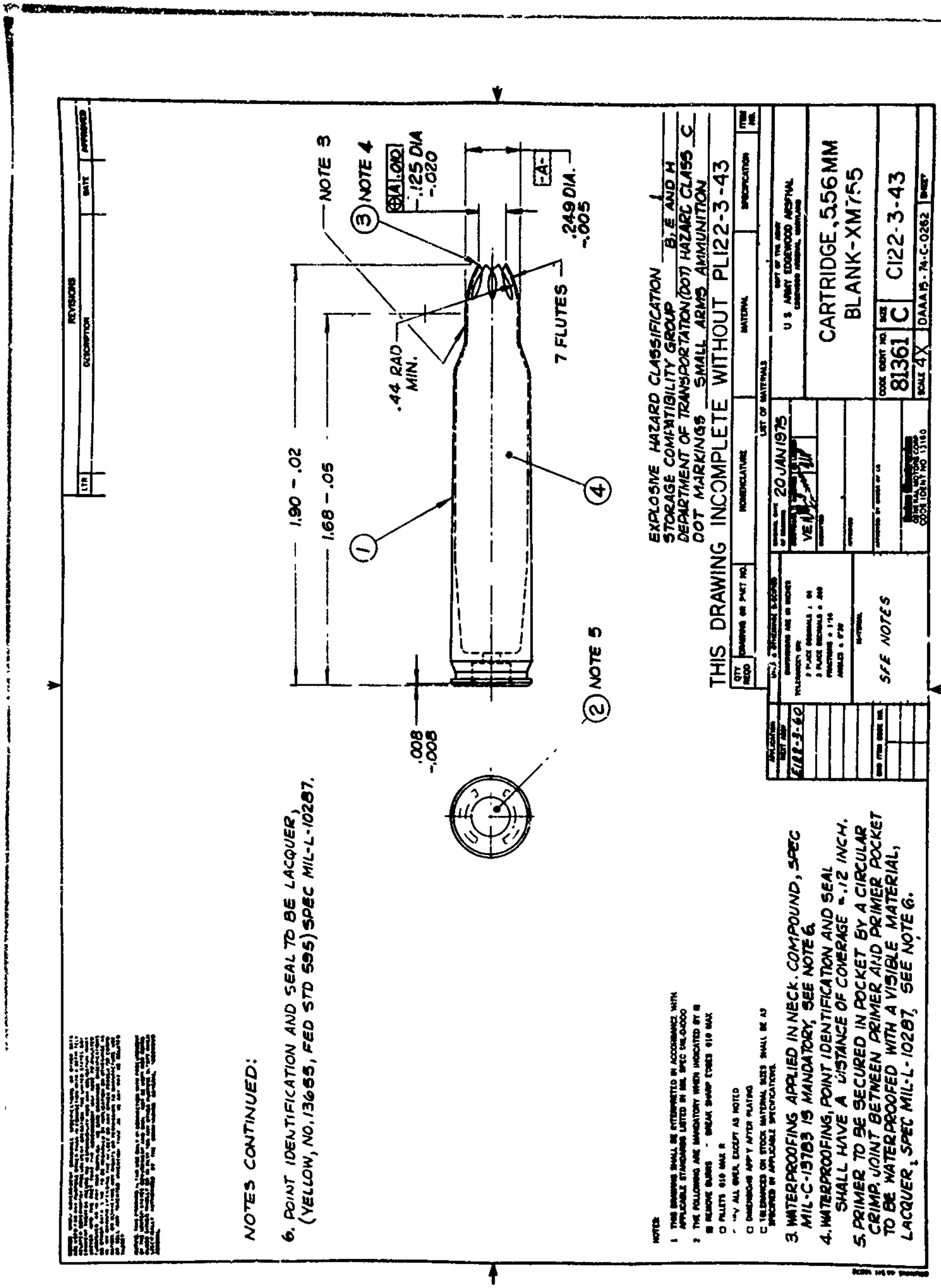
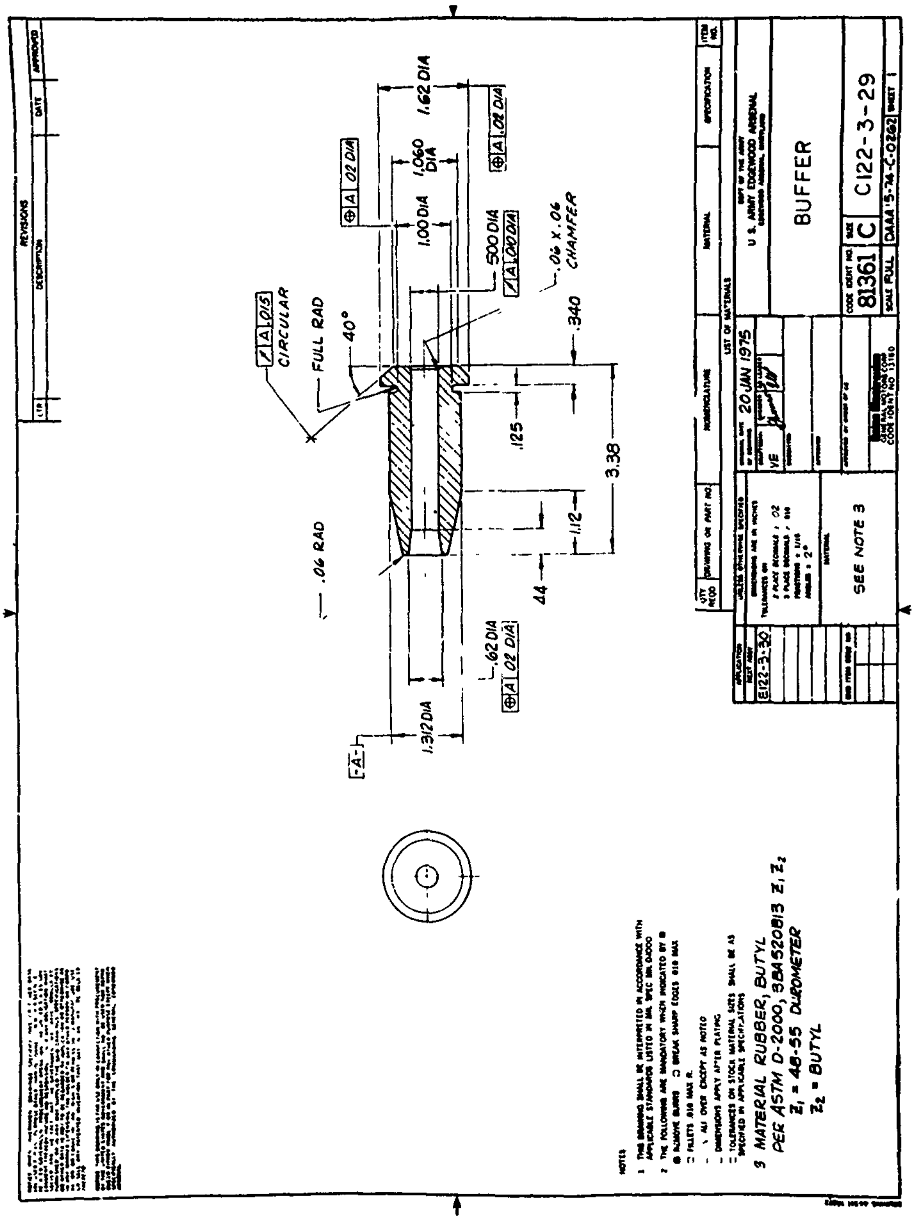

