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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/351

Comparison of the Physical, Chemical, and Ballistic Properties of Various Lots of Caliber .45 M1911 Pistol Ball Ammunition Used for the Proof Testing of Helmets and Body Armor Components

BY

A. Hurlich
Assoc. Metallurgist

[redacted] ERIALS RESEARCH AGENCY
WATERTOWN, MASSACHUSETTS DATE 4 December 1944

WATERTOWN ARSENAL
WATERTOWN, MASS.

[redacted]

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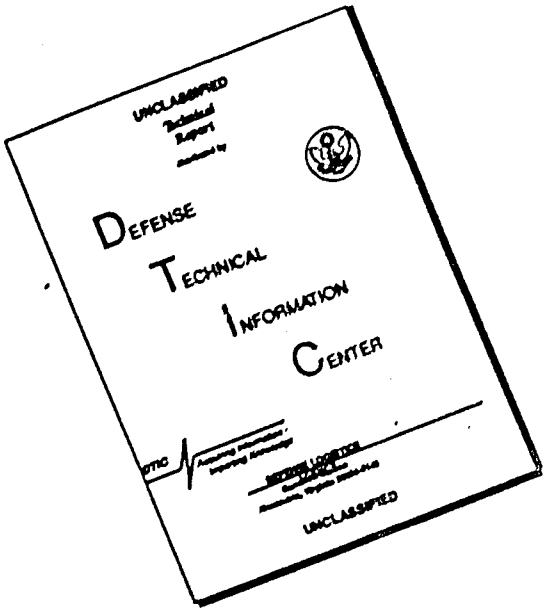

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/351

Final Report on Problem B-7.8

4 December 1944

Comparison of the Physical, Chemical, and Ballistic Properties of Various Lots of Caliber .45 M1911 Pistol Ball Ammunition Used for the Proof Testing of Helmets and Body Armor Components

Abstract

Examination of caliber .45 M1911 pistol ball ammunition from five different lots revealed important variations in ballistic performance traceable to differences in the chemical composition of the lead cores and to differences in the jackets; four lots containing gilding metal jackets and one lot containing copper-clad steel jackets. Ballistic behavior indicates excellent uniformity of projectiles within each lot. The copper-clad steel jacketed projectiles are most resistant to deformation upon impact and produce the lowest ballistic limits against Hadfield steel. The projectiles used for acceptance testing of production M1 helmets are the softest and yield the highest ballistic limits. In view of the large amount of experimental data accumulated by testing a large variety of materials at this arsenal, it is recommended that the copper-clad steel jacketed projectiles be standardized for all development and experimental testing of helmet and body armor materials.

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1. Differences in the physical and ballistic characteristics of various lots of caliber .45 M1911 pistol ball ammunition were first observed at this arsenal in May 1944 during the ballistic testing of various experimental body armor materials. At that time two lots of ball ammunition were on hand at the ballistic range; one consisting of preloaded service velocity (850-900 ft./sec.) rounds and the second of caliber .45 balls which were hand loaded into complete rounds, using varying powder loads to obtain the desired striking velocities. The preloaded service velocity rounds were employed whenever a striking velocity in the range of 850-900 ft./sec. was desired, while the other ammunition was hand loaded to produce velocities outside that range. Reverse ballistic limits were successively obtained on some material, resulting from partial penetration by the service velocity rounds and complete penetration by the hand loaded ammunition at lower striking velocities. Normal ballistic limits are obtained by averaging the highest velocity at which partial penetration occurs and the lowest velocity resulting in complete penetration, the latter velocity always being higher than the former. Investigation of the anomaly of reverse ballistic limits disclosed important differences in the physical and ballistic properties of the two lots of ammunition.

2. The lead cores of the service velocity ammunition were found to be encased by gilding metal jackets, whereas the hand loaded projectiles were enclosed in copper-clad steel jackets. Projectiles from the two lots were visually indistinguishable, but could be separated with the use of a magnet. Ballistic testing established that the steel jackets effectively increased the resistance of the projectiles to deformation. A projectile which deforms less utilizes less of its energy in self-destruction, its striking energy is distributed over a smaller area of the impacted plate, and it is consequently able to penetrate at a lower velocity than a more extensively deforming projectile. The copper-clad steel jacketed projectiles were found to be capable of penetrating Hadfield manganese steel sheets at velocities from 100 to 200 ft./sec. lower than gilding metal jacketed projectiles. The Office, Chief of Ordnance, was informed[1,2] of the variations in projectile performance and it was suggested that the copper-clad steel jacketed projectiles be standardized for the development and experimental testing of helmet and body armor materials because these projectiles were the only ones available at this arsenal which could be used at all striking velocities.

