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TECHNICAL REPORT 4283

ADVANCED PRODUCTION ENGINEERING FOR THE 105 MM XM494E3 ANTIPERSONNEL-TRACER CARTRIDGE (U)

FRANKLIN R. CHENG

NOVEMBER 1971

PICATINNY ARSENAL
DOVER, NEW JERSEY

CONFIDENTIAL

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TECHNICAL REPORT 42[illegible]

ADVANCED PRODUCTION ENGINEERING FOR THE 105MM XM494E3 ANTIPERSONNEL-TRACER CARTRIDGE (U)

FRANKLIN R. CHENG

NOVEMBER 1971

AMMUNITION ENGINEERING DIRECTORATE
PICATINNY ARSENAL
DOVER, NEW JERSEY

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(U) SUMMARY

The primary objective of this Advanced Production Engineering (APE) program by the Ammunition Engineering Directorate's Ammunition Engineering Laboratory was to resolve production bottlenecks in the manufacture of flechette ammunition and provide a critical analysis of the 105mm XM603 Antipersonnel (APERS) Projectile for the 105mm XM494 Antipersonnel-Tracer (APERS-T) Cartridge prior to production. This study was also to determine the producibility of the various metal parts components and to re-design components where necessary for economic production and for enhancing the overall effectiveness of the projectile.

Several modifications were introduced which provided cost savings both through simplified production procedures and utilization of more economic materials. As a result of this study, a substantial improvement in the cost/effectiveness of the projectile has been realized. The labor manhours required to produce a single unit have been reduced by 22.2% and cost of the raw materials has been reduced by 37.2%. This study further resulted in the XM494L3 Cartridge with a more effective XM603E1 Projectile (Figure 1) by virtue of an increase in payload of 500 additional flechettes or approximately 11%.

Among the most significant technical accomplishments, resulting from this study is the development of an improved method of assembling flechettes by use of a weaving method. This breakthrough enabled the manufacture of Beehive ammunition on a mass production basis for the first time. Other services which utilized the concept of weaving flechettes to facilitate loading were the Air Force (2.75-Inch Rocket) and the Navy (81mm MK-120 Mortar). This single breakthrough resulted in cost savings of $3.8 million validated in FY66 and $14 million follow-on savings in FY67 which is in excess of 18 times the $990,000 budgeted for this APE Program.

It is also significant that the round developed under this APE measure was utilized for limited production (LP) and will also be used for the Engineering Test/Service Test (ET/ST). Limited production requirements were received in FY68 and production of the product improved round resulting from this APE was accomplished by the metal parts contractors with minimal production problems and waiver requests. Projectile hardware was made available to the loading plant and initial deliveries to the user proceeded on schedule. The benefit of this APE measure is further evidenced by the elimination of major production problems normally experienced in initial metal parts production.

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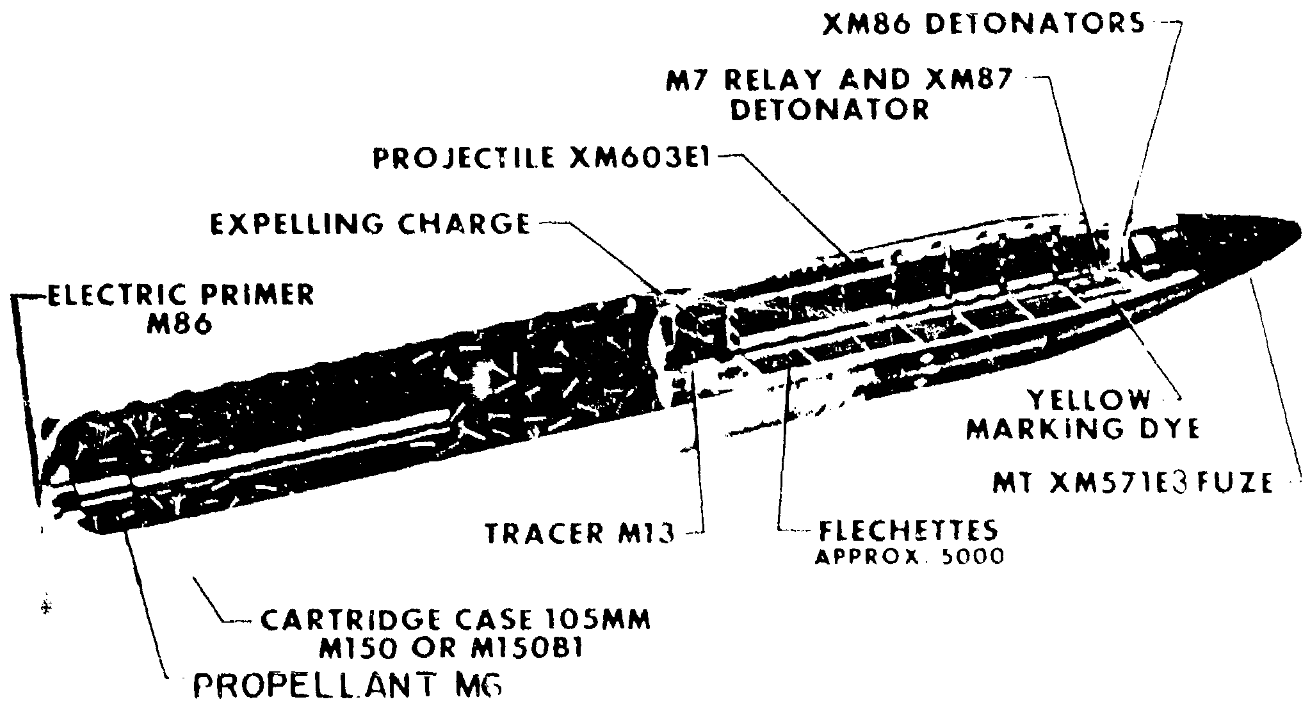
(C) CONCLUSIONS (U)

(U) An analysis of the results of the APL program for the 105mm XM494E3 APERS-T Cartridge (Figure 1) led to these observations:

The engineering effort resulted in a substantial cost reduction in direct labor and raw materials for manufacturing the XM603E1 Projectile. An estimated cost saving of approximately $25 per unit below the R&D version can be realized based on an annual production quantity of 84,000 rounds (Appendix A).



(C) FIGURE 1
105MM XM494E3 APERS CARTRIDGE FOR M60 SERIES TANK
(PRODUCTION ENGINEERED VERSION) (U)

Several basic innovations -- such as the development of an improved method of weaving flechettes -- greatly enhanced the manufacture of a family of Beehive rounds.

In addition, a few major design changes were adopted as a result of this study. Among them, the use of a serrated keying system to key the flechette bays together, which utilizes setback forces to emboss the outer spacers in lieu of a bent tab keying system; simplified relay and detonator housing; and the use of forging and impact extrusion for manufacturing the rear and front projectile bodies, respectively.