NOTES CONTINUED:
6. TISSUE BINDER MATERIAL TO BE ITEM 3 WITH 15% OF ITEM 4 ADDITIVE BY VOLUME
7. COAT WITH ITEM 5.
FOLD EDGE
12
(2) TISSUE REF
(3) BINDER
VIEW A
TYPICAL DOUBLE TISSUE WRAP SCALE: NONE
3. WEIGHT: 34.5 ± 1.0 GRAMS
4. CONTINUOUS 20 WRAPS/INCH
5. WRAP ASSEMBLY; TEST TO BE CONDUCTED ON 3 WRAPS TAKEN FROM CAVITY AREA OF ASSEMBLED PROJECTILE
YIELD FORCE - 15 TO 25 POUNDS
YIELD STRAIN - .030 TO .040 INCHES/INCH
TISSUE WRAP THIS AREA. ALL FOLD EDGES SHALL FACE IN THIS DIRECTION
1.35
1.31
.04
.01
.050 SPACING TYP
START WRAP
2.05
2.03 DIA
(2) SEE VIEW A
.08
2.45
2.42 DIA
.38
.25
SEE NOTE 7
(1)
1.77
1.75 DIA
THIS DRAWING INCOMPLETE WITHOUT PL122-3-75
SEE P/L
27 JAN 1975
ELLIOTT
D122-3-60
U.S. ARMY EDGEWOOD ARSENAL
PROJECTILE, 64MM - XM743
81361
C
C122-3-75
2X
DAAA15-74-C-0262
SHEET 1


NOTES CONTINUED:
6. POINT IDENTIFICATION AND SEAL TO BE LACQUER, (YELLOW, NO. 13655, FED STD 595) SPEC MIL-L-10287.
NOTES
3. WATERPROOFING APPLIED IN NECK. COMPOUND, SPEC MIL-C-13783 IS MANDATORY, SEE NOTE 6.
4. WATERPROOFING, POINT IDENTIFICATION AND SEAL SHALL HAVE A DISTANCE OF COVERAGE ≈ .12 INCH.
5. PRIMER TO BE SECURED IN POCKET BY A CIRCULAR CRIMP. JOINT BETWEEN PRIMER AND PRIMER POCKET TO BE WATERPROOFED WITH A VISIBLE MATERIAL, LACQUER, SPEC MIL-L-10287, SEE NOTE 6.
1.90 - .02
1.68 - .05
.44 RAD MIN.
7 FLUTES
NOTE 3
NOTE 4
NOTE 5
.125 DIA -.020
.249 DIA. -.005
-A-
.008 -.008
EXPLOSIVE HAZARD CLASSIFICATION
STORAGE COMPATIBILITY GROUP B, E AND H
DEPARTMENT OF TRANSPORTATION (DOT) HAZARD CLASS C
DOT MARKINGS SMALL ARMS AMMUNITION
THIS DRAWING INCOMPLETE WITHOUT PL122-3-43
20 JAN 1975
U.S. ARMY EDGEWOOD ARSENAL
CARTRIDGE, 5.56MM BLANK-XM755
81361
C
C122-3-43
SCALE 4X
DAAA15-74-C-0262
SFE NOTES
E122-3-60



REVISIONS
1.62 DIA
1.060 DIA
1.00 DIA
.500 DIA
.06 X .06 CHAMFER
.340
40°
FULL RAD
CIRCULAR
.015
.125
3.38
1.12
.44
.06 RAD
.62 DIA
1.312 DIA
A
.02 DIA
LIST OF MATERIALS
20 JAN 1975
U.S. ARMY EDGEWOOD ARSENAL
BUFFER
81361
C
C122-3-29
DAAA 15-74-C-0262
SCALE FULL
SHEET 1
E122-3-30
SEE NOTE 3
NOTES
3 MATERIAL RUBBER, BUTYL
PER ASTM D-2000, 3BA520B13 Z1 Z2
Z1 = 45-55 DUROMETER
Z2 = BUTYL

LTR.	DESCRIPTION	AUTH.	DATE	APPROVED
A	COMPLETELY RE-DIMENSIONED WITH TOLERANCES.		23 JULY 74	
B	REMOVED LAUNCHER CLIP INTERFACE. CHANGED WEIGHT TO: 32.0-34.0 GRAMS 33.0 GRAMS NOMINAL WAS: 27.0 ± 3.5 GRAMS		14 AUG 74	
C	ADDED TOLERANCE		26 AUG 74	
D	WEIGHT 34.5±1.0 GRAMS WAS: 32.0-34.0 GRAMS - 33.0 GR NOTE 5 IV ONLY WAS III ONLY DIM. 1.76±.010 DIA WAS 1.77±.010 DIA DIM 2.435±.010 DIA WAS 2.44±.010 DIA		22 NOV 74	

NOTES:

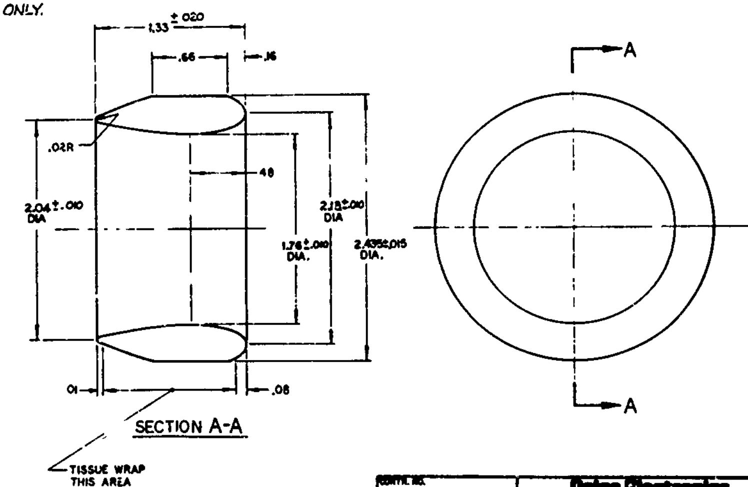
1 WEIGHT · 34.5 ±1.0 GRAMS

2. PROJECTILE SHALL MAINTAIN STRUCTURAL INTEGRITY AND NOMINAL SHAPE WHEN LAUNCHED AT A VELOCITY OF 220 FT/SEC MAX. AND A SPIN RATE OF 5500 RPM.

