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WATERTOWN ARSENAL LABORATORY

Final

MEMORANDUM REPORT

NO. WAL 710/720

Resistance of M1 Helmets of Varying Thicknesses and of M1 Helmets Fitted with Plastic Liners to Perforation by the Soft and Hard Types of Caliber .45 M1911 Ball Ammunition

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BY

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Assoc. Metallurgist

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DATE 30 January 1945

WATERTOWN ARSENAL
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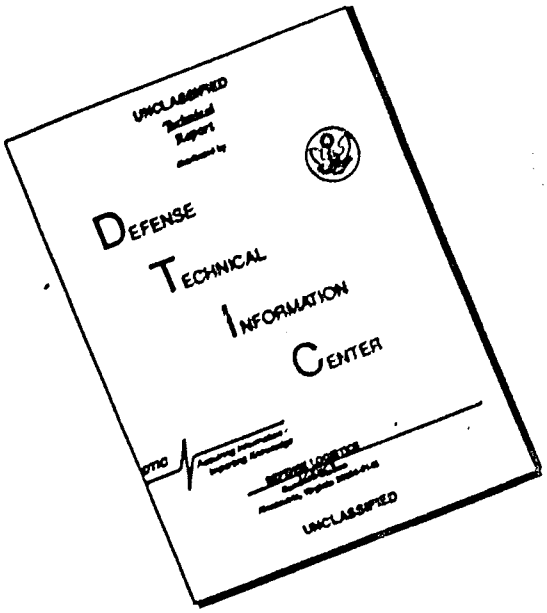

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/720

Final Report on Problem S-7.6

30 January 1945

Resistance of M1 Helmets of Varying Thicknesses and of M1 Helmets Fitted with Plastic Liners to Perforation by the Soft and Hard Types of Caliber .45 M1911 Ball Ammunition

ABSTRACT

Ballistic tests conducted upon the fronts and backs of M1 helmets of varying thicknesses showed marked increases in ballistic resistance up to thicknesses of 0.035" to 0.037" above which thickness the increase was negligible. The front of the M1 helmet has a ballistic limit approximately 5% higher than the back. The plastic liner was found to behave in a brittle manner and to have no effect upon the ballistic resistance of M1 helmets. The replacement of the liner by an equivalent weight of steel in the helmet shell resulted in a considerable increase in the ballistic efficiency.

I Authority

O.O. 421/3260, Wtn 421/454, dated 14 August 1944
O.O. 421/3395, Wtn 421/486, dated 22 November 1944
The above letters are contained in Appendix A.

II Introduction

A. Discussion

It had been determined in the Detroit Ordnance District that it was possible to reduce the depth of draw of the M1 helmet by as much as 1/4" without impairing the fit of the plastic liner into the helmet. It was suggested that the reduction in the depth of draw would result in the production of lighter weight helmets which would be thicker, nevertheless,

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than the normal M1 helmets in the zone below the top of the crown where the reduction in gage is at a maximum. In addition, it was believed that the resultant decrease in the extent of cold working would prove effective in lowering the residual stresses and thus help alleviate the age cracking problem.

Mr. E. F. Baldwin of the Detroit Ordnance District Office has developed a removable fabric suspension which can be attached by clips to a metal headband spot welded to the inside of the M1 helmet shell. This development was made with the idea of replacing the plastic liner, which weighs approximately 9½ to 10 ounces, with an equivalent weight of steel in the helmet shell for the purpose of improving the ballistic resistance. It was found that the helmet shell could be increased in thickness by approximately 0.008" (25%) and, when fitted with Mr. Baldwin's suspension, weigh no more than the present M1 helmet fitted with a plastic liner.

B. Object of Tests

1. To determine the ballistic limits of 0.043" and 0.046" thick Hadfield steel discs.

2. To determine what increase in ballistic efficiency is obtained by fabricating helmets from thicker steel stock.

3. To determine whether or not the slight changes in curvature and design resulting from the decreased depth of draw result in changes in the ballistic resistance.

4. To determine the ballistic characteristics of the plastic liner when assembled into the M1 helmet as a unit.

5. To compare the ballistic resistance of M1 helmets fitted with plastic liners to steel helmets of equivalent weight.

III Conclusions

1. When tested with the gilding metal jacketed, soft lead cored caliber .45 M1911 pistol ball ammunition, the ballistic limits of both the front and the back of the helmets increased rapidly with increasing thickness of the helmets up to 0.037", above which thickness the increase was slight.