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A Description of Manufacture for the production-engineered (PE) projectiles, which will aid future manufacturers of the PE design, was made available to the Government

It is considered that the most opportune time to initiate an APE of this type is before production Fortunately, the urgent requirement for this item, which resulted in LP action prior to Type Classification (TC) occurred after the APE program and resulted in the APE design being utilized during production

(U) RECOMMENDATION

This APE program resulted not only in a major technical breakthrough -- development of a flechette-weaving machine -- but also in substantial cost savings and maximized producibility of the 105mm XM603E1 APERS Projectile. It also virtually eliminated delays and slippages normally encountered in production of the projectile metal parts during the LP phase.

Benefits from this APE investigation of the various costly components comprising the projectile and its metal parts components are significant since the heavy items that make up the shell body and auxiliary components cost the most to produce.

As a general rule, it is suggested that APE measures be instituted, wherever possible, on hard-to-make ammunition items prior to LP or regular production to de-bug production problems which oftentimes result in delays, slippages, waiver requests and high costs.

(C) STUDY (U)

Background

(U) In its early stage of development, the XM494 Cartridge [illegible] the (Howitzer-designed) XM380 Projectile, containing about [illegible] grain flechettes together with the 1309 Mechanical Time (MT) Fuze, the standard 105mm Tank Gun Cartridge Case and the standard propellant ignition system. This cartridge design was designated the XM494E1 Cartridge

(U) It was originally proposed to use the XM380E1 Beehive [illegible] developed for the 105mm M103 Howitzer for the tank application as the projectile component for the 105mm XM494 APERS-T Cartridge. This [illegible] would enable the developing agency to provide the M60 Tank with [illegible] munition in minimal time. However, there were difficulties in handling this round in the limited area of the tank's interior. Also the [illegible] MT Fuze, graduated in one-second increments and set with a fuze-setting wrench, could not be efficiently handled. To overcome this problem a hand-settable fuze would be required. In addition, the overall cartridge length of 43 inches required that this ammunition must be stored in the ready racks only, since they would not fit in the storage racks.

(C) In June 1964, a revised Small Development Requirement (SDR) was prepared incorporating design characteristics to correct these problems and the round was designated XM494E2 Cartridge. Department of the Army authorization was received for the development of a variable range fuze graduated in 200-meter increments from zero (muzzle action) to 4,400 meters and hand-settable. The fuze was designated the XM571 MT Fuze. The maximum overall length of the cartridge was reduced from 43 to 39 3 inches to facilitate handling and storage within the M60 Tank.

(C) The revised SDR enlarged the purpose of the Beehive Cartridge for the 105mm M68 Tank Gun to include use in direct fire against personnel, helicopters and unarmored or lightly armored ground vehicles. The round was also to provide close-in defense against enemy mass assault attacks and have a capability of engaging low-flying, slow moving helicopters.

(C) During development of the improved cartridge, studies indicated that a newly designed 13-grain flechette was optimum for both the APERS and anti-aircraft characteristics desired by the SDR. It was also determined that an increase in velocity would add to the projectile's terminal effectiveness. The XM494E2 Cartridge was authorized for development in July 1965 to incorporate these new characteristics. The round would contain 4,500 13-grain flechettes and have a muzzle velocity of [illegible] fps.

(C) TABLE 1

105MM XM494E3 APERS CARTRIDGE FOR THE M68 TANK GUN
(PRODUCTION ENGINEERED VERSION) (U)

COMPONENTS

PROJECTILE	XM603E1
FUZE, MT	XM571E3
CARTRIDGE CASE	M150 OR M150B1
PRIMER, ELECTRIC	M86
BASE PROPELLANT CHG.	M9
PROPELLING CHARGE	M6 PROPELLANT
PACKING	2 ROUNDS PER BOX

BALLISTIC DATA

PAYLOAD	5000 FLECHETTES (13 GRAIN)
MUZZLE VELOCITY	2700 FPS
PROJECTILE WEIGHT	31.0 LBS.
RANGE	MUZZLE ACTION TO 4400 METERS LIMIT IMPOSED BY MAXIMUM FUZE TIME MARKING
CARTRIDGE LENGTH	39.3 INCHES
FUZE	HAND SETTABLE MUZZLE ACTION (0 TO 10 SECONDS). CALIBRATED IN METERS, 4400 MAXIMUM
TRACER	5 SECONDS BURNING TIME
DISPERSION	20° CONE OF FIRE FROM POINT OF INITIATION

(U) In February 1968, the Department of the Army had an urgent requirement for a limited quantity of Beehive rounds for the M68 Tank Gun. Fortunately, this project progressed sufficiently to enable a quick response to this requirement with an early delivery utilizing the pilot lot tooling developed for the projectile. As a result, the 105mm XM494E3 Cartridge, which resulted from this program, and utilized the 105mm XM603E1 Projectile containing an additional 500 flechettes (5,000 total) was type classified for limited production (TC LP). This cartridge is scheduled for TC Standard A in the Third Quarter, FY73.

Cartridge Description

(C) The 105mm XM494 APERS-T Cartridge was developed for the M68 Tank Gun used in the M60 Tank series to provide a close-in (zero range) defense against massed infantry assaults. Additional APERS firepower capabilities are gained using the cartridge against exposed enemy personnel during tank/infantry offensive operations. A secondary fire-power capability is provided against lightly armored vehicles and low-flying aircraft.

(C) The XM494E3 Cartridge weighs 55 lbs. with the overall length of 39.3 inches; its components include the M150 Cartridge Case, the M86 Electric Primer, the M6 Propelling Charge, the M13 Tracer (five-second burning time) and the XM571E3 MT Fuze. The 5,000 (13-grain) flechettes in the projectile are arranged in seven tiers. The forward four tiers are ejected as a result of fuze initiation followed by functioning of four radially positioned detonators which tear away and remove the forward portion of the ogive skin. Centrifugal force then adds to the flechette velocity, resulting in a 20° cone-shaped dispersion geometry. The rear three tiers of the payload are ejected by a piston plate which is propelled by a base charge. Additional velocity is imparted to the flechettes by the action and centrifugal force disperses the flechettes similar to the first four tiers.

(C) The flechette payload can be released at either muzzle action or anywhere along the direct fire trajectory to 4,400 meters. The hand-settable fuze is shipped set at muzzle action; this allows the gunner to quickly set the fuze at 100-meter increments starting at 200 meters. The gunner can adjust fire by observing the tracer on the aft end of the projectile and the yellow dye which bursts into a yellow ball when the projectile opens. The muzzle velocity of the cartridge is 2,700 fps. The military characteristics of the cartridge are detailed in Table 1.