3. PROJECTILE MASS DISTRIBUTION LAUNCH AND FLIGHT CHARACTERISTICS SHALL BE SIMILAR TO THE XM742 PROJECTILE, 64MM, RIOT CONTROL, CS, WHEN LAUNCHED FROM THE XM234 LAUNCHER, PROJECTILE, 64 MM.

4. PROJECTILE COMPLIANCE SHALL BE SUCH THAT IT IS NON-HAZARDOUS AT BODY IMPACT VELOCITIES OF 210 FT/SEC

5. THIS DRAWING APPLIES TO STING RAG IV ONLY.



DRAWN V. Edle 7-5-74	Delco Electronics	GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
CHECKED	TITLE	XM743 PROJECTILE, 64MM - RIOT CONTROL, KINETIC ENERGY
ENGR 7/5/74	SIZE C	CODE IDENT NO. 13188
APPD	DWG NO.	R022869
DSGN ACTIVITY APPD	REV	D
OTHER APPROVAL	SCALE 2X	WEIGHT — SHEET 1 OF

AB 75-3

DELCO STUDY CONTRACT

FINAL REPORT

Purchase Order 13501, Amendment 3617
Under Government Contract No. DAAA15-74-C-0262
September 1975

Final Report
by
Kenneth W. Misevich

Work done by: K.W. Misevich
J.J. Scanlon
C.L. Jackson

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ILLUSTRATIONS

INTRODUCTION

The work described in this report is the result of a special study contract from Delco Electronics Laboratories to Remington Arms Company, Incorporated, (Amendment 3617 of Purchase Order 13501, under Government Contract No. DAAA15-74-C-0262). The main goal was the improvement of the launching survival of the XM-743 Sting RAG projectile in the XM-234 launcher.

The Sting RAG projectile is similar to the Soft RAG (XM-742) projectile developed by Remington Arms Company, Incorporated, for Edgewood Arsenal, Maryland, under Contract No. DAAA15-73-C-0047, except the Soft RAG disseminates CS-2, a riot control agent, on impact and the Sting RAG does not. These projectiles are ring airfoil shaped which provides low drag, making it possible to launch them at a low velocity of 200 fps. This, in combination with the soft, low durometer rubber-bodied projectile, results in a kinetically non-hazardous projectile. To maintain the airfoil shape at the launch conditions of 200 fps and 5000 rps, a wrapped tissue breakband that is supple, yet of low ultimate break strain was developed. Since the Soft RAG must disseminate the riot agent on impact and graze against hard and soft targets, the breakband was designed to maintain a yield strain of 1-1/2 percent to 3 percent over all specified environmental conditions while holding a nearly constant tensile strength. This band was, therefore, used for the Sting RAG as ballistics and projectile weights are identical to the Soft RAG projectile.

The banding material is Aldex 17 tissue (Gould Paper Company, New York) cut in 1/4 inch widths, folded in half to 1/8 inch and impregnated with ethylene vinyl acetate (EVA), Du Pont Elvace® 1968. After experimentation with the Soft RAG dissemination characteristics, the best wrap rate was found to be between 17 to 20 per inch. The banding operation consists of banding six projectiles at a time, drying the tissue wetted with the EVA binder in a forced convection chamber, cutting the nose and tail ends to produce the tissue breakband, drying overnight, and crosslinking the EVA by heating for three minutes at 300°F. In the dry state the breakband ultimate yield strain is 1 to 2 percent, and wet 3 to 4 percent with a tensile strength of about 4500 to 5000 psi. (The tensile stress is based on a nominal cross section of 0.003 inch x 1/4 inch per wrap.)

Both the Soft and Sting RAG projectiles were test fired at Delco in November 1974 with excellent results. But in January 1975, further test firings at Edgewood Arsenal (and concurrently at Delco) revealed a launching survival problem for the breakband when in the dry, low ultimate strain condition. Only humidification, which increases the ultimate strain to about 3 percent, allowed the breakband to survive the complex launch dynamics.

A study was initiated to review the breakband mechanics and the rubber body distortions caused by the launch forces. This study showed that the combination of suppleness and low ultimate strain would be very difficult to obtain with available non-fibrous materials, so Edgewood Arsenal decided to pursue a course of permanent breakband plasticization. A change of the body material for the Sting RAG from Nordel® elastomer to a butyl rubber was also considered because Delco's work on the XM-234 launcher indicated that this formulation would be slower reacting to the dynamic launch forces due to its better damping characteristics.

OBJECTIVES

The goals of this study were very specifically set down after initial experiments at Edgewood Arsenal indicated that polyethylene glycol (PEG) of low molecular weight (300) would increase the ultimate strain of the breakband when added to the ethylene vinyl acetate (EVA) breakband binder. The purpose of this study was to determine the best material combination and process methods through five fabrication and testing tasks per Amendment 3617 of Purchase Order 13501 under Government Contract No. DAAA15-74-C-0262. These tasks are described below:

1. A. Fabricate 144 projectiles wrapped at a rate of 20 wraps per inch, using the three PEG binder ratios (48 projectiles each) shown below and without the oxalic acid cross-linking catalyst in the EVA.

   48 XM-743 projectiles with 15% PEG added to EVA

   48 XM-743 projectiles with 20% PEG added to EVA

   48 XM-743 projectiles with 25% PEG added to EVA

   B. Test the breakbands of six projectiles for strain and ultimate stress according to the following: Two breakbands from each lot under dry conditions (24 hours storage at 120°F); two under wet conditions (24 hours storage at 100°F and 100% relative humidity); and two at ambient conditions.

   C. Submit the remaining 42 projectiles from each group to Edgewood Arsenal for firing and biophysics tests.

2. A. Fabricate 48 additional projectiles using the best PEG/EVA binder ratio as determined by Edgewood Arsenal tests on the above samples.