2. When tested with the copper clad steel jacketed, hard lead cored caliber .45 M1911 pistol ball ammunition, the ballistic limits of both the front and the back of the helmets increased rapidly with increasing thickness up to 0.035", above which thickness no apparent increase occurred.

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3. The front of the helmet possesses greater ballistic resistance than the back, averaging approximately 50 ft./sec. higher against the soft projectiles and 35 ft./sec. against the hard projectiles.

4. The plastic liner for the M1 helmet behaves in a brittle manner under ballistic impact, fragments being broken off and the liner cracking even when the helmet shell itself is not penetrated by the projectile.

5. The plastic liner is completely ineffective in increasing the ballistic resistance of the M1 helmet, whereas replacing the liner by an equivalent weight of metal in the helmet shell resulted in a substantial increase in the ballistic efficiency.

6. Since no regular draw and reduced draw helmets of the same gage were submitted for proof testing, no exact conclusion regarding the effect of reduced draw upon the ballistic characteristics of the M1 helmet is possible. The ballistic tests which were conducted, however, indicate that little, if any, change in ballistic resistance results from the slight changes in curvature and design accompanying the reduced depth of draw.

7. The copper clad steel jacketed, hard lead cored caliber .45 M1911 pistol ball ammunition yielded ballistic limits from 130 to 170 ft./sec. lower than the gilding metal jacketed, soft lead projectiles when fired at helmet discs of the gages tested, and from 120 to 290 ft./sec. lower when fired at helmets.

8. The ballistic performance of materials tested with projectiles which deform upon impact is greatly influenced by the deforming characteristics of the testing projectiles. Lower ballistic limits result from the use of projectiles which are more resistant to deformation.

IV <u>Description of Material</u>

The material received for test consisted of the following items:

20 . . . Helmet discs, 0.043" thick.

20 . . . Helmet discs, 0.046" thick.

20 . . . Helmets, Steel M1, regular draw, 0.032" thick at back (station No. 8).

20 . . . Helmets, Steel M1, regular draw, 0.035" thick at back (station No. 8).

20 . . . Helmets, Steel M1, reduced draw, 0.034" thick at back (station No. 8).

20 . . . Helmets, Steel M1, reduced draw, 0.037" thick at back (station No. 8).

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20 . . . Helmets, Steel M1, reduced draw, 0.038" thick at back (station No. 8).

10 . . . Helmets, Steel M1, regular draw, 0.040" thick at back (station No. 8).

10 . . . Helmets, Steel M1, regular draw, 0.032" thick at back (station No. 8) and 0.032" to 0.035" thick at front (station No. 4).

10 . . . Plastic helmet liners.

The weights and serial numbers of the helmets and liners are contained in Appendix B.

The projectiles used consisted of two types of caliber .45 M1911 pistol ball ammunition. One lot consisted of gilding metal jacketed soft lead cores, Lot E.C. 24704X, produced by the Evansville Ordnance Plant. This lot was found to conform in chemical analysis, hardness, and ballistic characteristics to projectiles described as types Nos. 1 and 3 in Watertown Arsenal Memorandum Report No. WAL 710/351*. These soft projectiles are currently being used for the acceptance testing of helmets at the producers' plants. The second lot of projectiles consisted of copper clad steel jacketed hard lead cores similar to type No. 5 described in the above report.

The gun used was a caliber .45 Thompson sub-machine gun barrel fitted with a Springfield M1903 bolt action.

V Details of Test

A. Procedure

Ballistic limits were obtained on eight randomly selected discs of each gage (.043" and .046") using the soft projectiles against four of the discs and the hard projectiles against the remaining four. The discs were rigidly clamped to a wooden framework which provided a 14" x 7" unbacked area for ballistic testing.

The twenty helmets of each gage (.032", .034", .035", .037", and .038") were divided into two equal groups, each comprising ten helmets of each gage. One group was tested with the soft projectiles and the other with the hard projectiles. The ballistic limits of each unit of ten helmets of the same gage were obtained at both the front (station No. 4) and the back (station No. 8). The locations of the stations are

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*Watertown Arsenal 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". 4 December 1944.

illustrated in Figure 1. The stations are located along a longitudinal plane passed through the middle of the helmet, with the number 4 position lying 5½" up from the rim of the visor as measured on the surface of the helmet, and the number 8 position lying 5-1/4" up from the back of the helmet. These two positions coincide with the regions of maximum reduction in gage occurring during the deep drawing of the helmet shell. The ballistic acceptance test of the M1 helmet is always conducted at the front (station No. 4) of the helmet.