(U) ADVANCE PRODUCTION ENGINEERING PROGRAM

Introduction

An APE study was authorized to extensively examine the XM603 Projectile (R&D design) and provide an evaluation for manufacturing methods and processes

In February 1966, Picatinny Arsenal awarded Whirlpool Corporation of Evansville, Indiana an APE contract to make a critical analysis of the XM603 Projectile for the XM494E2 Cartridge, which was ultimately redesignated the XM494E3 Cartridge. This study was to encompass a production evaluation of the complete round which would result in redesign and change in production methods and processes as necessary. Results of this undertaking was to incorporate various design changes into a Technical Data Package (TDP) suitable for competitive procurement. To support this study, the contractor was to fabricate bench type equipment showing the feasibility of manufacturing and loading flechettes for the existing XM603 Projectile, which resulted in the XM603E1 Projectile.

The contractor's task was to redesign, fabricate and test hardware to provide an economically producible round. The results of the study were significant. The following paragraphs will discuss some of the noteworthy accomplishments. Projectile redesign under this contract will be discussed first, then special process equipment and finally a summary of all tasks. A summary of the test data which resulted in the adoption of the design changes is in Appendix B.

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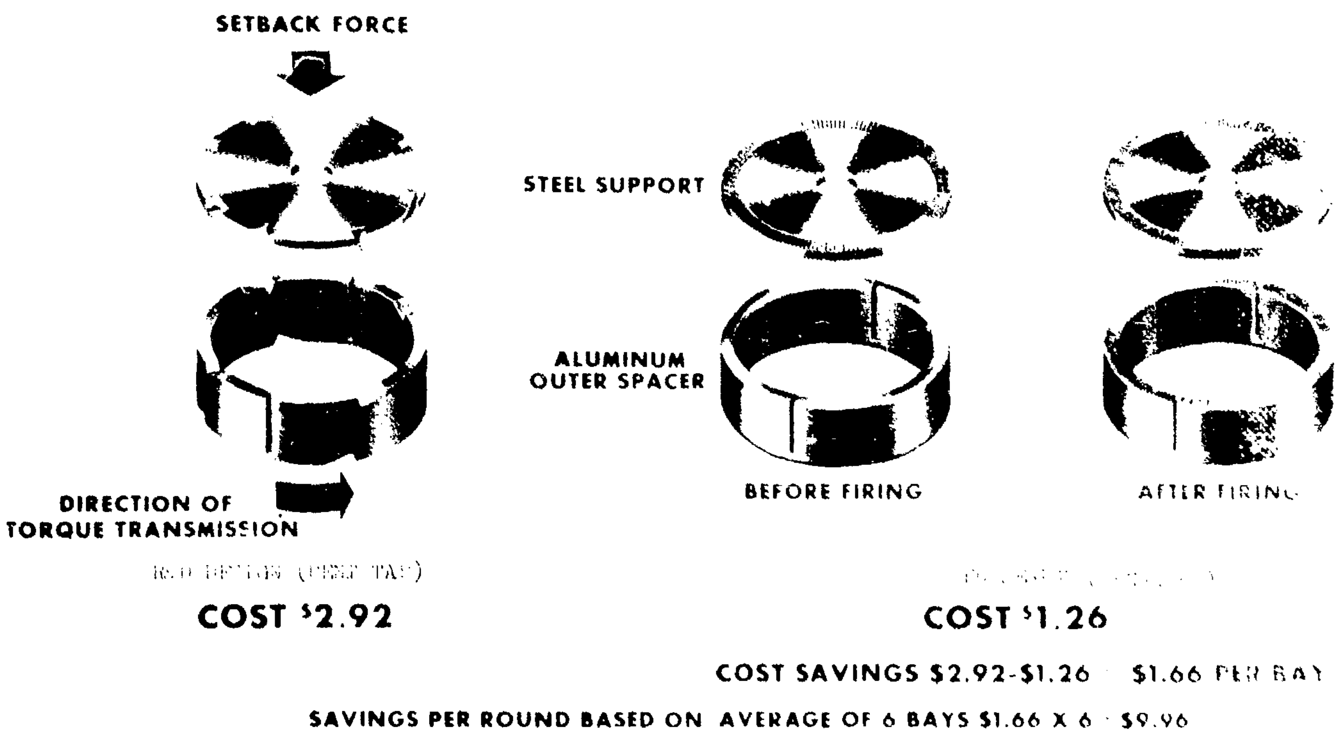
(U) IMPROVED KEYING SYSTEM FOR PAYLOAD DRIVE

Under this APE measure, a concept utilizing an improved and less costly method of keying the outer spacers to the support plates was conceived and implemented. This keying system consists of knurled serrations near the edge of both sides of the support plates in lieu of the bent tab design. Figure 2 shows the basic concept in schematic form and illustrates how the aluminum outer spacers are coined by the serrated support plates. The resultant embedment serves to drive the payload. This test-proven concept has not only been applied to the 105mm XM494E3 Cartridge, but also the 105mm XM546E2 Cartridge; 106mm M581 Cartridge and the 90mm XM580E1 Cartridge.

The estimated savings of $9.96 per round, as noted in Figure 2 and which applies to an FY68-approved LP procurement of 20,000 rounds for the 105mm XM494E3 APERS-T Cartridge, represents a cost reduction of $199,200 in material and direct labor for the concept.



(U) FIGURE 2
105MM XM603E1 APERS PROJECTILE
BENT TAB VS. SERRATED KEYING SYSTEM

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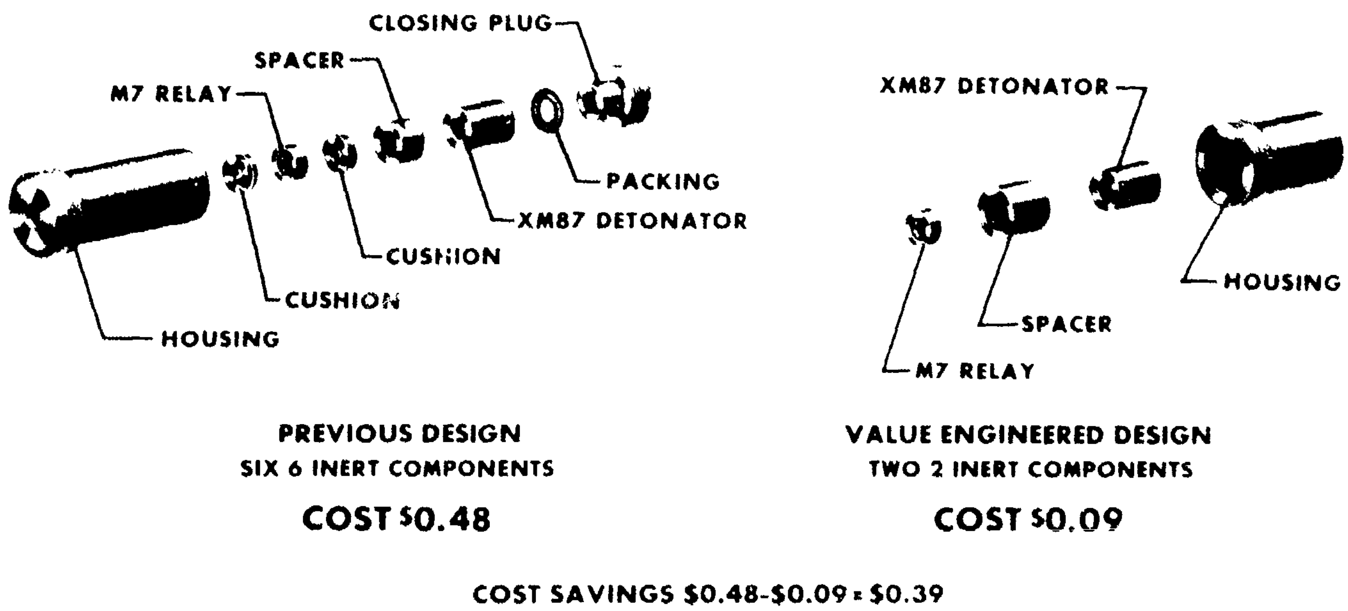
(U) SIMPLIFIED DETONATOR HOUSING ASSEMBLY

