REPORT R-2049

SEALING OF SABOT AND PRIMER OF XM645 CARTRIDGE (SFR)

by

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July 1972

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Philadelphia, PA 19137

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ABSTRACT

Waterproof sealing of the sabot and primer of the XM645 Cartridge (SFR) has been achieved using a pigmented resin-solvent formulation. Firing tests conducted on experimentally sealed rounds have given every indication that seals are acceptable. Efforts to effect sealing of the sabot by means of commercially available dry-shrink or heat-shrink preformed plastic caps, or to mold caps having the desired wall thickness, were unsuccessful. A rapid, reduced pressure leak test was employed.

FOREWORD

The authors appreciate the technical advice and assistance provided by Mr. M. H. Sandier, U. S. Army Coating and Chemical Laboratory, and his supplying of the various coating materials. They also acknowledge the service and efforts of Mr. H. A. Hittner Engineering Services Branch, Manufacturing Engineering Division, Frankford Arsenal, in evaluating the molding or preformed cap seals.

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INTRODUCTION

In the present design of the XM645 (SFR) experimental cartridge, a composite polyester, glass-filled reinforced sabot, coated with a cured teflon formulation, and a piston-primer are being evaluated. The sabot is machined from a preformed rod consisting of a poly ester resin matrix with longitudinally oriented glass fibers (Figure 1). The sabot is cross-slit (eight cross-cuts) at the tip to facilitate its stripping on leaving the gun barrel to free the flechette. An alternate sabot also is being tested which is fabricated by precasting the polyester-glass fiber sabot. After curing, the sabot is compacted (crushed) so as to permit its stripping when the round is fired. The crushed sabot is not coated with teflon (Figure 2). The primer cup and primer-cup cavity are designed to provide a short rearward displacement of the weapon to eject the spent case and to reload the chamber (Figure 3).

The slitting or the crushing of the sabot and the subsequent crimping of the cartridge case mouth rim to secure the sabot-projectile component results in voids, holes, and crevices, which permit easy ingress of humidity or water. Since water and water vapor are readily absorbed by the propellant powder, when these are accessible to the powder, degraded ballistics could result. Also, contact of the primer and case is essentially at the rim of the primer cup, inside the case. This cannot be depended on to insure a gas-or-water-tight seal in every instance. Consequently, to preclude the potential problem, the development of efficient seals and practical methods for applying these for the sabot and primer was required and approved for investigation.

At present, no seal for water proofing purposes is in use with the sabot. The cured teflon coating which is applied was intended to serve as a lubricant to reduce gun barrel erosion by the glass fibers. For the primer, a compound consisting of molybdenum disulfide (MoS_2) dispersed in a resin solution (Drilube #108) is applied in the primer pocket crevice to serve as a seal. Since it was demonstrated that this material does not function as a seal, attention was directed to other materials for effecting a seal at the primer.

This report describes the work pursued toward developing effective, practical sealing of the sabot and primer of the XM645 round. The approaches taken, including the selection of materials (Table I), tests employed in the laboratory, and results of laboratory and firing tests, are presented. Sealing materials and application methods amenable to present production facilities are recommended.

OBJECTIVES

This investigation was to accomplish effective leak-proofing of the sabot and primer member of the XM645 cartridge; to recommend suitable materials for these purposes, and to develop application methods which could be adapted to current production line operations, utilizing existing equipment.

EXPERIMENTAL

Teflon Coating - Sabot

The teflon coating currently being applied to machined R&D sabots (prior to attachment of the flechette) was found to chip or skin off quite readily under normal handling. Because of this, and the expected poor adhesion of any coating applied over the teflon surfaces, tests were conducted to determine whether the teflon coating might be eliminated without adversely affecting the ballistic characteristics of the projectile. It will be recalled that the essential purpose of the teflon coating was to prevent erosion of the gun barrel by the glass fibers contained in the sabot.