B. Test the breakbands of six projectiles for strain and ultimate stress as defined in Task #1, and submit the remaining 42 projectiles to Edgewood Arsenal for tests.

3. Fabricate 96 projectiles with a butyl rubber to be supplied by Remington Arms Company, Inc., wrapping half at 17 and the remainder at 20 wraps per inch. Divide these two lots in half, coating one lot with EVA and the rest with PEG/EVA binder selected in Task 1-C.

4. Fabricate 96 projectiles with a butyl rubber material furnished by Delco. Wrap and coat as done in Task #3.

5. Prepare 48 talc-filled Soft RAG projectiles (XM-742), wrapping 24 projectiles at 17 and the remainder at 20 wraps per inch. Coat these with the PEG/EVA binder employed in Task #2, but cross-link all projectiles. This was not done in Task #2.

Other tasks included: Investigating the introduction of the polyethylene glycol into the Sting RAG manufacturing process (Task #6); and technical meetings and testing at Edgewood Arsenal and submitting this final report (Task #7).

SUMMARY

Projectiles tested in Task #1 performed about equally well, but the binder with the 15% PEG added to the EVA was selected since it produced the best breakband integrity and processibility. Even though the breakband strains are about 3 percent as desired, the addition of the PEG causes a problem. The PEG greatly reduces the adhesive quality of the EVA which results in repeated instances of the breakband unwinding from the leading edge of the projectile in flight. To determine whether consolidating the nose portion of the breakband wrap would prevent the unwrapping half of the Task #2 projectiles were dipped in pure EVA. But, this was not effective.

Since Du Pont's butyl formulation, which met the ASTM specification that Delco requested, could not be processed in the available molding equipment the regular 30 percent brass-filled Nordel® elastomer was substituted for it in Task #3. The 96 projectiles fabricated were divided into four test groups: 1) a control group, 2) extra wet binder applied, 3) post-dipped over 1/4 inch of the nose portion of the band with the 15 percent PEG/EVA binder and, 4) with the breakband cut off about 1/16 inch further back from the nose. All projectiles were dried for one-half hour in a blower chamber and then one hour at 130°F to insure that a good clean breakband cut off from the banding mandrels would result. These projectiles were then hand-carried to Edgewood Arsenal by R.E. Belden for a joint testing and technical meeting on June 5, 1975.

Firing tests of the variously banded projectiles permitted agreement on the final band properties which provides adequate performance. Under the worst conditions of dryness, it was found that the breakbands plasticized with the polyethylene glycol could still have some small breaks at the nose. These breaks, opened by the spin and aerodynamic forces are undesirable. Since no reasonable way of positively eliminating these breaks was possible within the time scale of the program, it was decided to minimize this effect by coating the nose of the finished projectile with rubber cement.

The Sting RAG breakband specifications are as follows:

- Wrap with the Aldex 17 tissue at 20 wraps per inch.
- Coat tissue binder consisting of 15 percent polyethylene glycol (Union Carbide Carbowax 300) added to plain Du Pont Elvace® 1968.

- Dried at 50°C for 20 minutes by forced air blower.
- Cut the band in the nose and tail sections.
- Coat nose with a thin application of rubber cement (B.F. Goodrich Vulcalock) about 1/4 inch.

Details of the task activities and the process description are given in the following section.

EXPERIMENTAL DETAILS

Since this contract was only for a month and many variations were made throughout, the work is presented chronologically for clarity. Then, a summary of the process conditions is given.

5/19/75 Work began with wrapping trials utilizing samples of Union Carbide Carbowax® 300 provided by Edgewood Arsenal. A number of observations were made:

- The addition of PEG to the EVA forms a much thinner binder.
- The PEG greatly decreases the EVA resin build-up on those surfaces exposed to the wetted tissue.
- Intra-wrap adhesion is much less to the point where the breakband can be unwrapped without tearing even after it is dried completely.
- Much longer drying times (an hour or more compared with the previous 15 minutes) are required before band cutoff can be done.
- Even after apparent complete drying, the cutoff is difficult and in some instances tearing or pulling occurs.
- As the percentage of PEG increases the breakband gets a more "oily" or "wet" feel.

At the initiation of Task #1, the 15 percent PEG/EVA binder solution was made as follows: 75cc of Union Carbide Carbowax® 300 were added to 500cc of plain 50 percent solids Elvace® 1968 to create the 15 percent binder ratio. At first the projectiles with 20 wraps per inch breakbands were coated with this solution and dried 1/2 hour before attempting to cut the bands. Many tears resulted so the drying time was increased to one hour. But, the cut off was still not uniformly clean.

Finally, projectiles soaked for one hour at 130°F, cooled for one hour at room temperature and then crosslinked by heating them at 300°F for three minutes, produced good, cleanly cut bands.

To make the 20 percent PEG/EVA solution, 17.5cc PEG were added to the 405cc of the 15 percent PEG/EVA binder and the process was repeated for another 48 projectiles. The 25 percent PEG/EVA solution was made by adding 11cc of PEG to the remaining 260cc of 20 percent PEG/EVA solution.

Six projectiles of each binder ratio were set aside for tensile testing.

<u>5/20/75</u> The butyl rubber formulation procured by Remington A Company, Inc., was requested only in a sample quantity of 10 pounds since the moldability was never demonstrated in our press. While Du Pont felt that the Nordel® elastomer formulation could be effectively repeated in butyl, the actual sample was ordered according to the Delco specification (ASTM D2000,3BA520B13Z_1Z_2;Z_1 = 40 ± 5 Shore "A", Z_2 = Butyl) provided verbally on March 6. The sample was received on April 15 and was tried immediately. But, it was too stiff to be transferred into the mold. Du Pont suggested pre-heating the molding billets, but no further trial could be made until May 20.

Various pre-heating cycles were attempted but none softened the material sufficiently so the 2000 psi available in the transfer press could hardly fill the mold. Preparations were then made to order another sample with better processibility. (The order was cancelled May 30 at Delco's direction to substitute 30 percent brass-filled Nordel® elastomer for the Remington-supplied butyl in Task #3.)

5/21/75 The Task #1 projectiles were shipped to Edgewood Arsenal under Remington Arms Company, Incorporated, shipping memorandum TD 1931. Eighteen tensile samples, six from each binder ratio, were made by cutting the breakband and taking eight wraps from the portion over the body cavities. These strips were then cut to 7-inch lengths, covered on each end by 1/2 inch masking tape and put into the test storage. Three from each binder ratio were stored for 24 hours at 130°F, and 24 hours at 100°F and 100 percent R.H.