The detonator housing assembly was redesigned to reduce the loading cost and the number of component parts. The redesigned assembly consists of only two metal parts components: a detonator housing and a spacer. This simplified detonator housing resulted in the elimination of the retainer plug, two cushions and an O ring. A comparison of the costs and the resultant unit savings is shown in Figure 3. This redesigned detonator housing assembly is applicable to all other fuzed Beehive Projectiles. Application of this product improvement resulted in a validated savings of $87,909 for the FY68 and FY69 buys of the 105mm XM546 Cartridge in addition to an estimated savings of $7,800 projected for the LP production of 20,000 rounds of the XM494E3 Cartridge.

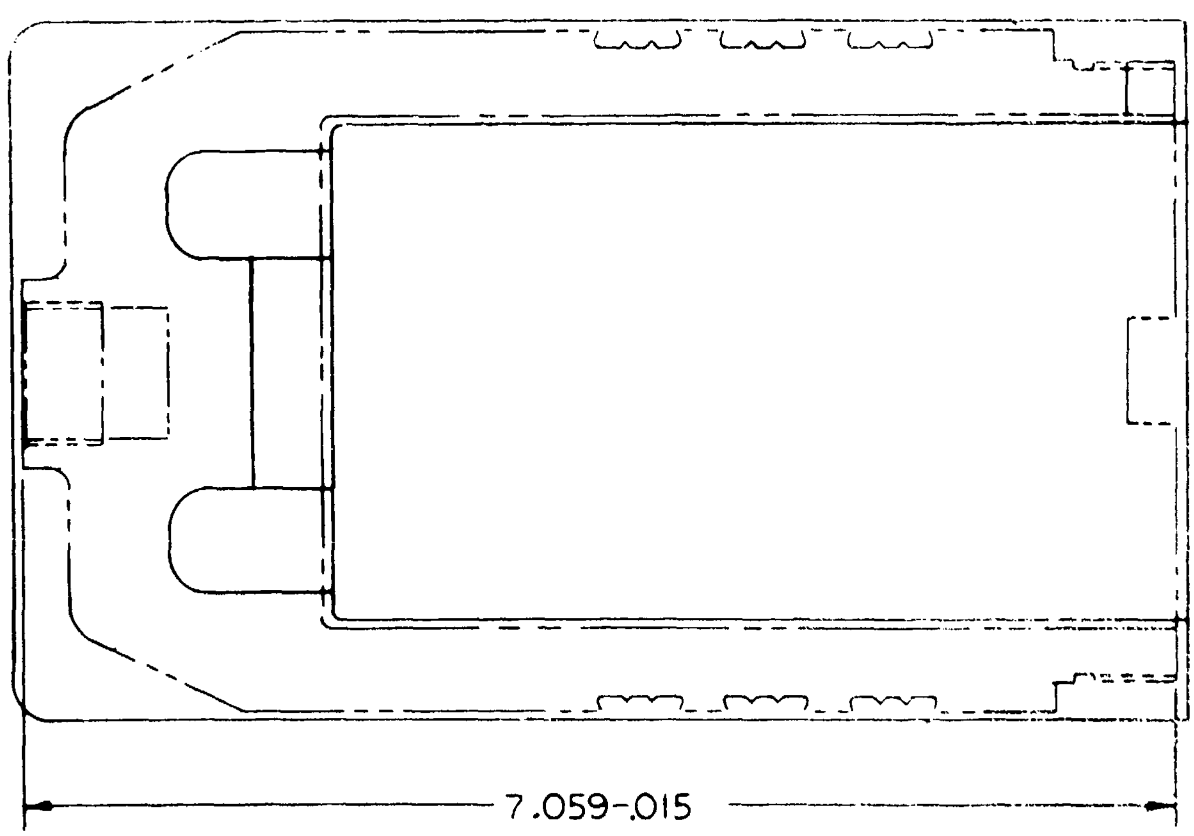


(U) FIGURE 3
105MM XM603E1 APERS PROJECTILE
RELAY AND DETONATOR HOUSING LOADING ASSEMBLIES

(U) FORGED REAR BODY

The R&D version of the rear body of the XM603 Projectile specified AISI 4140 alloy steel bar stock which required excessive amount of machining to meet the dimensional requirements. Under the APE program, it was determined that the rear body could be made economically from an 4140 alloy steel forging.

The 4140 alloy steel forging design proved to be reliable in ballistic tests under all extreme conditions and under excess pressure. As a result, the forged rear body was incorporated into the TDP for the 105mm XM603E1 APERS Projectile. Metal parts suppliers for the FY68 procurement utilized forged rear bodies for the LP of the projectile metal parts. Figure 4 is a sketch of a blank forging showing minimal metal removal.