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1. Wtn. 400.112/3119 (r), 29 May 1944

2. W.A. Memorandum Report No. WAL 710/[illegible]35 - "Ballistic Tests of 0.040-0.050" Hadfield Steel Sheet With Caliber .45 Ball Projectiles for Development of Specification Requirements." Majo. W. A. Matthews and A. Hurlich, 18 May 1944.

3. The acceptance tests of the M1 helmet include the ballistic testing of a certain number of samples selected from each lot produced. The Ordnance Department maintains a ballistic range at each of the two facilities producing helmets, and all ballistic testing of production helmets is conducted at these ranges. Specification AXS-645-2 "Helmet, Steel, M1" stipulates that the selected helmets must resist complete penetration by gilding metal jacketed caliber .45 M1911 ball projectiles at a striking velocity of 725 ft./sec. Normal production helmets made from satisfactory quality steel have been able to meet this test with marked success. In October 1944 an epidemic of ballistic failures occurred at the McCord Corp., and investigation revealed that the failures resulted from the use of a new lot of gilding metal jacketed projectiles which contained alloyed lead cores of greater hardness and resistance to deformation than those previously used. Again, the increased resistance to deformation resulted in projectiles of greater penetrative power. Representatives from the Detroit Ordnance District Office visited this arsenal and witnessed the ballistic testing of Hadfield steel sheets and helmets with both types of projectiles which were used at the McCord Corp.

4. As a result of the large number of variations in the physical, chemical, and ballistic characteristics thus encountered in different lots of caliber .45 ball projectiles, the Office, Chief of Ordnance,[3,4] was notified of the extreme urgency for standardization of the caliber .45 M1911 ball projectiles used for the acceptance testing of helmets and body armor components and for experimental and development work being undertaken by the various Ordnance Department agencies. Since a considerable amount of ballistic data had already been accumulated with the copper-clad steel jacketed projectiles, it was recommended that these bullets be standardized for all development and experimental testing. The ballistic data obtained to date covers a large variety of nonmagnetic and magnetic steels, nonferrous metals, and nonmetallic materials.

5. It was considered advisable to collect all the pertinent information regarding the different physical, chemical, and ballistic characteristics of the various lots of projectiles examined at this arsenal and to submit this data, with the approval of the Office, Chief of Ordnance, at the meeting of the Helmet Industry Integration Committee held in Detroit on 8-9 November 1944. Captain [redacted] W. Hewitt at that time verbally requested that the information be transmitted to the Office, Chief of Ordnance, in the form of a Memorandum Report.

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3. Wtn. 400.112/7203 (r), 11 October 1944, See Appendix A.

4. Wtn. 471.2/45 8 (r), 12 October 1944, See Appendix A.

[redacted]

6. The various lots of caliber .45 M1911 ball ammunition from which samples were examined at this arsenal consisted of the following:

Type No.	Source of Ammunition	Manufacturer	Mfr's. Lot. No.	Date of Mfr.
1	Detroit Ord. District	Western Cartridge Company	WCC 6139	1942
2	" " "	Frankford Arsenal	FA-S-1505	1944
3	Schlueter Mfg. Co.	Remington Arms Co.	1209	1941
4	Watertown Arsenal	Frankford Arsenal	FA-1349	1942
5	" "	Frankford Arsenal	Unknown	Unknown

Types Nos. 1 and 3 represent the projectiles which always have been and are currently being used for the acceptance testing of M1 helmets. Type No. 2 is the new lot of ammunition which, when used at the McCord Corp., resulted in a succession of ballistic failures which were subsequently traced to a change in the ballistic performance of the ammunition resulting from an increase in the hardness of the lead core. Type No. 4 is the preloaded service velocity gilding metal jacketed ammunition available at this arsenal, and type No. 5 consists of the copper-clad steel jacketed projectiles used for the great majority of the development and experimental ballistic testing of helmet and body armor materials conducted at this arsenal.