The Delco-supplied butyl arrived and was immediately checked at the same settings used for the Nordel® elastomer, that is, platen temperature to give 350°F molds and 1600 psi transfer pressure. But, after five minutes the butyl rubber did not fully cure. The time was increased gradually until full curing was effected at 10 minutes.

Butyl rubber projectile bodies were then made in a two-step process: Five minutes in the transfer press, five minutes in the hydraulic press at 350°F and then stripped. Altogether, over 100 projectile bodies were made. The molds had to be periodically cleaned of a black residue which was produced from the filled butyl. The build-up was much faster than with the brass-filled Nordel® elastomer.

5/22/75 The tensile tests were conducted on the eighteen breakband samples from Task #1 with the Instron driven at 0.2 inches per minute and the chart at 10 inches per minute using a 20-pound full scale. The results are shown in Table B-I. Note that the yield strain is determined by the displacement from the extrapolated zero strain to the point of first maximum stress. Later, Edgewood Arsenal defined the yield strain using the best straight line through the 5 and 15-pound readings. For this reason, Edgewood's method usually gave a slightly higher strain value to yield.

5/23/75 The Task #1 projectiles fired at Edgewood Arsenal flew well but the breakband unraveled from the nose. In a meeting after the test, methods to prevent the unraveling were discussed, namely: use sharper cutoff knives, add more binder to nose region, use a different drying cycle before cutoff, or try separate EVA and then PEG impregnation.

5/23/75 Butyl projectiles fabricated by Delco were checked for Shore "A" durometer. They were averaged between 30 and 35 instead of 40 ± 5. Nothing could be done to correct this situation in the time period available.

5/27/75 According to verbal instructions from Delco, the banding of the Task #2 projectiles was to be done using the 15 percent PEG/EVA binder ratio applied extra wet. Half of the 48 projectiles had additional pure EVA applied to the nose region of the breakband while on the banding mandrels. (The EVA was dyed red for identification.) One half hour of blower drying and one hour at 130°F preceeded the cutoff which was done with new knives. Then all of the projectiles were dried further for 24 hours at 130°F.

TABLE B-1

TASK #1 TENSILE TESTS

Binder Ratio	Condition	Max. Force (lb.)	Tensile Strength (psi)	Yield Strain (%)	Break Strain (%)
15% PEG	Wet	7.75	1292	3.2	4.2
15% PEG	Wet	7.30	1216	3.7	4.6
15% PEG	Wet	8.10	1350	3.9	5.6
		Average	1286	3.6	4.8
20% PEG	Wet	6.95	1158	3.2	5.0
20% PEG	Wet	6.85	1142	3.4	4.5
20% PEG	Wet	6.50	1083	3.3	4.8
		Average	1128	3.3	4.8
25% PEG	Wet	7.10	1183	3.0	4.3
25% PEG	Wet	7.30	1216	3.4	4.9
25% PEG	Wet	6.70	1117	3.0	4.4
		Average	1172	3.1	4.5
15% PEG	Dry	18.00	3000	3.0	4.8
15% PEG	Dry	17.00	2833	3.1	4.7
15% PEG	Dry	16.05	2675	2.8	4.0
		Average	2836	3.0	4.5
20% PEG	Dry	16.40	2733	2.9	4.5
20% PEG	Dry	18.30	3050	2.9	3.6
20% PEG	Dry	16.55	2758	3.0	4.4
		Average	2847	2.9	4.2
25% PEG	Dry	15.45	2575	2.7	3.7
25% PEG	Dry	15.60	2600	2.9	3.5
25% PEG	Dry	14.30	2383	2.5	3.4
		Average	2519	2.7	3.5

Wet Condition - 26 hours 100°F and 100% R.H.
Dry Condition - 27 hours 130°F
Tensile Specimen - 8 wraps by 6 inches effective length, .003" x .25 x 8 cross section
Cross Head Speed - 0.2 inches/minute

KWM:KLK
8/6/75

5/28/75 Molding of the projectiles with Delco-supplied butyl was completed.

A TWX from Delco was received confirming the 5/27/75 verbal instructions. The Task #2 projectiles were hand-carried to JFK airport to Mr. Robert Peterson under Remington Arms Company, Inc., shipping memorandum TD 1938.

Six tensile specimens were made from the Task #2 projectiles and put into wet and dry storage.

The XM-742 package machine was set up in preparation for the requirements of the Task #5 XM-742 projectiles.

5/29/75 The packages for the XM-742 projectiles of Task #5 were made. Tensile tests on Task #2 breakbands were run. The results are shown in Table B-II.

5/30/75 A TWX was received from Delco directing that Nordel® elastomer be substituted for the Remington-supplied butyl in Task #3. All projectiles were to be prepared using 20 wraps per inch with 15 percent PEG/EVA binder, dried one-half hour with the blower and then an hour at 130°F before cutting off. The projectile breakdown was:

- 24 projectiles with leading edge of breakband cut back .050" to .060" further than normal.
- 24 projectiles after drying dip the projectile nose about 1/4 inch into the 15 percent PEG/EVA binder.
- 24 projectiles with even heavier binder wetting in impregnation.
- 24 projectiles made in the normal manner.

In addition, 48 of the Task #4 projectiles were banded according to the previous production banding operation, half 17 wraps per inch and half 20 wraps per inch.

The Soft RAG XM-742 projectiles were assembled for Task #5.

TABLE B-II

TASK #2 TENSILE TESTS

Binder Ratio	Condition	Max. Force (lb.)	Tensile Strength (psi)	Yield Strain (%)	Break Strain (%)
15% PEG	Wet	6.85	1141	4.0	5.6
15% PEG	Wet	7.60	1268	4.2	6.2
15% PEG	Wet	7.80	1300	4.0	5.2
		Average	1236	4.07	5.67
15% PEG	Dry	17.7	2950	2.5	3.5
15% PEG	Dry	18.5	3083	2.7	5.1
15% PEG	Dry	19.6	3267	2.9	No Data
		Average	3100	2.7	4.3

Wet Condition - 24 hours $100^{o}F$ and 100% R.H.
Dry Condition - 24 hours at $130^{o}F$
Tensile Specimen - 8 wraps by 6 inches effective length, .003" x .25 x 8 cross section
Cross Head Speed - 0.2 inches/minute

KWM:KLK
8/7/75

Projectile molds were cleaned and repaired as required.

6/2/75 Mr. R.E. Belden of Edgewood Arsenal observed the production of the above 144 Tasks #3 and #4 projectiles.

6/3/75 The Task #3 and half of #4 projectiles were hand-carried by R.E. Belden to Edgewood Arsenal under Remington Arms Company, Incorporated, shipping memorandum TD 1946.