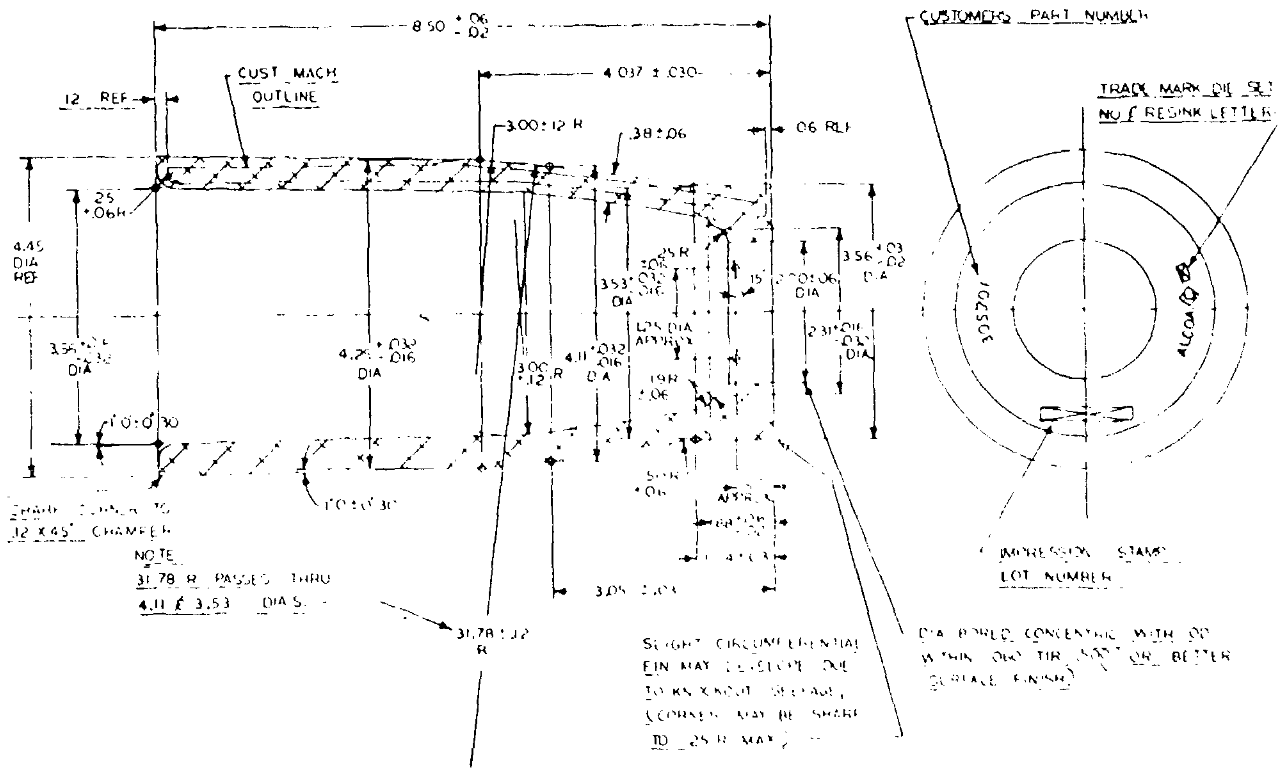
(U) FIGURE 4
FORGING BLANK FOR REAR BODY
105MM XM603E1 APERS PROJECTILE
(PRODUCTION ENGINEERED VERSION)

(U) FORGED (IMPACT EXTRUDED) FRONT BODY

The use of a forged (impact extrusion) aluminum front body as an alternate to bar stock or heavy wall tubing was investigated. Both static and dynamic testing proved that the forged aluminum front body would fracture and open up as intended on functioning of the XM86 Detonators. As a result of the successful testing program, the use of an aluminum forging was specified in the TDP.

The two firms which fabricated the metal parts for the FY68 buy availed themselves of the reduced cost resulting from the use of forgings.

A drawing of the rough forging blank (Figure 5) shows the minimal amount of metal removal required by a properly designed impact extrusion.



(U) FIGURE 5
FORGING BLANK FOR FRONT BODY
105MM XM603E1 APERS PROJECTILE
(PRODUCTION ENGINEERED VERSION)

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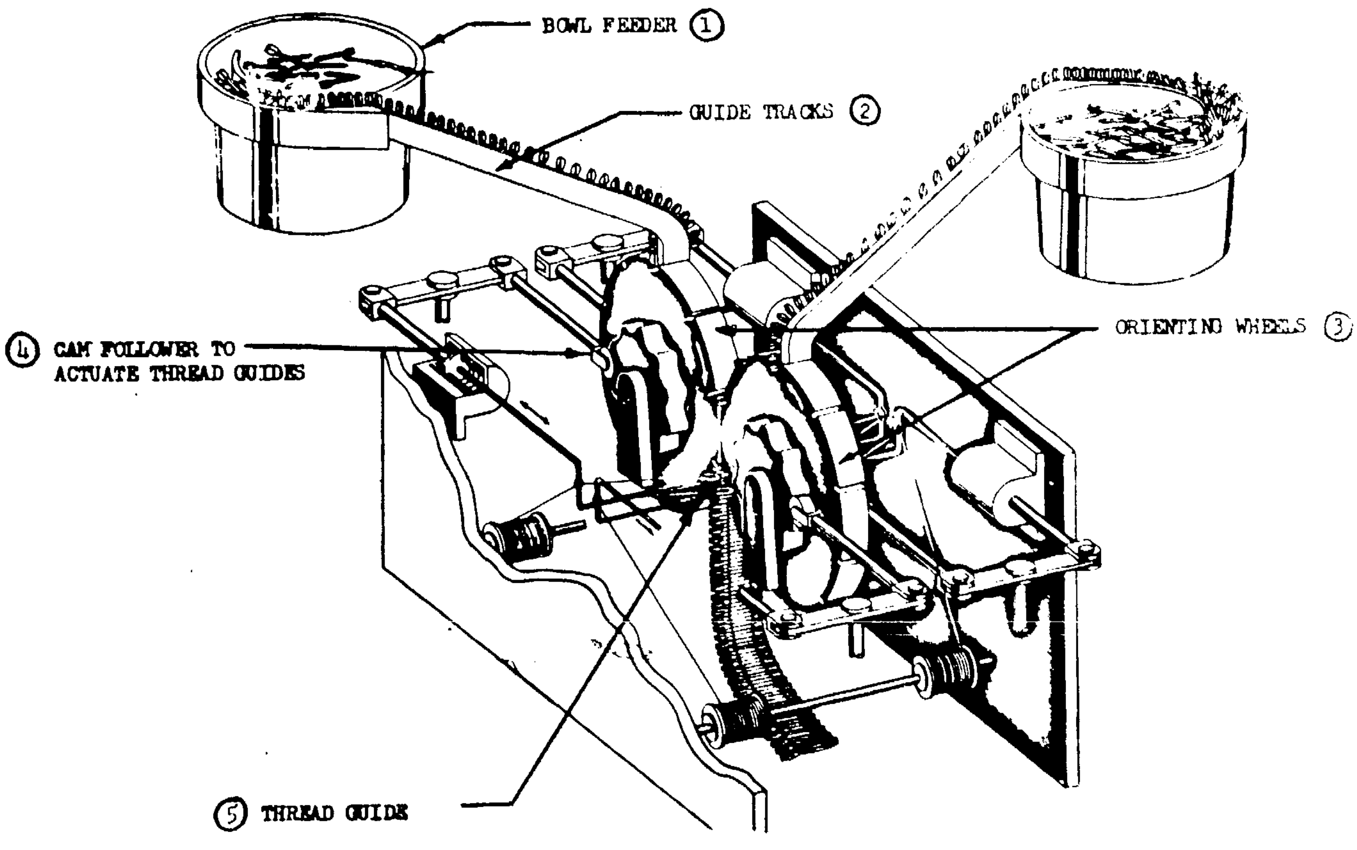
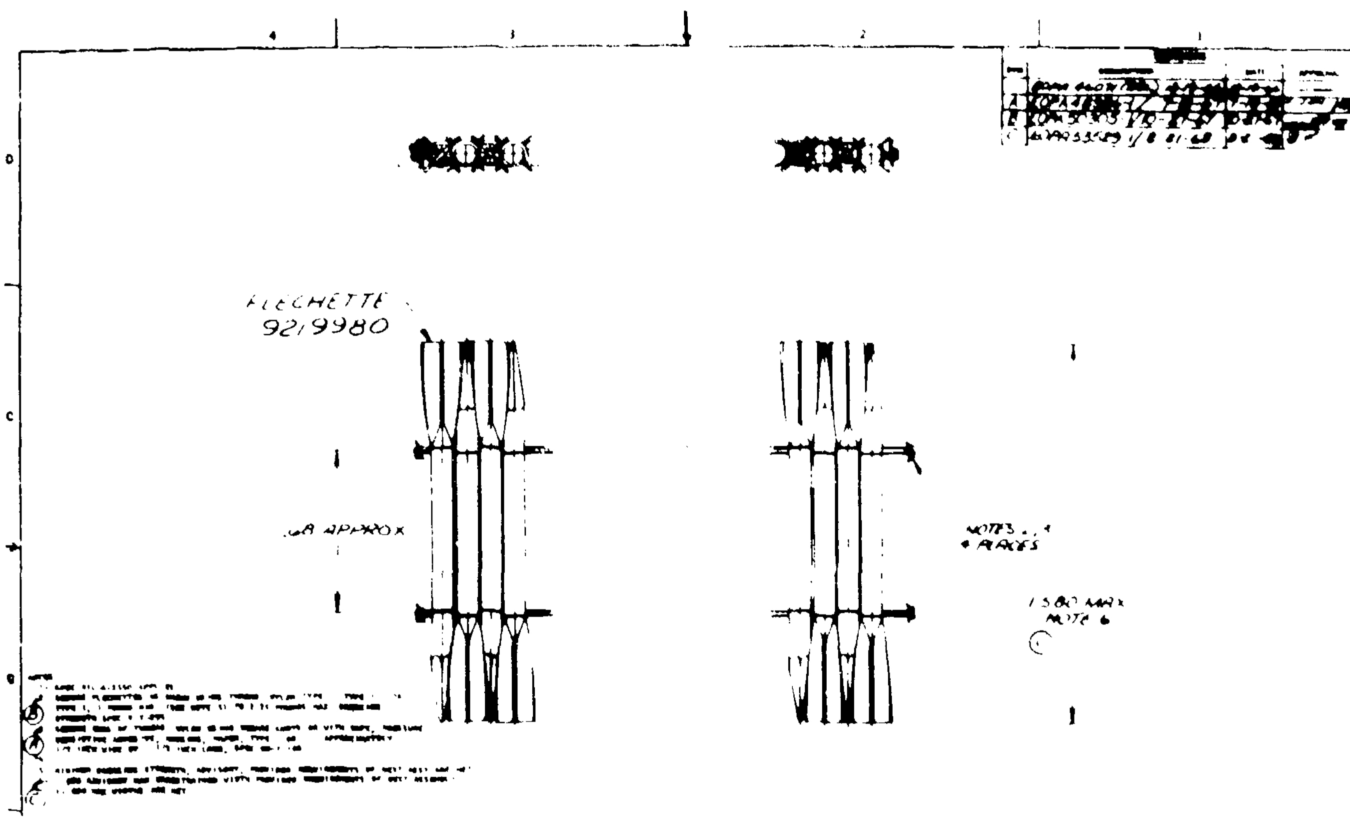
(U) FLECHETTE-WEAVING MACHINE