The helmets were mounted on a wooden frame for ballistic testing in such manner that the projectiles impacted the helmets normal to the tangent of the impacted surfaces, see Figure 1. The gun was mounted on a tripod at a distance of 25 feet from the target. The striking velocities were measured by means of an Aberdeen chronograph connected to screens placed 10 feet apart; the nearest one being 10 feet from the gun.

Ballistic limits were obtained at both the number 4 and 8 stations by firing at successive helmets of the same gage with varying velocities until partial and complete penetrations were obtained at velocities within 50 ft./sec. of each other. In the majority of cases at least 2 partial penetrations and 2 complete penetrations were obtained at velocities with ± 25 ft./sec. of the ballistic limit velocity.

B. Results and Discussion

A summary of the results of the ballistic tests is contained in Table 1. The results of the tests of the helmets of various gages are plotted graphically in Figures 2 and 3, and the detailed ballistic records are contained in Appendix C.

The ballistic results obtained from firing at flat helmet discs with both the soft and hard projectiles are comparable to those previously obtained upon similar material in the past* and are indicative of satisfactory quality material.

The fronts (station No. 4) of the helmets were found to be consistantly superior to the backs (station No. 8) in ballistic resistance, averaging approximately 50 ft./sec. higher against the soft projectiles and 35 ft./sec. against the hard projectiles. Unfortunately, except for one group of helmets, only the backs (station No. 8) were gaged. Examination of a relatively large amount of production data on hand at this arsenal indicate that the station No. 4 position generally averages

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*Watertown Arsenal Memorandum Report No. WAL 710/351 op. cit. also, Watertown Arsenal Memorandum Report No. WAL 710/635 "Ballistic Tests of 0.040" - 0.050" Hadfield Steel Sheet with Caliber .45 Ball Projectiles for Development of Specification Requirements." 18 May 1944.

0.001" greater in thickness than the station No. 8 position. The difference in the ballistic properties of the front and the back of the M1 helmet cannot be entirely attributed to the difference in thickness of these two zones and may in part be traceable to differences in curvature, hardness, and residual stress conditions.

Figure 4 contains photographs of the front and the back of a helmet after ballistic testing, showing the partial penetration of the front at a velocity of 842 ft./sec., whereas the back was completely penetrated at a velocity of 814 ft./sec. The extensive indenting of the helmet upon partial penetration is characteristic of the effect produced by the easily deforming gilding metal jacketed soft lead bullets. Upon complete penetration, the soft bullets generally produce large holes which result from the tearing out and folding back of large flaps of metal. The copper clad steel jacketed hard lead bullets, on the other hand, deform to a much lesser degree than the soft bullets and produce characteristically different penetrations and lower ballistic limit values, see Figure 5. Since the hard bullet deforms less, the striking energy is distributed over a smaller area while less of the bullet's kinetic energy is used in self-deformation, allowing the bullet to penetrate at lower velocities than the soft bullets. For the same reasons, the hard bullets generally produce smaller openings upon complete penetration than result from the penetration of soft bullets. Since the hard bullets produce lower ballistic limits, partial penetration by the hard bullets occur at lower striking velocities, resulting in less indentation and deformation at the region of impact.

Figure 6 contains photographs of two helmets, one .035" thick and the other 0.040" thick at the back (station No. 8). Both were impacted with gilding metal jacketed soft lead bullets. The upper photograph again indicates the superior ballistic resistance of the front of the helmet, while the lower photograph shows partial penetration of both the front and the back at relatively high velocities, demonstrating the increased ballistic resistance of thicker helmets.

The plastic helmet liner was found to behave in a brittle manner under ballistic attack and to contribute nothing to the ballistic efficiency of the M1 helmet. The upper photograph of Figure 7 shows a helmet which had been partially penetrated by a gilding metal jacketed soft lead bullet. The lower photograph of Figure 7 shows the plastic helmet liner which was fitted into the helmet during the ballistic testing. The liner was extensively cracked and a piece was knocked out, even though the helmet shell had not been penetrated by the bullet.

Figure 8 shows the inside of a liner which had been fitted into a helmet during the ballistic testing. Complete penetration of the helmet by soft projectiles resulted in the cracking and breaking of the plastic liner in the vicinity of the impacts.