6/4-5/75 A trip was made to Edgewood Arsenal to observe the test firings of the Task #3 and #4 projectiles. All of the humidified projectiles flew well without band breaks and all of the dried projectiles (24 hours at 130°F) had some sort of breaks or cracks in the band near the nose. It was found that the spin up to 5000 rpm in a wind tunnel at 210 fps would open these cracks and probably cause flight irregularities. In longer range firings this would be a problem.

The overall situation was discussed at length and it was decided to coat over the nose end of the breakband with rubber cement to help maintain breakband integrity during flight even if a crack developed. It worked well.

The final Sting RAG configuration was set by consensus as described in the summary, previously. Only specification of impregnation, drying before cut off and rubber cement application remained.

A discrepancy in the yield strain values existed between tests at Edgewood and Remington Arms Company, Inc. This resulted since Edgewood Arsenal uses the best straight line through 5 and 15 pounds for dry specimens and then calculates the yield strain from the abscissa when the ordinate is maximum force. To alleviate the discrepancy, Edgewood's method was adopted for further tests at Remington Arms.

6/6/75 A TWX from Delco authorized the rewrapping of the 3000 Sting RAG projectiles which were already delivered to Delco under P.O. 13501 and fabricated by the old method. In addition, the 48 balance of the Task #4 Delco butyl projectiles and the Task #5 Soft RAG's were to be banded also at 20 wraps per inch and coated with rubber cement.

6/9-10/75 The wrapping of the Task #4 and #5 projectiles was completed. The B.F. Goodrich Vulcalock rubber cement was applied by hand with a coffee stirrer while hand turning the projectiles which were made for special tests. It was decided to hold up the cement application until the procedure was refined.

During the final wrapping it became obvious that the drying time before cut off was too long to get any kind of production rate at all. A new drying cabinet was, therefore, considered necessary for the hot forced air drying.

A special check was made of the impregnation of the binder into the tissue. About ten feet of tissue was drawn through the impregnator at the normal setting of the squeegee. The weight was 24.5 grains. The same length without binder is 6.2 grains so 18.3 grains of 15 percent PEG/EVA was deposited. After drying for 30 minutes at 120°F the weight dropped to 18.0 grains, a loss of 6.5 grains. This indicated that not all of the 50 percent water in the EVA had evaporated, since 15.9 grains of EVA should be contained in the 18.3 grain total. The water content is 7.95 grains initially so 1.45 grains or 18 percent of the water remains in the band presumably because of the PEG.

Tightening of squeegee down to the driest attainable impregnation setting still yielded 25 grains for the wet tissue and binder. The impregnation is totally insensitive to squeegee pressure in the impregnator being used. More binder could not be added to the tissue until the squeegee was actually lifted from the tissue. This situation is, of course, irrelevant.

6/11/75 A plywood cabinet was designed to accommodate standing mandrels from the wrapping process in a lower 12" x 16" x 12" high chamber, and a Nutone Model 9605 Heater/Ventilator above. (See Figure B-1)

6/12/75 The breakband drying cabinet was built and assembled for operation.

6/13/75 Experiments with the drying cabinet showed that the air was entering the chamber at about 70C but in the center of the chamber had dropped to 50C because of mixing with air from the 3" x 16" opening above the door in front. In order to be consistent in band drying in a continuous process, a special cycling jig was made to space and move the mandrels as they were wrapped. As Figure B-2 shows, the mandrels are set into the center of the cabinet from the rear to the front. When one set of four are wrapped, the sliders uniformly move the stacked mandrels about 3 inches to the left leaving room for four more. When eight sets are wrapped in about 20 minutes, the first one is dry and is removed from the left rear of the cabinet. They are taken out for cutoff in the same order as put in, so all get a uniform drying exposure in the continuous process. The whole system works very well.

6/16/75 Various methods of applying the rubber cement to the nose of the projectile were tried in breadboard fashion: dipping, trough rolling, syringe application and sponge application. None were satisfactory or suitable for quick economical implementation. It was decided, therefore, to apply the cement to the projectile while it was being rotated with its symmetry axis horizontal, at 175 rpm. A can of the cement is placed right below the rotating projectile and a coffee stirrer (about 1/4" x 6") is pulled up from the cement, right to the nose of the projectile. This works fine but requires careful hand dexterity.

6/19/75 The tensile samples were prepared from a random selection of the Sting RAG projectiles which were undergoing the rewrap operation. They were put into a 130°F oven for 24 hours and tested as described earlier. The results are shown in Table B-III.

7/1/75 A new aluminum rubber cement applicator as shown in Figure B-3 was made. This permitted an even application of the cement over the initial breakband wraps without getting much up on the front of the nose.

TABLE B-III

TYPICAL PRODUCTION BREAKBAND TENSILE TESTS

Breakband Binder - 100 parts Elvace 1968, 15 parts Carbowax 300 (by volume)

Drying Schedule - 20 minutes, 50C force air before cutoff

Post Drying for Tests - 24 hours at 130F

No.	Time from 130F Oven (Min.)	Yield Force (Lb.)	Yield Stress* (Psi)	Tensile Modulus (Psi)	Yield Strain** (%)	Break Strain (%)
1	1	17.3	2883	117,000	2.9	5.15
2	5	16.75	2792	109,000	3.1	5.0
3	9	17.0	2833	106,000	3.2	6.3
4	11	16.5	2750	95,000	3.3	5.1
5	15	16.55	2758	101,000	3.3	5.9
6	17	14.95	2492	95,000	3.2	6.4
7	21	16.35	2725	101,000	3.2	6.0
8	23	15.9	2650	95,000	3.2	6.4
9	28	15.3	2550	98,000	3.2	5.2
10	31	16.55	2758	100,000	3.3	5.2
Average		16.3	2719	102,000	3.2	5.7
Extreme Variation		2.35	391	23,000	0.4	1.4

* Yield Stress based on a cross section of 0.003" x 1/4"/wrap. Each specimen was 8 wraps by 6" effective length.

** Yield Strain is the abscissa of the best straight line through 5 and 15 lbs. force drawn to the maximum force.

Tests 6/20/75 by KWM

STING RAG PRODUCTION PROCESS: BREAKBAND AND RUBBER CEMENT

Breakband The Aldex 17 Tissue (Gould Paper Company, New York) is folded in half from 1/4" to 1/8" and then passes through the impregnator bath. The binder is made up in one quart batches. (That is, 1000 cc Du Pont Elvace® 1966 plus 150 cc of Union Carbide Carbowax® 300) After passing through about 6 inches of the binder, the tissue is squeegied of the excess binder by a small piece of Nordel® elastomer (30 durometer Shore "A") held against a stainless steel lip with modest leaf spring force. The adjustment of the force does not vary the binder content in the tissue. It stays at about 25 grains per 10 feet, wet.