The key to mass production of the XM494E3 Cartridge as well as all other Beehive rounds is the ability to process flechettes rapidly into loaded bay assemblies. To meet this capability, a flechette-weaving machine was conceived by Picatinny Arsenal engineers. This machine (Figure 6) exceeded all production expectations and is recognized as a major technological breakthrough.



(U) FIGURE 6
FLECHETTE LOADING MACHINE

This machine weaves flechettes into a threaded belt, bandoleer style (Figure 7) which facilitates loading into bay assemblies. The flechettes are alternately positioned nose-to-tail in the belt by weaving with 0.002-inch-diameter nylon thread. Tests proved that the optimum packing density of the payload can be obtained by use of the woven belt. Dynamic testing proved that weaving the flechettes did not adversely affect distribution of the payload when the round functions.



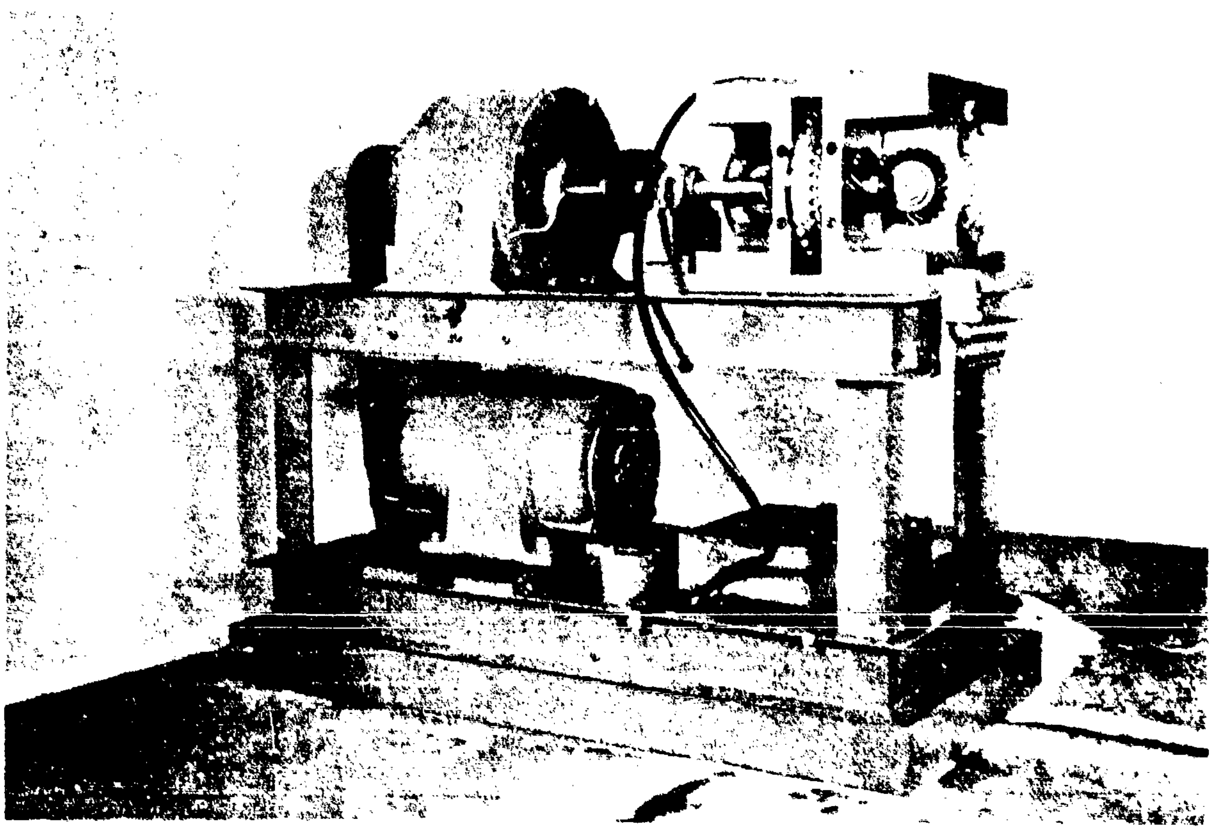
(U) FIGURE 7
FLECHETTE BELTING

With minor variations, this machine was adopted by every Beehive metal parts producers as the standard production method for packaging flechettes.