TABLE 1.
Materials

Coating Materials for Sealing

CCL-668-111 MoS_2 & Teflon Polyvinylbutyral O.D. (15% solids)	Coatings & Chemical Laboratory Aberdeen Proving Ground	Sabot, Primer
TT-E-516-O.D. Styrenated alkyd resin	CCL - APG	Sabot
MIL-L11195 O.D. or MIL-L-11195, CCL-711-1101 pigmented, green, Nitrocellulose resin (modified)	CCL - APG	Sabot, Primer
CCL-711-1102, Nitrocellulose resin (modified)	CCL - APG	Sabot, Primer
3 above (green) 4% teflon (dispersion) added	CCL - addition at FA	Sabot
3 above (green) 4% molybdenum disulfide (submicron particles) added	CCL - addition at FA	Sabot
CCL-710-191 Aroclor resin 5460 (70% solids, xylene)	CCL - APG	Primer
CCL-710-192 Cumar resin (65% solids xylene)	CCL - APG	Primer
CCL-710-201 Velsicol AB11 resin (65% solids, xylene)	CCL - APG	Primer
CCL-710-202, Piccolyte 5115 resin (60% solids, xylene)	CCL - APG	Primer
Acrylic Hydrosol, PB-9011 (30% solids) Methyl Methacrylate Copolymer dispersion (H_2O)	E.I. duPont deNemours Electrochemical Dept Wilmington, DE	Sabot
Elvamide PB-3-1521 Polyamide resin dispersion (alcohol)	E.I. duPont	Sabot
Elvax D, D-1070 Ionomer resin dispersion (H_2O)	E.I. duPont	Sabot
Spherical Polyethylene, dispersion X2092-75 (Trichlor-ethylene and ethonol mix)	Hercules Powder Company Kenvil, NJ	Sabot
Saran resin F-310 (20% in methyl ethylketone)	The Dow-Chemical Company Midland, MI (solution prepared FA)	Sabot
Micorcrystalline wax (B-square) m.p. 85-115° C (185-239° F)	Petrolite Corporation Bareco Division Tulsa, OK	Sabot, Primer

Preformed Caps

Cellulosic polymer 7 x 15 mm O.D. clear water-swollen (dry shrinkable)	Thatcher Plastics Packaging New York, NY	Sabot
Vinyl-chloride polymer 11 x 20 mm O.D. clear (heat shrinkable)	Gilbreth Company Philadelphia, PA	Sabot

Sheet Materials for Molding

The various types of thermoplastic sheet materials are listed in Table III.

Dip coatings of microcrystalline wax or other seal-coating materials were applied to sabots with or without the teflon coating. These were then test-fired to compare the ballistic performance of the flechette.

Sabot Seals

Microcrystalline Wax

Preliminary experiments were directed to determine whether a seal could be accomplished effectively by dip-coating techniques. An added purpose was to evaluate the proposed leak testing procedure described below. For this purpose, microcrystalline wax, m. p. ca. 85 - 115° C (185 - 239° F) was used. To effect a seal, assembled rounds with machined (R&D) sabots, with and without teflon coatings, were coated by simple dipping of the sabot end of the round into the molten (ca. 100° C) wax to a distance slightly beyond the case mouth (Figure 4). This resulted in a wax coating on the sabot of about 0.0015 to 0.002 inch with a maximum total change in diameter of 0.004 inch. The round was held in an inverted position until the wax solidified. Wax collected on the case beyond the case mouth rim was pared away. Some rounds with compacted sabots were also coated with wax.

Resin Formulations

For the sabot, a variety of candidate resin formulations were evaluated as sealants. These included emulsions or dispersions in a water medium or solutions in organic solvents containing mineral pigments, as included in Table II. These were selected for evaluation from the viewpoint of sealing efficiency, wide range of properties, good thermal stability, ease of application, and reasonably good general resistance to damage by action of microorganisms. Each was evaluated for (1) setting and drying, (2) thickness of film produced from a single dip, (3) brittleness or susceptibility to damage of film produced, and (4) gun-barrel fouling on firing experimentally sealed rounds.

TABLE II.
Firing Data of Rounds with Nitrocellulose CCL-711-1101 Sealed Sabots and/or Primer

			Date of Test and Firing Data							
			March 11*		May 10			July 9*		
Added	Sabot**	Primer Seal	Chamber Pressure (ksi)	Avg Coat Thickness [mil (mm)]	Chamber Pressure (ksi)	Velocity (ft/sec)	Avg Coat Thickness [mil (mm)]	Chamber Pressure (ksi)	Avg Coat Thickness [mil (mm)]
4% Teflon	Filled	Yes	70.3	1.5 (0.038)	60	4927	1.2 (0.031)	60	0.5 (0.013)
4% MoS_2	Filled	Yes	68.4	1.5	67	4990	1.2	64.1	0.5
								67.0	1.1
None	Filled	Yes	59.4	1.5	60.2	4928	1.2	63.6	0.5
								64.8	1.2 (0.031)
None	Filled	No			61.1	4954	1.2		
None	Filled								
None	Filled	Yes			61.8	4935	1.2		
None	Filled	Yes			63.0	4965	[illegible]		
None	No	Yes			63.0	4979			
None	No	No			59.6	4956			

*Velocity data not included.
**Seal coating applied over filler; bare, machined sabots used.