A rolling guide then directs the tissue onto the projectiles which are wrapped from tail to nose at speeds up to about 220 rpm. After wrapping, the breakband is consolidated over the tail and nose portion with a piece of damp cloth, but not over the cavities. This would cause a depression in the outer diameter.

The wrapped mandrel of six projectiles is then carefully removed from the banding machine and set into the forced air drying box (Figure B-2). The air temperature at the projectiles is uniformly held at 50C by the room temperature air passing through a 1500 watt heater. The air velocity, though not measured, is estimated to be 1000 feet per minute or less. The wettest projectiles are always placed in the entering hot air, and in about 10 minutes they are moved to the left to make room for newer ones. (See Figures B-1 and B-2) The total time at 50C is about 10 minutes. Another 10 minutes is spent at the slightly cooler and moister condition as they are positioned behind the wetter projectiles. The total drying time of 20 minutes is sufficient for clean cut off, and for maintaining a continuous wrapping process. As long as the drying is sufficient for cut off, the moisture content of the breakband is irrelevant in the process.

The banding operation is normally done in the morning. After cut off the projectiles are stacked at room condition for 3-5 hours until the rubber cement is applied.

The rubber cement application is done in a hood in one batch each day. The tail of the projectile is set onto an old modified aluminum banding mandrel unit and turned at 175 rpm. The dipstick shown in Figure B-3 is lifted from one quart B.F. Goodrich Vulcalock rubber cement can up to the projectile. After the stick contacts the projectile, it is moved down until the proper amount of cement is applied. With no further movement the stick is held against the projectile until the coating is uniformly smooth. Of course, there is still a measure of art and dexterity involved in this process. The average weight of the rubber cement for 24 sample coatings is 2.25 grains (mostly 2 grains but up to 3 grains) after drying overnight in the hood.

Care is taken not to get rubber cement onto the front of the nose, but it does happen. Also, they are stacked very carefully so as not to disturb the coating. When packaging, the lightly painted side of the cardboard separators are placed against the nose end of the projectiles. In case some sticking occurs during unpacking, sliding the projectiles along the cardboard permits them to be removed with minimal, if any, disturbance of the coating. Mr. Arbogast of Edgewood Arsenal has experienced severe sticking of the coating to polyethylene film after a short storage in a hot car trunk. Obviously, the cement softens and sticks when warm. (No special handling, coating or packing instructions have been received so it is presumed that the shipment method is satisfactory.)

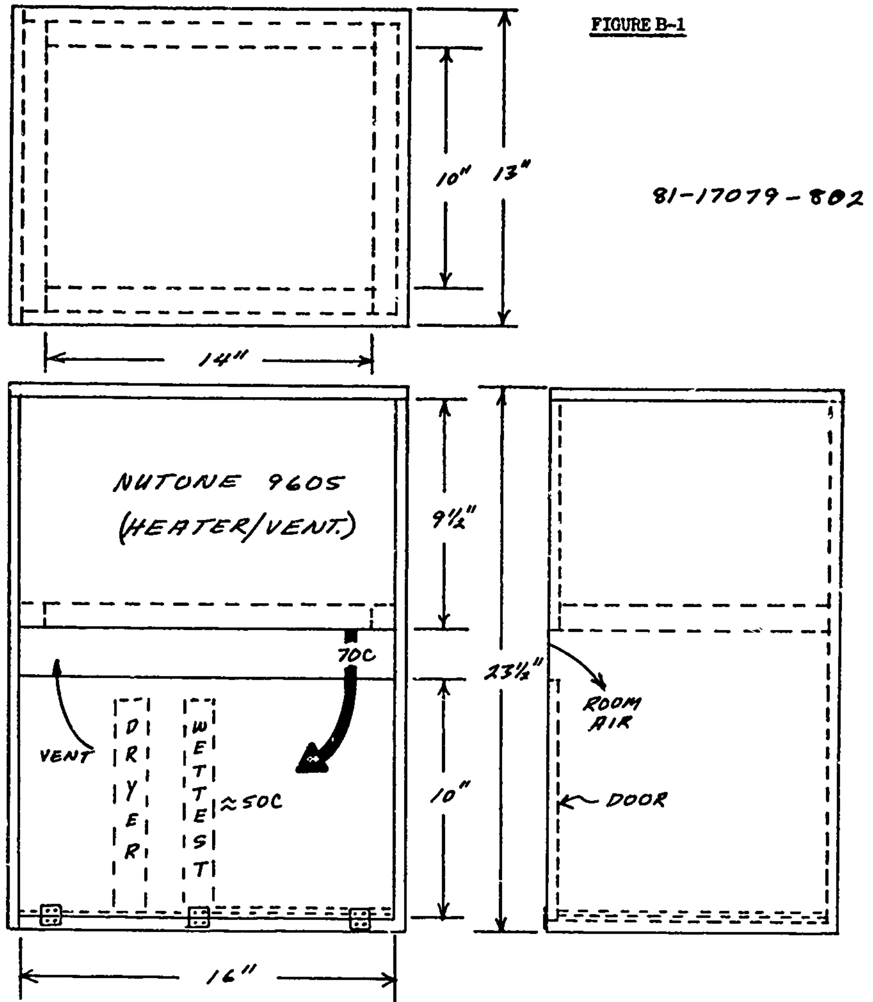
RECOMMENDATIONS

There are no particular recommendations concerning the processing of the breakbands and application of the rubber cement as directed by Delco. Further production equipment simply requires the operations be designed into the automatic machines as carefully and as cleanly as the projectile specifications demand.