The high-speed production method developed under this program had a significant impact on the rapid production and deployment of Beehive munitions for howitzers, recoilless rifles and guns. Other services which utilized the concept of weaving flechettes to expedite loading were the Air Force (for the 2.75-inch rocket) and the Navy (81mm MK-120 Mortar). This single breakthrough resulted in cost savings of $3.8 million validated in FY66 and $14 million follow-on savings in FY67 -- which is in excess of 18 times the $990,000 expended for the APL program.

Four-Wheel Flechette Forming Machine

A study was performed to determine the feasibility for mass production of a four-wheel rotary flechette-forming machine fabricated under a previous contract (Figure 8). This machine, with a capacity of 4,000 flechettes per minute, will replace approximately 10 modified nail headers presently used.



(U) FIGURE 8
FOUR-WHEEL FLECHETTE FORMING MACHINE

Die development continued under this contract. Also, the machine was further improved by addition of a cooling and lubricating system to lubricate and maintain the dies at a constant temperature. The resulting small pilot lot of flechettes proved its feasibility. An additional contract provided for investigation of various materials, tool steel hardness, and further improvement of design. A final production run was conducted using punches of design and material developed under the previous contract and it was determined that additional minor refinements to the punch design would be required before the four-wheel machine could fully qualify for continued production usage.

(U) ADDITIONAL BENEFITS FROM APE PROGRAM

As a result of the technological breakthrough in the method of assembling flechettes, urgent requirements (ENSURE, Southeast Asia) for 105mm XM546 APERS-T Cartridge; 106mm M581 APERS-T Cartridge; 90mm XM590E1 Canister and 90mm XM580E1 APERS-T Cartridge were expeditiously fulfilled.

As indicated, this method of assembling flechettes was also used to meet production requirements for munitions outside the Department of the Army -- specifically, the 2.75-Inch WDU-4A/A Flechette Warhead for the Air Force and the 81mm MK-120 APERS Flechette Mortar for the Navy.

In addition, this principle not only increased the production potential of these munitions, but also resulted in cost savings for the required machinery.

The cost of the flechette-loading machine developed during this APE program is less than $10,000 and it produces flechettes at a rate of 2,000 parts per minute. Compared to an earlier model to meet R&D requirements costing $20,000 which operated at a rate of 100 parts per minute, the production capability for an expenditure for capital equipment has been increased by 40 times.

It is noteworthy that the basic concept for new keying system and the flechette manufacturing and loading devices previously illustrated were conceived by Picatinny Arsenal engineers (for which patent applications and patent allowances have been assigned).

As a result of the APE Program's completion prior to the Engineering Test/Service Test (ET/ST) phase, the design will be used during ET/ST. This has the advantage of TC of the design planned for production. It should be noted that production of this design has gone through the shake-down period due to an LP requirement, and projectiles for ET/ST were manufactured by the LP producer. In addition, the PE XM603E1 Projectile contains approximately 500 more flechettes than the XM603 round -- resulting in improved effectiveness.

Furthermore, many of the design concepts proven during this program are applicable and are scheduled to be phased into other Beehive munition items, as they are tested and implemented. Since every item experiences different setback and spin forces inherent in the particular weapon system, ballistic testing and modification of these changes are required on an end-item basis.

Additional production improvement programs are planned for other Beehive rounds. For a long time, Beehive ammunition had the reputation of being costly. However, PE measures of this type have significantly reduced the cost of these complex items to a point where it no longer represents a logistic block. Production of this ammunition can now be based solely on User requirements.

APPENDICES

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(U) APPENDIX A

Cost Data

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(U) SUMMARY OF THE COST BREAKDOWN BETWEEN R&D AND PE PROJECTILE VERSIONS

Name of Part	Labor Hours Prior To PE Study	Labor Hours After PE Study	Material Cost Prior To PE Study	Material Cost After PE Study
Body, Front	0.26	0.26	$10.30	$3.05
Body, Rear	09	0.69	$7.64	$7.40
Adapter, Fuze	0.17	0.14	$1.40	$1.24
Rotating Bands (3)	0.009	0.009	$1.89	$ .89
Detonator Housing	0.014	0.010	$0.013	$0.01
Plug, Retainer	------	------	$0.07	------
Rubber Cushions (2)	------	------	$0.12	------
Preformed Packing	------	------	$0.06	------
Detonator Spacer	0.004	0.005	$0.007	$0.01
Flechettes (5,000)	0.07	0.07	$1.60	$1.60
Outer Spacer, Bay 1	0.047	0.03	$0.95	$0.44
Outer Spacer, Bay 2	0.074	0.044	$0.83	$0.51
Outer Spacer, Bay 3	0.074	0.055	$0.83	$0.35
Outer Spacer, Bay 4	0.09[illegible]	0.055	$1.52	$0.51
Outer Spacer, Bay 5	0.056	0.020	$0.68	$0.09
Outer Spacer, Bay 6	0.050	0.020	$0.68	$0.09
Outer Spacer, Bay 7	0.056	0.020	$0.51	$0.09
Front Disc	0.012	0.012	$0.06	$0.06
Inner Spacer, Bay 1	0.03	0.02	$0.08	$0.06
Inner Spacer, Bay 2	0.022	0.011	$0.08	$0.10
Inner Spacer, Bay 3	0.022	0.011	$0.19	$0.[illegible]
Inner Spacer, Bay 4	0.022	0.011	$0.2[illegible]	$0.10
Inner Spacer, Bays 5, 6 & 7	0.033	0.033	$0.30	$0.30
Payload Ejection Piston	0.035	0.009	$0.32	$0.22
Rear Flash Tube	0.014	0.014	$0.36	$0.36
Front Flash Tube	-------	0.005	-------	$0.11
Propellant Cavity Liner	-------	0.007	-------	$0.055
Propellant Cover	0.007	0.004	$0.04	$0.03
Support, Bay 1	0.03	0.02	$0.16	$0.16
Support, Bays 2 & 3	0.06	0.04	$0.44	$0.44
Support, Bay 4	0.053	0.036	$0.22	$0.22
Support, Bays 5 & 6	0.06	0.016	$0.20	$0.20