7. The tests conducted upon samples of the various lots of ammunition consisted of the following:

a. Chemical analysis of the lead core
b. Chemical analysis of the gilding metal jacket
c. Hardness surveys of the various components
d. Thickness measurements of the jackets
e. Determination of ballistic performance against Hadfield steel sheet.

To obtain hardness readings, the bullets were sectioned transversely just below the ogive. The bases and the cut surfaces were ground to produce parallel plane surfaces, and the sectioned surfaces were metallographically polished. Hardness impressions were made with a Knoop hardness indenter under a load of 100 grams. The hardness impressions are in the form of very much elongated diamonds, the major axes of which are measured on the ground glass of a microscope camera at a magnification of X1000. The Knoop hardness numbers correspond roughly to Vickers Pyramid hardness numbers and Brinell hardness numbers, particularly at lower hardnesses such as encountered in nonferrous metals.

Rockwell H hardness readings (with 1/8" diameter ball penetrator and 60 kilogram load) were attempted upon the lead cores but were found unreliable because of the marked ability of lead to flow under relatively light loads, causing the dial indicator needle to move constantly after application of the load.

The thicknesses of the gilding metal jackets and of the components of the copper-clad steel jackets were measured at the same time that the Knoop hardness impressions were measured.

The results of the tests performed upon samples of the various lots of ammunition are reported in Table I. All values of chemical analysis, hardness, and thickness measurements represent the average of determinations upon two randomly selected projectiles from each lot. In no case was any significant difference noted between projectiles from the same lot. Furthermore, the ballistic behavior indicates excellent uniformity within the lot. The ballistic characteristics were determined from firing at from three to ten sheets of fully annealed Hadfield manganese steel which were 0.044 to 0.046" in thickness.

8. Examination of the data contained in Table I shows that the chemical composition of the lead cores definitely influences the hardness. The lead cores of types Nos. 1 and 3 are relatively pure, containing more than 99.95% lead, and have hardnesses of 5.0 and 5.2 Knoop. According to a handbook published by the International Nickel Company[5], chemically pure lead (99.9% Pb) has a hardness of 5 Brinell. These data indicate the correlation between Knoop and Brinell hardness values over the low range of hardnesses. The lead cores of types Nos. 2, 4, and 5 contain from 1.73 to 2.29% antimony and from 0.04 to 0.84% tin, both of which elements are hardening agents when alloyed with lead. The hardness of these latter bullet cores are 10.0 to 11.6 Knoop.

9. The compositions and hardnesses of the gilding metal jackets of types Nos. 1, 2, 3, and 4 are relatively constant. Although there is a variation in thickness of the gilding metal jackets between different lots of ammunition, the variation is not believed sufficient to exert more than a slight influence upon the deforming characteristics and ballistic behavior of these projectiles. The copper-clad steel jackets of type No. 5 were probably designed to conserve copper at the time when copper, because of excessive demand, became a strategic

5. "Properties of Some Metals and Alloys" - International Nickel Company, Inc., New York. Published in 1943.

metal. In spite of the fact that the steel has a very low carbon content, it is significantly harder than the gilding metal, averaging 290 Knoop whereas the latter has a hardness of 150-180 Knoop. The combination of harder jacket and harder lead core causes projectiles of type No. 5 to be considerably more resistant to deformation than all the other types examined.

10. Examination of the ballistic data in Table I indicates a definite correlation between projectile hardness and ballistic limit obtained from firing at 0.044-0.045" thick annealed Hadfield manganese steel. The harder the projectile, the lower the ballistic limit, see Figure 1. Type 5 projectiles produced a still lower ballistic limit because of the added stiffness resulting from the steel jacket. Photographs of samples of the various projectiles after impact against a 0.045" thick sheet of Hadfield steel at striking velocities of 1000-1050 ft./sec. are shown in Figure 2. The large variations in the degree of projectile deformation are readily apparent.

11. The variations in the physical, chemical, and ballistic characteristics between different lots of caliber .45 ball ammunition make it mandatory to standardize the projectiles used for the testing of both production helmets and experimental materials if comparable data are to be obtained at all times. In view of the large amount of data accumulated at this arsenal with copper-clad steel jacketed projectiles, these projectiles are recommended for development and experimental ballistic testing.