The comparison between the ballistic properties of 0.032" thick M1 helmets fitted with plastic liners and steel helmets of equivalent weight is shown in Table I. The M1 helmets fitted with plastic liners were considerably thicker in the front than in the back, averaging 0.035"

at station No. 4. By comparing the ballistic properties of the M1 helmets fitted with plastic liners to those of the backs of .032" thick helmets and the fronts of 0.034" and 0.035" thick helmets it is apparent that the liner produces no change whatsoever in the ballistic resistance of the M1 helmet. Steel helmets of equivalent weight to M1 helmets fitted with liners averaged 0.040" thick at the back (station No. 8). These helmets were found to have considerably higher ballistic limits than the thinner helmets fitted with liners.

Since the plastic liner contributes nothing to the ballistic efficiency of the M1 helmet, the use of a weight of approximately 10 ounces in the form of a non-protective covering may well be questioned. It is believed that consideration should be given to the design of a helmet which has a thickness at station number 4 and 8 of not less than 0.037", and with a sturdy suspension attached to the inside of the helmet shell to seat the helmet firmly upon the head and at the same time keep the inside surface of the helmet from coming into contact with any portion of the head.

Analysis of production data covering a total of 510 helmets reveals that 46.8% of the total production has a thickness at the front (station No. 4) of 0.032" or less. Figures 2 and 3 point to the unnecessarily low ballistic efficiency of almost half the currently produced helmets. The results of this ballistic program definitely indicate the advisability of increasing the thickness of the M1 helmet.

If changes in the design and thickness of helmets are contemplated, it would probably be necessary to conduct fragmentation tests to determine the resistance of various types of helmets to penetration by odd shaped fragments of greatly varying size and velocity. Such tests could be performed by placing a group of helmets around a 20mm H.E. shell so that all helmets present identical surfaces to the fragments resulting from the detonation of the shell. Such tests must of necessity be conducted upon a statistical basis using a sufficient number of helmets and tests to yield significant results. The weight and number of fragments penetrating and being retained inside the helmets could be used to evaluate their ballistic efficiency. Similar tests of flat helmet steel and body armor components have been conducted at the Ordnance Research Center, Aberdeen.

The helmets having the normal depth of draw were 0.032" and 0.035" thick at station No. 8, whereas the reduced draw helmets were 0.034", 0.037", and 0.038" thick at station No. 8. Consequently, no exact determination could be made of the effect upon the ballistic properties of the changes in curvature and design resulting from the reduced draw. The results of the ballistic tests indicate, however, that little if any changes in ballistic behavior resulted from the changes in curvature induced by the reduced draw.

The weights of the helmets submitted for ballistic testing are contained in Appendix B, and a graph showing the relationship between the

weight and the thickness of helmets is shown in Figure 9. The effect of the reduced draw upon the weight of helmets could not be determined since the regular draw helmets were not in the finished condition, whereas the reduced draw helmets were fitted with edging, loops, and chin straps, and were painted. Figure 9 indicates that an increase of gage of 0.001" is accompanied by an increase in weight of approximately one ounce.

A. Hurlich
A. Hurlich
Assoc. Metallurgist

APPROVED:

E. L. Reed
E. L. REED
Research Metallurgist
Acting Chief, Armor Section

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TABLE I

Ballistic Tests of Helmets and Helmet Discs

Helmet Discs

Lift No.	Heat No.	Thickness inches	Cal..45 M1911 Ball Projectiles Used for Testing	Ballistic Limit ft./sec. (Average of 4 Tests)
73286	200594	.043	Gilding metal jacketed, soft lead cores	1120 ± 24
73327	210557	.046	" "	1146 ± 11
73286	200594	.043	Copper clad steel jacketed hard lead cores	949 ± 15
73327	210557	.046	" "	1013 ± 12

Helmets

Projectiles - Cal..45 M1911 Ball Ammunition, gilding metal jacketed, soft lead cores.

Thickness at Station No. 8, inches	Type of Helmet	Ballistic Limit - ft./sec. Front of Helmet (Station No. 4)	Ballistic Limit - ft./sec. Back of Helmet (Station No. 8)
.032	regular draw	836	783
.035	regular draw	911	861
.034	reduced draw	863	791
.037	reduced draw	956	943
.038	reduced draw	967	882

TABLE I (Cont'd)