Name of Part	Labor Hours Prior To PE Study	Labor Hours After PE Study	Material Cost Prior To PE Study	Material Cost After PE Study
Rear Body Keys (2)	------	0.032	-------	$0 06
Marker Bag	------	0.002	-------	$0.06
Marker Dye	------	------	$ 0 02	$0.02
Marker Dye Assembly	------	0.006	-------	------
Inner Spacer & Front Disc Assembly	0.004	0.004	-------	------
Plug	0 014	0.014	$ 0.03	$0.03
Disc	0.0007	0.0007	$ 0.002	$0 002
Plug & Disc Assembly	0 017	0.017	-------	------
Cushions (4)	0.002	0 002	$ 0 05	$0 05
Protective Paper	------	------	$ 0.02	$0.01
Base Charge Parts Arrangement	------	------	$ 0 24	$0 24
Gasket, Closing Plug	------	------	$ 0 03	$0.03
Closing Plug	0.004	0.004	$ 0 30	$0 06
Body Assembly	0 15	0.15	-------	------
Bay Assembly, Bays 1-7	0 36	0 36	-------	------
Payload EjectionPIston Assembly	0 01	0.01	$ 0 01	$0 01
Base Charge Loading Assembly	------	0 003	-------	------
Ejection Charge Loading Assembly	0 008	0.008	-------	------
Assemble Projectile	0 23	0.25	-------	------
TOTALS	3 265	2.540	$32 462	$20.367

COST COMPARISON

	R&D XM603 Projectile	PE XM603E1 Projectile	Net Saving
Material Cost	$32.46	$20.37	$12.09
Direct Labor @$3.50/hr	11.43 (3.26/hr)	8.99 (2.54/hr)	2.54 (.72/hr)
Burden @235%	26.86	20.86	6.00
G&A @ 10%	7.08	5.02	2.06
Profit @ 10%	7.78	5.52	2.26
Unit Cost	$85.61*	$60.69*	$24.95

*Cost comparison of the two projectile versions was made as a part of the APE study and was based on an annual production quantity of 84,000 rounds (7,000 rounds per month).

Reduction In Labor Manhours:

$$\frac{\$3.265 - 2.540}{3.265} = \frac{0.725}{3.265} \times 100 = 22.2\%$$

Reduction In Raw Material Cost:

$$\frac{\$32.46 - 20.37}{\$32.46} = \frac{\$12.09}{\$32.46} \times 100 = 37.2\%$$

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(U) APPENDIX B

Test Data

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(U) TEST RESULTS SUMMARY of the Principal Design Changes Adopted for the Production Engineered 105MM, APERS, XM503E1 Projectile

Test Sites: Camp Atterbury Test Facility, Edinburg, Indiana
Jefferson Proving Ground, Madison, Indiana

A total of 95 multiple firings was conducted for this APE program which included several of the designed features highlighted below:

Design Feature Used	Test Made	Qty Fired	Remarks
Serrated Keying System	Fired rds conditioned at -[illegible]°F and +100°F at both service and 125% rated pressures in a series of tests including hard recovery, muzzle action and 1,[illegible]00 meter phases (See Note 1).	70	All tests resulted in verification of stability and metal parts integrity. Visual observation of recovered metal parts indicated proper imbedment of the serration into the outer spacers and no slippage was noted. (Slippage can be readily determined by wiping action of support plates on the outer spacers.)
Simplified Detonator Housing	Fired rds conditioned at -[illegible]°F and +100°F at both service and 125% rated pressures in a series of tests including hard recovery, muzzle action and 1,500 meter phases (See Note 1).	[illegible]	Simplified detonator housing performed satisfactorily. [illegible] relays and M[illegible] detonators functioned properly indicating the safety and reliability of the detonator housing component.
Support Plates with [illegible] inch and 0.020 inch flats on the knurled teeth	Fired rds conditioned at +100°F and at 125% rated pressure for hard recovery (See Note 1).	5 (3 rds with 0.010 inch flats; 2 rds with 0.020 inch flats)	Good results were obtained with both the [illegible] inch and [illegible] inch flats. The test verified that if rds using support plates with 0.020 inch flats were fired, adequate imbedment would occur. Although drawing and inspection requires 0.010 inch flats, purpose of test was to be assured of proper functioning if serrations with 0.020 inch flat occurred.

Design Feature Used	Test Made	Qty Fired	Remarks
Forged Aluminum Alloy 7075-T6 Front Body	Fired rds at ambient temp in a series of tests including hard recovery, muzzle action and 1,600 meter phases.	70	The tests confirmed that the forged front body would fracture properly to allow dispersion of the payload.
Forged AISI 4140 Steel Rear Body	Fired rds at ambient temp. in a series of tests including muzzle action and 1,600 meter phases.	20	Forged rear body in lieu of rear body using machined bar stock was acceptable for use on the projectile.
Support Plates with heat treatment reduced to Rockwell C24-17 from C42-[illegible]	Fired rds at ambient temp. in a series of tests including muzzle action and 1,600 meter phases	55	Recovered support plates revealed satisfactory performance. It was determined that support plates with a RC 25 minimum would satisfactorily meet the strength requirements

Notes:

1. The excess pressure was achieved by filling the cartridge case to capacity with propellant and conditioning the complete round at +100°F for a minimum of 24 hours prior to testing.

2. In addition, proof and acceptance (P&A) firings consisting of a total of 3[illegible]0 test rounds (ambient temp--245 rds were fired for muzzle action and the remaining rds were fired for downrange to ascertain the metal parts integrity) to determine the acceptability of the projectile metal parts of the PE design during LP, were fired. No adverse results were experienced.

3. Firing records delineating various tests are contained in the Final Engineering Summary Report for "Production Engineering of Cartridge, 105MM, APERS, XM[illegible]" (U) 31 August 19[illegible], which was prepared by Whirlpool Corporation, Ordnance Division, Box 4227, Station A Evansville, Indiana 47711 for Picatinny Arsenal.

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FOR THE
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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Picatinny Arsenal U.S. Army Munitions Command Dover, New Jersey

13. ABSTRACT

(U) The primary objective of this Advanced Production Engineering (APE) program by the Ammunition Engineering Directorate's Ammunition Engineering Laboratory was to resolve production bottlenecks in the manfacture of flechette ammunition and provide a critical analysis of the 105mm XM603 Antipersonnel (APERS) Projectile for the 105mm XM494 Antipersonnel-Tracer (APERS-T) Cartridge prior to production. This study was also to determine the producibility of the various metal parts components and to re-design components where necessary for economic production and for enhancing the overall effectiveness of the projectile.

(U) Several modifications were introduced which provided cost savings both through simplified production procedures and the utilization of more economic materials. As a result of this study, a substantial improvement in the cost/effectiveness of the projectile has been realized.

(U) Among the most significant technical accomplishments, resulting from this study is the development of an improved method of assembling flechettes by use of a weaving method. This breakthrough enabled the manufacture of Beehive ammunition on a mass production basis, for the first time.

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