In some cases the candidate polyvinylbutyral and nitrocellulose formulations were modified by the addition of finely divided molybdenum disulfide or teflon. It was considered that these added materials might serve as dry lubricants, to reduce friction of the sabot on the gun barrel and possibly erosion of the gun barrel by the glass fibers of the sabot. In each case, the molybdenum disulfide or teflon was added in the quantity of four percent by weight. The molybdenum disulfide was a fine, dry, submicron powder; the teflon was a dispersion of fine particles in a Freon liquid.

The candidate sealants used for the sabot were also tried as sealants for the primer. For this purpose, effective penetration of sealant liquid into the primer-cup crevice was desired. Further, it was necessary that the mixture dry or set slowly enough to prevent the formation of voids caused by bubbles of air displaced in the crevice by the infiltrating liquid.

Preformed Seals

Efforts were directed to determining the feasibility of employing preformed plastic caps as seals for the sabot (Figure 5). Commercial plastic formers and fabricators were contacted to ascertain the availability of preformed caps, or of suitable sheet plastics from which such caps might be molded. It was determined that a cap wall thickness should not exceed 0.001 inch (0.0254 mm), since a thicker wall would lead to difficulties in inserting capped rounds into the gun chamber. Plastics manufacturers (Celanese Corporation, New York, NY, and duPont Co., Inc., Wilmington, DE) and suppliers and fabricators (Thatcher Plastics, New York, NY, and Gilbreth Company, Philadelphia, PA) were consulted for advice, for available materials that would be used to form the caps, and for information as to plastic formers who might produce the desired caps. The consensus was that caps of 0.001 inch (0.0254 mm) wall thickness were not available and would not be available from any source. However, Thacher made available water expanded cellulosic caps (7 by 15 mm - similar to pharmaceutical capsule halves), which when dry had a wall thickness of 0.004 inch (0.102 mm). Heat shrinkable caps were furnished by Gilbreth. These were prepared from vinyl chloride tubing having an inside diameter of 0.420 inch (10.7 mm), and a thickness of 0.004 inch (0.102 mm), cut into bands and heat sealed at one end. Celanese and duPont furnished sheet samples of various resins for experimental forming use. Since preformed caps of the desired size and wall thickness could not be acquired from commercial sources, attempts were made to mold the caps at the experimental plastic shop at Frankford Arsenal. A variety of sample polymeric resin films acquired for this purpose were used.

Filling Voids Prior to Sealing

Frequently in the applications of microcrystalline wax or resin formulations to seal the sabot, large voids failed to become filled or bridged. Often, small differences in temperature, such as slight heating of the case from handling, or from proximity with molten wax, resulted in some expansion of the air inside the case. This caused blistering of seal coating and blow-out of the blisters over the larger voids in the sabot. Consequently, to improve the efficiency of sealing by the dipping method, a heavier pigmented formulation was employed to fill the larger holes and voids. This material is referred to as a filler or caulking. It is readily made by adding sufficient quantity of a suitable pigment, e.g., finely divided titanium dioxide to any of the resin formulations to achieve the desired end, as was done in this investigation. The filler is applied by dipping the sabot into the filler mixture slightly beyond the case edge, withdrawing it, and wiping off the excess with a cloth. This does not change the diameter of the sabot. Prior to applying the wax seal, the filler was permitted to dry, but drying was not essential prior to the application of the resin seals. The resin-base seal coating may be applied immediately after the filler. The resin seal coatings were applied to a maximum thickness of 0.0005 inch to 0.0015 inch (0.013 to 0.038 mm) with a diameter increase of 0.001 to 0.003 inch (0.025 to 0.076 mm).