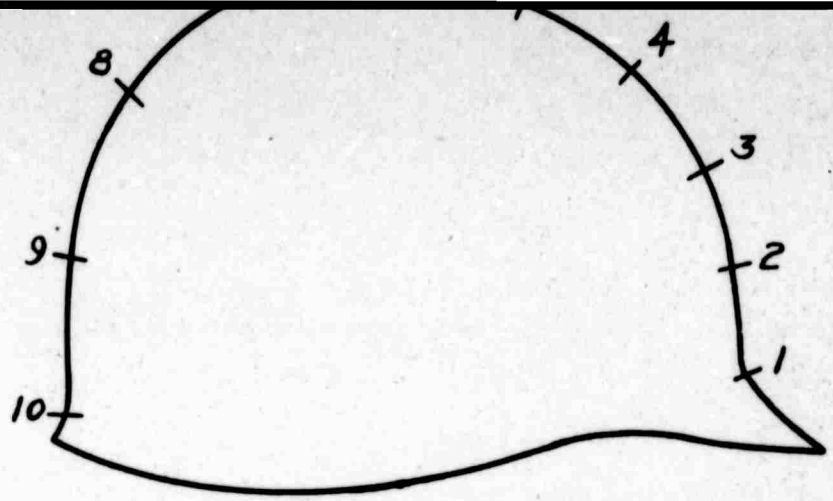
Projectiles - Cal. .45 M1911 Ball Ammunition, copper clad steel jacketed, hard lead cores.

Thickness at Station No.8, inches	Type of Helmet	Ballistic Limit - ft./sec. Front of Helmet (Station No. 4)	Back of Helmet (Station No. 8)
.032	regular draw	564	542
.035	regular draw	735	674
.034	reduced draw	700	669
.037	reduced draw	704	652
.038	reduced draw	723	707

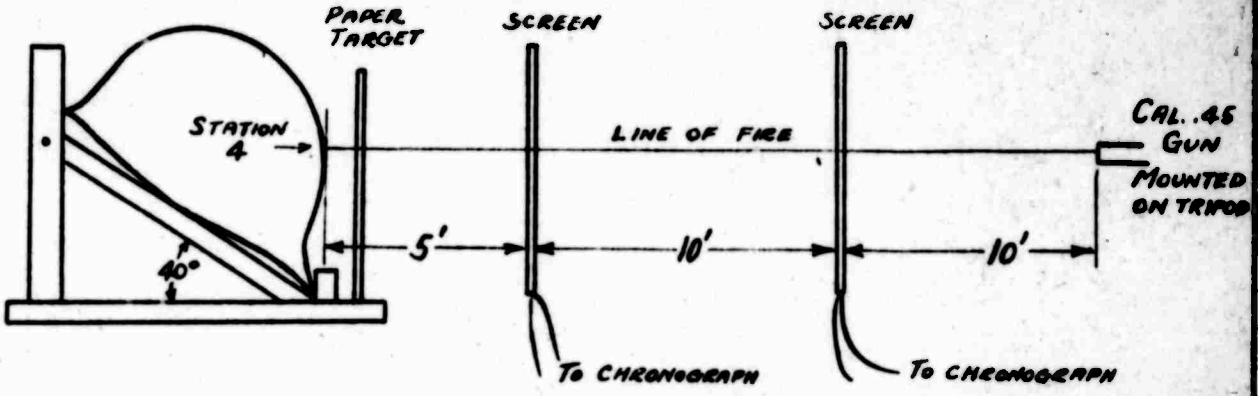
Comparison of .032" M1 Helmets plus plastic liners to .040" Helmets.

Thickness at Station No.8 inches	Type of Helmet	Cal..45 M1911 Ball Projectiles Used	Front of Helmet (Station No. 4)	Back of Helmet (Station No.8)
.040	Steel helmets	gilding metal jacketed, soft lead cores	957	918
.032	M1 helmets plus liners	" "	920*	786
.040	Steel helmets	copper clad steel jacketed hard lead cores	716	682
.032	M1 helmets plus liners	" "	621*	Not determined

*Fronts of helmets averaged .035" (station No. 4) while backs of helmets were .032" (station No. 8).



LOCATION OF STATIONS. BALLISTIC TESTS PERFORMED AGAINST STATION 4 (FRONT) AND STATION 8 (BACK).



METHOD OF TESTING HELMETS.