A. Hurlich

A. Hurlich
Assoc. Metallurgist

APPROVED:

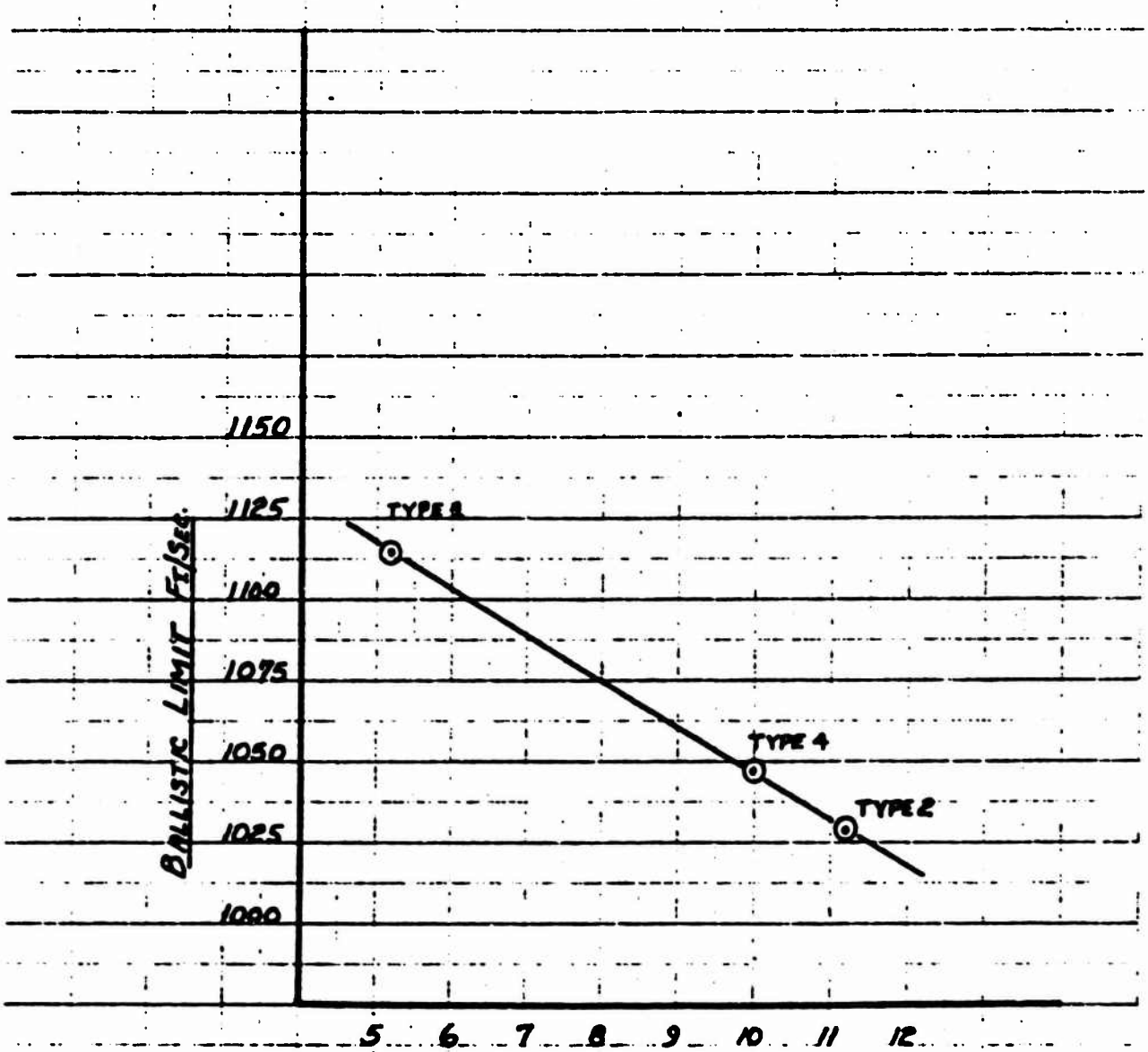
E. L. Reed

E. L. REED
Res. Metallurgist
Acting Chief, Armor Section

TABLE I

Tests of Various Lots of Caliber .45 M1911 Ball Ammunition

		Type #1 Detroit Old Lot Soft Projectiles	Type #2 Detroit New Lot Hard Projectiles	Type #3 Schluster Old Lot Soft Projectiles	Type #4 W.A. Gilding Metal Jacket	Type #5 W.A. Copper-clad Steel Jacket
Chemical Analysis of Lead Core	Sb	0.01	2.29	nil	2.05	1.73
	As	0.001	0.007	0.002	0.012	0.006
	Sn	nil	0.63	0.04	0.04	0.84
	Pb	remainder	remainder	remainder	remainder	remainder
Chemical Analysis of Gilding Metal Jacket	Cu	89.91	89.32	89.84	89.83	
	Pb	0.04	0.03	nil	0.06	
	Fe	trace	trace	trace	trace	
	Zn	remainder	remainder	remainder	remainder	
Knoop Hardness of Components						
Lead Core		5.2	11.2	5.0	10.0	11.6
Gilding Metal		173	181	151	172	Outer copper layer - 200 steel - 290 Inner copper layer - 170
Thickness of Jackets Gilding Metal		.012-.016"	.017-.018"	.020-.024"	.020-.021"	Outer copper-.003-.005" steel-.011-.013" Inner copper-.003-.004"
Average Ballistic Limit against 0.044-0.045" Hadfield Steel Sheet Ft./sec.		1115 ± 15	1029 ± 15	Not determined	1046 ± 14	960 ± 25



RELATION BETWEEN BALLISTIC LIMIT AGAINST .044-.045" HADFIELD STEEL AND HARDNESS OF LEAD CORES OF GILDING METAL JACKETED CAL .45 M1911 BALL AMMUNITION

FIGURE 1

1045 f/s. 1038 f/s. 1004 f/s. 1016 f/s.

OLD PROJECTILE SOFT LEAD — DETROIT ORDNANCE DIST.

NEW PROJECTILE HARD LEAD

GILDING METAL JACKET — WATERTOWN ARSENAL

COPPER-CLAD STEEL JACKET

Mag. X1

Deformation produced upon impact against 0.045" thick annealed Hadfield manganese steel. Numbers under the projectiles are the striking velocities. Partial penetration of the sheet steel resulted in all cases except for the copper-clad steel jacketed projectile, which completely penetrated and was stopped by another 0.045" thick sheet placed one foot behind the first sheet.

FIGURE 2.

APPENDIX A

Correspondence

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Sullivan/ELR/avk

IMMEDIATE ACTION