Testing for Leaks

Experimental seal coatings were evaluated for leaks by completely immersing prepared rounds in water, to a depth of at least one inch (30 to 40 mm) in a heavy walled suction flask. The flask was connected in series to a closed-end mercury manometer and a vacuum pump.

In making the leak test, the system was reduced to about 3/4 atmosphere pressure (ca. 570 mm). Rounds with only sabot seals were fitted with rubber boot seals over the primer end prior to the test; this was to preclude escape of air from the primer-case crevice. Alternately, when only the primer seal had been applied, the rubber boot was placed on the sabot end before the test. When the seal coating had been applied to the sabot and primer areas, the rubber boot seal was omitted. An effective seal was considered to prevail if at the reduced pressure no air bubbles escaped from the round. The leak test covered in the XM645 Purchase Description was not applied in this work because of the long time (24 hours) necessary for its completion. The reduced pressure test was preferred since tests could be performed as required and completed within a few minutes.

Firing Tests

Pressure and velocity measurements from actual firing tests were obtained for experimental sealed rounds. These data in addition to examinations for residue in the gun barrel were the criteria for determining the suitability of the seal or the seal material. Approximately 20 or more rounds were employed in each firing test; and sealed rounds were compared to unsealed rounds. The pressure, velocity and accuracy data were the basis for deciding whether solid lubricants affected ballistic performances. Specifically, these included tests (1) to determine the value of the cured teflon coating on machined sabots by comparing firing rounds with sabots with and without the cured coating and with or without applied experimental seal coatings; and (2) to established the effects of incorporating teflon (fine particles) or molybdenum disulfide (submicron particles) to selected seal coating formulations.

RESULTS

Filler

When sabots of assembled rounds were attempted to be sealed by dipping the sabot into molten wax, sealing was only about 40 percent effective. The escape of air from inside the case at voids and crevices on the sabot caused bubbles to form and eventually holes or rupturing of the bubbles. Application of the filler prior to the wax seal, or any of the dispersion or resin-solvent seal coatings, was essential.

Results of tests, which were performed with attempted seals using microcrystalline wax and the saran or other resins dispersed in several liquid media, revealed the necessity of the use of a filler material to close the large voids. A resin-solvent filler itself was demonstrated to serve as a sealer for the sabot. Nevertheless, subsequent work was performed with the filler followed by a sealer; this provided greater assurance of non-leakers (over 90 percent), the possibility of providing coatings with low friction characteristics, and seals with uniformity in thickness.[1]

Filler Microcrystalline Wax Seal

From the results of static-leak tests and actual firings conducted on a few hundred rounds with microcrystalline wax seal of the sabot, the sealing of the round was demonstrated as workable. Beyond this, no further experiments were conducted with the wax, since it was not contemplated to make any recommendations for its use. Wax seals were viewed as unsuitable firstly because of their embrittlement at lower temperature (e.g., -40° F) and their tackiness at higher temperatures (e.g., 165° F), and secondly because of their susceptibility to deterioration by microbial action.

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[1]Memorandum (DF) to J7100 from L8300, Subject: Report on Status - Sealing of SPIW Rounds, 13 Oct 69.

Sixty standard rounds (sabot with cured teflon coating) and sixty microcrystalline wax sealed (sabot) rounds were fired for velocity and pressure information. The gun barrel was borescoped before and after firing each set. The microcrystalline wax in no way altered the accuracy or velocity, and the results were similar to those of the standard. A repeat test with 30 rounds each and 0.0015 inch (0.038 mm) thick wax seals indicated only slightly higher chamber pressures (ca. 1000 psi) for the latter. There was no fouling of the gun barrel in either case.[2,3,4]

Resin-Solvent Coatings

Each of the resin-solvent formulations, i.e., polyvinylbutyral, styrenated alkyd, nitrocellulose, and saran (with appropiate solvents), was readily thickened for use as a filler. Each formulation could be adjusted to give the desired coating thickness. All were acceptable for use as sealants on the basis of the preliminary evaluation results. The unaltered nitrocellulose formulation was selected as the more suitable material because of (1) rapidity of setting and drying, (2) the toughness of the dry coating, (3) good adhesion to the sabot surface, and (4) the probability of its causing less fouling of the gun barrel of the weapon. Another reason for choosing it was its easy adaptibility for use on sealing the primer-case crevice. Hence, most of the results which follow will pertain to the nitrocellulose formulation.[5,6]

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[2]Memorandum (DF) to J7100 from L8300, Subject: Report on Status - Sealing of SPIW Rounds, 13 Oct 69.