KWM:KLK
8/15/75

FIGURE B-1

81-17079-802



SCALE - 1:5

MATERIALS:

½" PLYWOOD

1"x1" PINE

#8 FLATHEAD SCREWS

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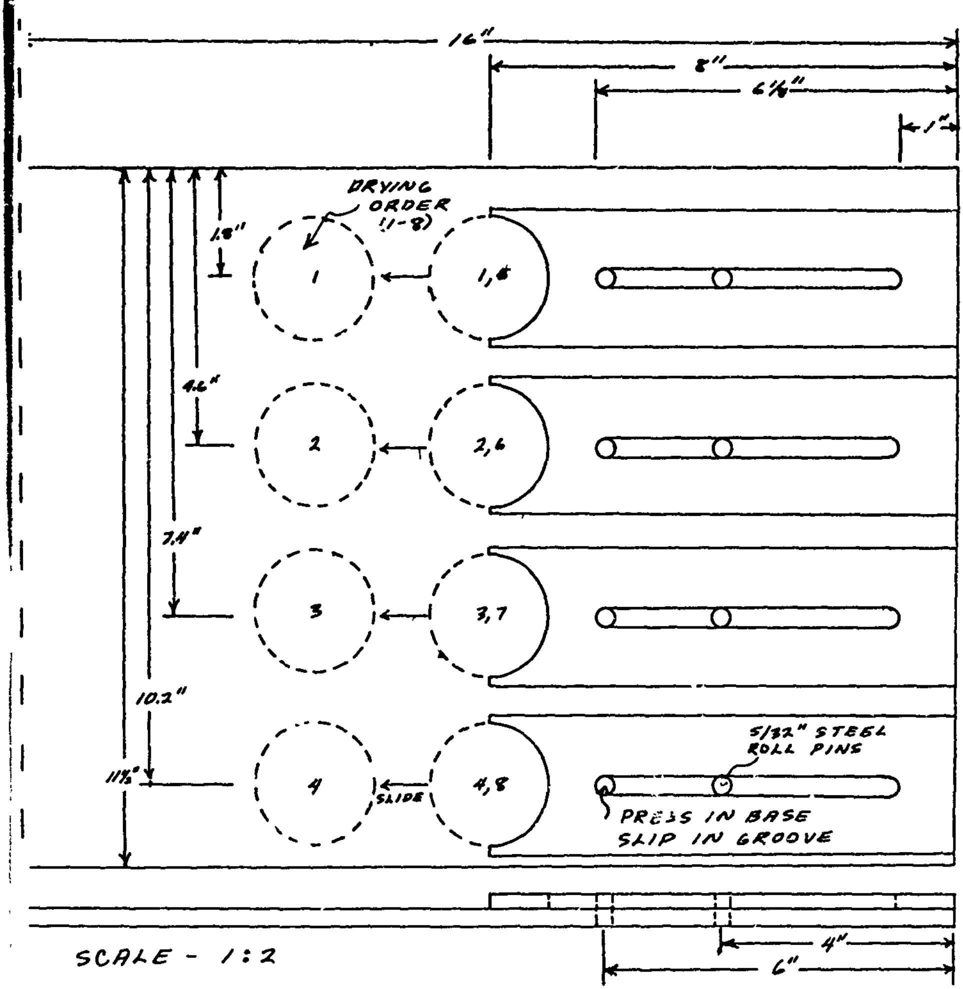
RESEARCH & DEVELOPMENT DEPT.

RAG BAND DRYING CABINET

DRAWN KWM | APP'D KWM | DATE 6/12

SKRL- 6-1275-3

FIGURE B-2



SCALE - 1:2

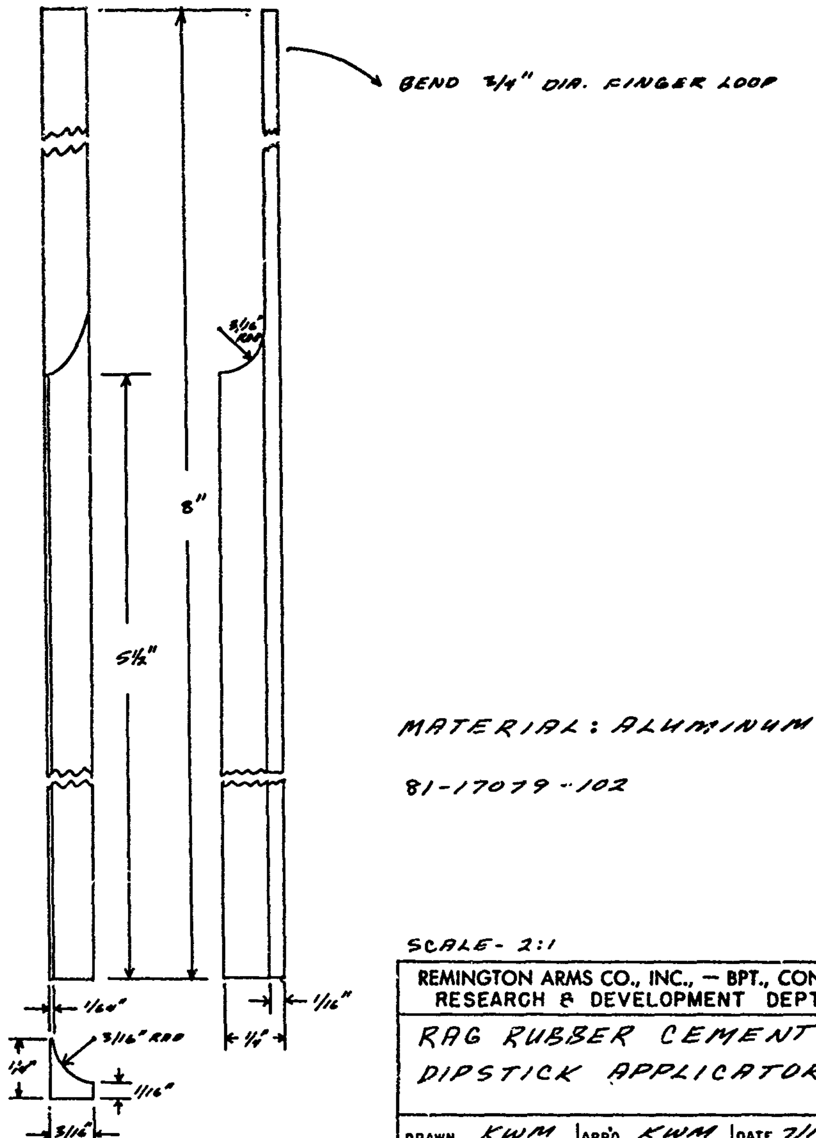
MATERIAL: ¼" MASONITE

81-17079-802

REMINGTON ARMS CO., INC., — BPT., CONN RESEARCH & DEVELOPMENT DEPT.
RAG DRYING CABINET PROCESS CYCLER
DRAWN KWM | APP'D KWM | DATE 6/12/.
SKRL- 6-1375-1

R.D. 979 K.

FIGURE B-3



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RESEARCH & DEVELOPMENT DEPT.

RAG RUBBER CEMENT DIPSTICK APPLICATOR

DRAWN KWM | APP'D KWM | DATE 7/11

SKRL- 7-275-1