11 October 1944

ftn. 400.112/3203 (r)
aboratory (ELR)

Subject: Steps to Validate Evaluations of Resistance Characteristics of Light Armor Materials

To: Chief of Ordnance
Army Service Forces
Pentagon Building
Washington 25, D. C.

Attn: SPOTS - Major Clark

1. Earlier this year (29 May 1944) there was reported to his office (Wtn 400.112/3119) instances of errors in evaluating the resistance characteristics of light armor materials which may arise from a variation in the physical properties of test projectiles. In those instances the errors were attributable to the change in the jackets of standard cal. .45 ball projectiles from gilding metal to copper-clad steel. Fortunately this substitution was discovered before the errors were incorrigible and before too many erroneous evaluations had been made.

2. Currently there has come to the attention of this laboratory the introduction of another variable—a change in the chemical composition of the lead which greatly increases its hardness—in a lot of gilding metal jacketed cal. .45 ball projectiles supplied to the Detroit Ordnance District for use in the acceptance testing of helmets.

3. Neither of the above variations had been brought to the attention of the recipients by the suppliers and the differences were discovered only as the result of fortuitous combinations of circumstances.

4. Although it is realized that such variations in an anti-personnel projectile are of little significance in service, it is to be regretted that projectiles should be thus indiscriminately supplied to armor testing facilities. The successful conduct of programs of development or procurement of ordnance material should never be left to the vagaries of fortune. Their successful conduct is, however, vitally dependent upon the procurement of projectiles of constant physical characteristics so that the relative resistance of various materials may be evaluated as validly over a period of years and at various establishments as they may be on successive tests conducted the same day at a single facility.