[3]Memorandum (DF) to J7100 from L8300, Subject: Investigation of Sealing Materials and Sealing Methods for the SPIW Round, 19 June 69.

[4]Memorandum (DF) to L8300 from J7100, Subject: Firing Summary - Microcrystalline Sealant, 15 Dec 69.

[5]Memorandum (DF) to J7100 from L7800, Subject: Report of Status - Sealing of SPIW Rounds, 6 Jan 71.

[6]Memorandum (DF) to L8300 from J7400, Subject: Firing Summary of CCL-668-1111 Sealant, (no date).

Pressure-time measurements were made using polyvinylbutyral sabot seals 0.001 inch thick. The sabots were machined and not previously coated with teflon. Approximately 60 rounds were fired, and the results compared to standard rounds with machined, teflon-coated sabots. The chamber pressure of the experimental rounds met the requirements with an average of 52,000 psi compared to 53,800 psi for the standard rounds. But the accu acy result result was somewhat deficient. A small amount of char was found on the stripper.[7] This would not be considered objectionable for a weapon of the SFR design, which is without a gas tube.

Coatings with Teflon or Molybdenum Disulfide Additions

Firing Tests were included to ascertain the influence of four percent MoS_2 additions to the polyvinylbutyral and nitrocellulose formulation on performance. These mixtures were applied to seal uncoated, machined sabots and the primer-case crevice of the test rounds. Rounds with bare, machined sabots and no primer seal were also fired for purposes of performance. The average peak pressures obtained were:

Polyvinylbutyral + MoS_2	58,000 psi
Nitrocellulose + MoS_2	59,000 psi
Control	57,000 psi

Velocity data were comparable.

Nitrocellulose seals applied to rounds with uncoated sabots, at the thickness of 0.0015 inch (0.038 mm), were compared with machined, teflon-coated sabots. Pressure for the sealed rounds averaged approximately 3,000 psi higher than that for the standard.

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[7]Memorandum (DF) to L8300 from J7400, Subject: Firing Summary of CCL-668-1111 Sealant, (no date).

Velocity averaged about ten percent lower than the standard. These deviations from the standard were attributed to the thickness of the seal coating on the sabot.[8,9,10]

Ballistic data reveals that the thickness of the seal coating does affect the chamber or peak pressure. Consistently higher chamber pressures resulted where the thickness of a specific coating was greater. For example, in Table II under July 9, the 0.5 mil coating gave lower pressures than the 1.1 or 1.2 mil coatings. All rounds with sealed sabots resulted in chamber pressures higher than that of the standard rounds with teflon coated sabots. It appears that a 0.5 mil thick sabot seal would be optimum for all purposes. The thickness of the sealed sabot did not significantly change the velocity of the flechette.

Teflon addition to the nitrocellulose composition does not alter the ballistic performance of the round, but the addition of molybdenum disulfide (four percent) to the composition consistently results in higher chamber pressure, exceeding the permissible limit. This effect is independent of the seal coating thickness.

Overall it is apparent that seal coatings can be effectively employed without appreciably altering the performance of the round. The nitrocellulose seal fulfills the need and very probably will contribute least to fouling of the gun tube.

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[8]Memorandum (DF) to J7100 from L7800, Subject: Report of Status - Sealing of SPIW Rounds, 6 Jan 71.

[9]Memorandum (DF) to J7400 from L7800, Subject: XM645 Cartridge, Retest (3) Experimental Seals, 18 Jun 71.

[10]Memorandum (DF) to J7100 from L7800, Subject: Quarterly Status Report, 1 April - 30 June - Sealing of XM645 Cartridge, 7 Jul 71.

Sabot Seal Thicknesses

Rounds with the relatively thicker coatings, 0.0015 inch (0.038 mm), of microcrystalline wax offered no difficulties in chambering or firing. However, the heavier thicknesses of resin dispersion or solvant coatings (ca. 0.0015 inch), or preformed cap seals, 0.004 inch (0.102 mm), were troublesome The heavier resin coatings did not resist chambering but did cause higher chamber pressures on firing. The preformed seals prevented chambering.