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[redacted] IATE ACTION

Subject: Steps to Validate Evaluations of Resistance Characteristics of Light Armor Materials 11 October 1944

To: Chief of Ordnance, A.S.F., Pentagon Bldg., Washington 25, D. C.
Attn: SPOTS - Major Clark

5. It is, therefore, urgently suggested that steps be taken by his office toward the procurement of a lot (or lots) of cal. .45 ball projectiles of constant physical properties of sufficient number to anticipate the needs of development and proof facilities for several years. It is further suggested that this lot (or these lots) be specifically designated as reserved for armor testing and that measures be undertaken to assure the inviolability of such a designation. In the interests of preserving the value of extant data it is suggested that projectiles duplicating the physical characteristics of the projectiles used to obtain the current data be the subject of procurement. Samples of such projectiles are inclosed. It is contended that such steps will assure valid evaluation of the resistance characteristics of light armor materials for several years.

6. From such a lot (or lots) of projectiles, this laboratory has current need for about two thousand (2000) projectiles. The assistance of his office in procuring this number of projectiles duplicating the samples inclosed is hereby solicited.

For the Commanding Officer:

N. A. MATTHEWS
Major, Ord. Dept.
Assistant

3 Incls.
Cal. .45 Projectiles

[redacted] COPY

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[redacted]

Hurlich/ELR/avk

IMMEDIATE ACTION

12 October 1944

Wtn. 471.2/458 (r)
Laboratory(ELR)

Subject: Variations in Physical and Ballistic Properties of Caliber .45 Ball Projectiles Used for Acceptance Testing of Helmets

To: Chief of Ordnance
Army Service Forces
Pentagon Building
Washington 25, D. C.

Attn: SPOIS - Major F. M. Volberg

1. Ballistic tests conducted at this arsenal for Mr. Khoury, Resident Inspector of Ordnance at the McCord Radiator and Manufacturing Company and Mr. Baldwin of the Detroit Ordnance District Office demonstrate the urgent necessity of standardization of the caliber .45 ball projectiles used for acceptance testing of helmets and for experimental firing programs such as have been performed at this arsenal.

2. A recent epidemic of ballistic failures at the McCord plant has been traced to the use of a new lot of caliber .45 ball projectiles which differ from the previously used projectiles in that the lead filling is alloyed with 0.5% tin and 2.15% antimony, resulting in a substantially harder and more rigid projectile of greater penetrative power. Tests conducted at this arsenal with both types of projectiles indicate that the harder projectiles result in an 8.4% lowering of the ballistic limit when fired at flat, annealed helmet stock averaging 0.045" in thickness.

3. The major portion of the ballistic testing performed at this arsenal upon helmet steels and body armor components of numerous types has involved the use of a third type of projectile; a copper-clad steel jacketed bullet rather than the gilding metal jacketed projectile. This problem of projectile variability has also been brought to the attention of Major Clark of the Small Arms Development Division and samples of the projectiles currently being employed at this arsenal were forwarded to him with the suggestion that they be standardized for the development and testing of body armor components. The continued use of at least three and possibly many more types of caliber .45 ball projectiles, each of different penetrative power, will create an enormous amount of confusion, will lead to the accumulation of conflicting and unreliable data, and will eliminate the possibility of determining whether improvements in the ballistic properties of personal armor components had been made through the years.

[redacted]

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IMMEDIATE ACTION

Subject: Variations in Physical and Ballistic Properties of Caliber .45 B-11 Projectiles Used for Acceptance Testing of Helmets

12 October 1944

To: Chief of Ordnance, A.S.F., Pentagon Bldg., Washington 25, D. C.
Attn: SPOIS - Major F. M. Volberg

4. On the basis of the tests conducted at this arsenal, the Detroit Ordnance District Office will request that his office approve the lowering of the acceptance testing velocity currently employed for helmets from 725 feet/second to 665 feet/second; a reduction of 8.4%. This reduction will apply only to the new type gilding metal jacketed projectile having the harder, alloyed lead filling, and will require further modification upon the change to either the copper-clad steel jacketed projectiles of the former gilding metal jacketed soft lead filled bullets.

5. It is consequently recommended that the Ordnance Department take steps to obtain a sufficient supply of standard caliber .45 ball projectiles for issue to proof facilities engaged in the testing and development of helmets and body armor. Because of the extensive amount of ballistic data accumulated at this arsenal with the copper-clad steel jacketed projectiles described in paragraph 3, this arsenal suggests the standardization of this projectile.

For the Commanding Officer:

M. A. MATHEWS
Major, Ord. Dept.
Assistant

[redacted]

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