Effect of Teflon or Molybdenum Disulfide Additions

The addition of teflon or molybdenum disulfide to either the polyvinylbutyral or nitrocellulose formulations for sabot sealing yielded significant firing results. With seals ca. about 0.0005 inch (0.0127 mm), the teflon addition apparently offered no observable advantage over the unmodified formulations. On the other hand, the molybdenum disulfide modifications consistently resulted in higher pressure-time profiles. The effects of these additions in reducing barrel wear could not be obtained since sufficient rounds for this determination were not available.[11,12]

Preformed Seals

Heat-shrinkable or dry-shrinkable preformed caps (intended for sabot seals) of 0.001 inch or less thickness were not available commercially. Preformed cellulosic dry-shrinkable, or vinyl heat-shrinkable caps were obtained, but these were of minimum thickness of about 0.004 inch (0.102 mm) - much too thick for the desired application.

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[11] Memorandum (DF) to J7100 from L7800, Subject: Report of Status - Sealing of SPIW Rounds, 6 Jan 71.

[12] Memorandum (DF) to J7400 from L7800, Subject: XM645 Cartridge, Retest (3) Experimental Seals, 18 Jun 71.

No success was achieved in the efforts to form caps of 0.001 inch (0.0254 mm) wall thickness from any of the sheet materials acquired, although a variety of approaches and forming techniques were explored. This failure was not attributable to material deficiencies, but to the lack of suitable molding methods. It became apparent from some of the imperfectly formed caps made that the 0.001 inch (0.025 mm) thickness did present a handling problem; the shape could not be supported; the collapsed cap developed creases, tears, or perforations, even with minimal handling. The collapsed caps were difficult to restore to the desired form and were easily damaged in attempting to do so.[13]

In the Frankford Arsenal attempt to produce preformed cap seals for the sabot end of the cartridge, the results have been quite discouraging (Table III). In no case with the various resin materials tried were suitably dimensional caps produced. Slightly more promising possibilities appear to exist with the use of some of the polyethylene, cellulose-acetate-butyrate, and the polycarbonate materials. It may be that a higher degree of success in molding acceptable caps of the required dimensions can be achieved through additional molding development effort. In any event, should successful molding be achieved, these disadvantages are not likely to be erased: (1) the fragility (thinness) of the molded cap and difficulty in handling and applying the caps, (2) the probable high rate of rejection of molded caps because of wall thickness irregularities, and (3) the now obviously higher cost of producing and applying molded cap seals compared to dip-coating seals which have been tried.

Primer Seal

As is presently employed by the contractor, the molybdenum disulfide primer-seal formulation is ineffective. Experimental "standard" rounds with primer seals, in virtually every round tested, released air as determined the leak test adapted in this investigation.

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[13]Memorandum (DF) to J7400 from L7800, Subject: Initial Attempts to Mold Boot Seals for the XM645 Cartridge (SPIW), 7 May 71.

TABLE III.
Sheet Materials for Molding XM 645 Sabot Seals at Frankford Arsenal and Results Obtained

Sheet Material	Thickness [in (mm)]	Results
Cellulose acetate	0.007 (0.178)	Not full length mold; excessive thinning, apex damaged.
Cellulose acetate	0.007	Full length mold, (thickness ca. 0.002 inch) finning occurred.
Cellulose acetate	0.008 (0.203)	Full length mold, (thickness ca. 0.003 inch) finning occurred.
Cellulose acetate	0.006	About 1/2 length, ca. 0.004 inch thick at thinnest section.
Cellulose acetate butyrate	0.006 (0.152)	Full length mold, some finning, seems slightly better than cellulose acetate
Cellulose acetate butyrate	0.006	Not full length, excessive thinning.
Cellulose acetate butyrate	0.005 (0.127)	Not full length, excessive thinning.
Polycarbonate	0.010 (0.254)	Full length mold, some finning near base (ca. 0.004 inch).
Polycarbonate	0.010	Not full length, excessive thinning and rupture 2/3 from base to apex.
Polyethylene	0.011 (0.279)	Full length mold, some finning, thickness ca. 0.004 inch.
Polyethylene	0.006	Full length mold, excessively thin at apex
Polyethylene	0.005	Full length mold, excessively thin at apex.
Polyethylene	0.008	Full length mold, excessively thin at apex.
Polyethylene	0.008	Full length mold, excessively thin at apex.
Polyethylene (Grace)	0.008	Not full length, ruptured 2/3 from base to apex.
Polyfluoroethylene	0.005	Not full length, excessive thinning and rupture.
Polyfluoroethylene	0.005	Half length, too thick
Nylon (Comco, Strip)	0.010	Female, 1/3 length, excessive thinning at apex (1/2 mil).
Nylon (Comco, Strip)	0.010	Male, full length, finning, too thick.
Acetal (Comco)	0.005	Female, 1/2 length, thinning across bottom and rupture.
Acetal (Comco)	0.005	Male, full length, finning.
Polysulfone	0.005	Excessive thinning and rupture 1/3 from base to apex.
Polysulfone	0.005	Full length mold, finning entire length
Polysulfone	0.020 (0.508)	Heavy base to 2/3 length, excessively thin to apex, ruptured.
Polysulfone	0.010	Full length mold, ca. 0.002 inch, excessive finning.
Polysulfone	0.010	Heavy base to 2/3 length, excessive thinning 2/3 to apex, ruptured.
Polyvinylchloride		Excessive thinning from 2/3 length to apex, ruptured.

Seal formulations for primer purposes should possess sufficiently low surface tension. This is considered necessary to permit flow of the formulation into the crevice between the primer and pocket, and, in doing so, displace the air in that space. In addition, the setting time of the formulation should be slow enough to prevent air-blistering. Furthermore, a pigmented formulation is considered to provide more resistance to eruption as the air is displaced.

The nitrocellulose base formulation, as well as the polyvinyl-butyral and other base formulations, can be modified to achieve lower surface tension and slower rate of drying.

Most of the effort was directed to modification of the nitrocellulose base formulation since this was indicated as a suitable seal material for the sabot, and it was considered more expedient to develop that same basic material for the sabot and primer seals. Additions of a lower volatility solvent, e.g., cellosolve, resulted in a suitable modification of the nitrocellulose material to serve as an effective (ca. 98 percent) seal for the primer-pocket crevice.

Firing tests have given no indication of adverse effects with any of the formulations used as primer seals.[14, 15, 16]

Ballistic and cyclic rates of fire determinations were performed in the XM19 rifle on rounds with a nitrocellulose mixture. Standard rounds were included (machined sabots with teflon coating and Drilube #108 applied to the primer crevice). All rounds fired in the Mann barrel resulted in acceptable chamber pressures (within 1500 psi of the control average 58,500 psi). The primer seal had no effect on the cyclic rate of firing.[17]

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[14]Memorandum (DF) to J7400 from L7800, Subject: XM645 Cartridge, Retest (3) Experimental Seals, 18 Jun 71.

[15]Memorandum (DF) to J7100 from L7800, Subject: XM645 Cartridge - Experimental Seals, 4 May 71.

[16]Memorandum (DF), Subject: Summary of Ballistic Tests Conducted on Waterproofed XM645 Cartridges, 26 July 71.

[17]Memorandum (DF) to L8300 from J7400, Subject: Firing Summary - Piston Primer Sealants, 5 May 70.

Leak Test

Effective sealing of the caulked sabot and of the primer in assembled rounds was achieved in most cases with virtually all the resin base materials able to withstand up to 1/2 atmosphere gage pressure without escape of air bubbles.

CONCLUSIONS

1. Waterproofing of the sabot and primer of the XM645 cartridge can be readily accomplished by a simple dipping operation for the sabot, and by single drop application for the primer of an available nitrocellulose base lacquer (MIL-L-11195).

2. This method of sealing could be performed with only minor modification of existing machinery for assembling cartridge cases; no new equipment is necessary.

3. Firing of experimentally sealed XM645 cartridges has no adverse effects on the performance of the weapon nor the ballistics.

4. Preformed (cap) sabot seals are impractical for the XM645 cartridge. Molding techniques available are deficient for producing cap seals of the required dimensions. The deficiencies appear to be inherent with the molding processes and not with the thermoplastic sheet materials used.

5. The testing of cartridges for leakage by partial reduction of atmospheric pressure, to about three-quarters of normal, is reliable and rapid.

RECOMMENDATIONS

1. The sealing of the sabot and primer of the XM645 cartridge with nitrocellulose lacquer, MIL-L-11195 is recommended.

2. In lieu of the current 24 hour leak test required in Purchase Description for XM645 Cartridge,[18] the adoption of the reduced pressure leak test comparable to that used in this investigation is recommended.

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[18] Purchase Description for XM645 Cartridges, FA-PD-J5000-41, 19 Dec 68.

FIGURE 1 - Machined R&D Sabot of polyester resin, glass-fiber reinforced composite with and without nitrocellulose seal.

a. Sabot-flechette assembly before inserting in case.
b. Bare, unsealed.
c. Teflon-coated sabot.
d. Nitrocellulose formulation seal.

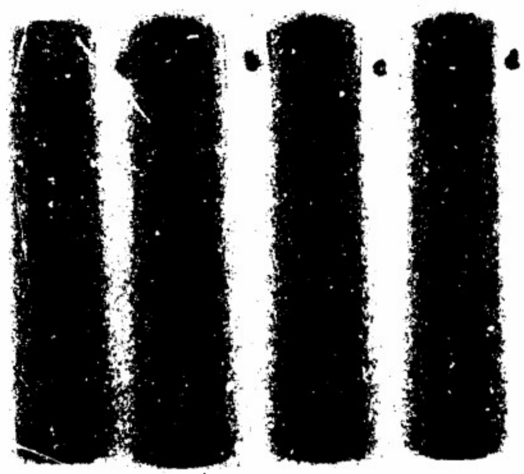

FIGURE 2 - Compacted ("Crushed") R&D various seals.

- **a. Bare sabot, unsealed.**
- **b. Microcrystalline wax seal.**
- **c. Polyvinylbutyral (+MoS_2) seal.**
- **d. Nitrocellulose formulation seal.**

FIGURE 3 - Piston Primer

a. Normal position in case.
b. Drilube 106 applied.
c. Nitrocellulose coating formulation (adjusted for flow and setting)
d. Sectioned primer showing penetration of nitrocellulose formulation.
e. Normal case.
f. Position of primer cup in case after firing of round.

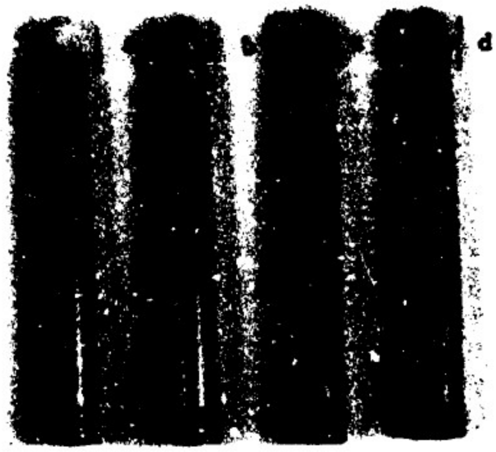

FIGURE 4 - Machined R&D Sabot - with and without microcrystalline wax seal.

a. Bare, unsealed.
b. Teflon coated sabot.
c,d. Microcrystalline wax seal.

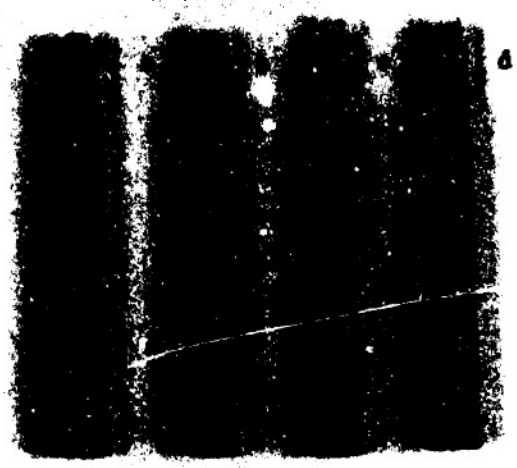

FIGURE 5 - Preformed Cap Seals

a,b. Cellulose polymer
(dry shrunk)
c,d. Vinyl chloride polymer
(heat shrunk)

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13. ABSTRACT

Waterproof sealing of the sabot and primer of the XM645 Cartridge (SFR) has been achieved using a pigmented resin-solvent formulation. Firing tests conducted on experimentally sealed rounds have given every indication that seals are acceptable. Efforts to effect sealing of the sabot by means of commercially available dry-shrink or heat-shrink preformed plastic caps, or to mold caps having the desired wall thickness, were unsuccessful. A rapid, reduced pressure leak test was employed.

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