FIGURE 1

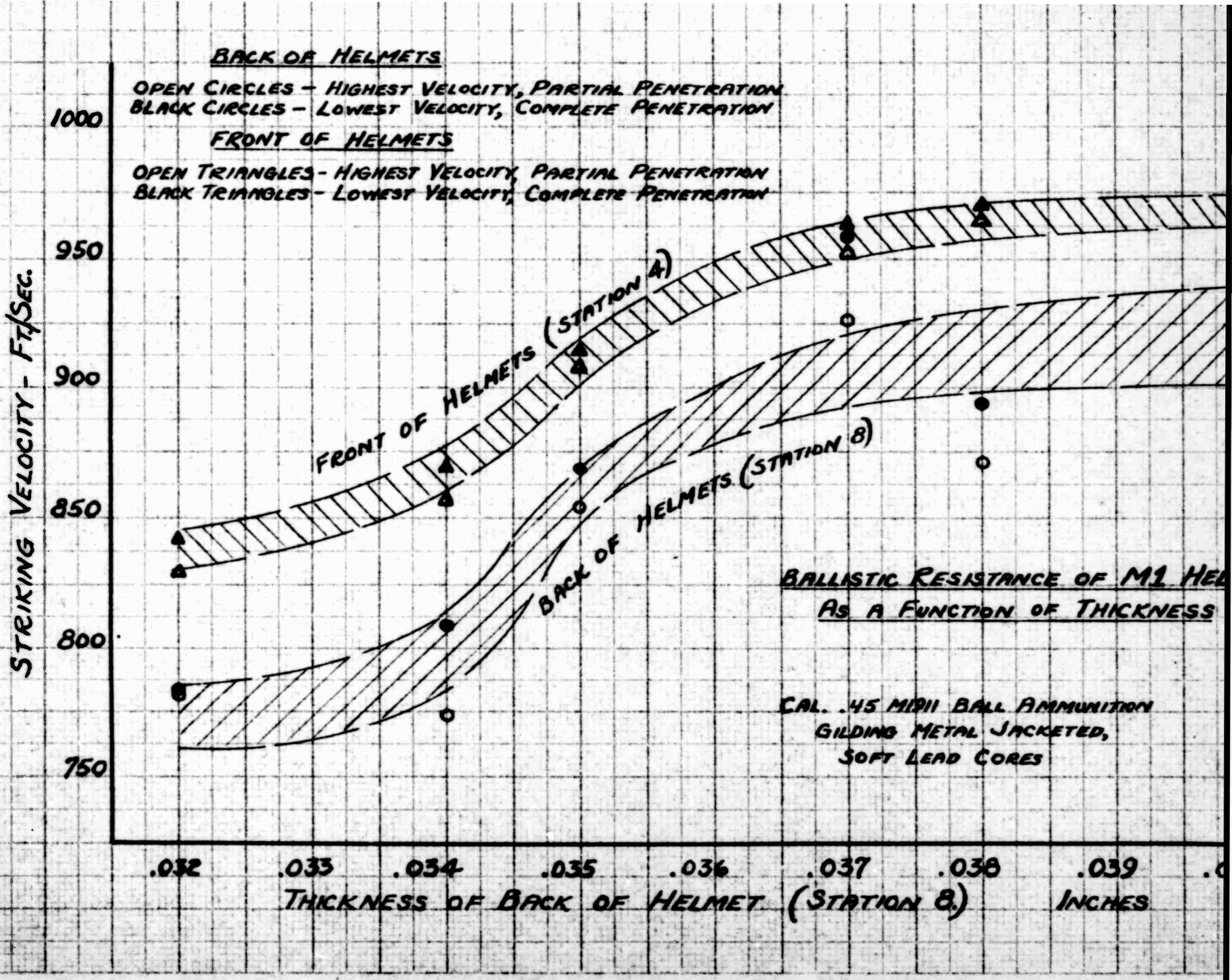

BACK OF HELMETS
OPEN CIRCLES – HIGHEST VELOCITY, PARTIAL PENETRATION
BLACK CIRCLES – LOWEST VELOCITY, COMPLETE PENETRATION
FRONT OF HELMETS
OPEN TRIANGLES – HIGHEST VELOCITY, PARTIAL PENETRATION
BLACK TRIANGLES – LOWEST VELOCITY, COMPLETE PENETRATION
FRONT OF HELMETS (STATION 4)
BACK OF HELMETS (STATION 8)
BALLISTIC RESISTANCE OF M1 HEL
AS A FUNCTION OF THICKNESS
CAL. .45 M1911 BALL AMMUNITION
GILDING METAL JACKETED,
SOFT LEAD CORES
STRIKING VELOCITY – FT/SEC.
1000
950
900
850
800
750
.032
.033
.034
.035
.036
.037
.038
.039
THICKNESS OF BACK OF HELMET (STATION 8.) INCHES

FIGURE 2.

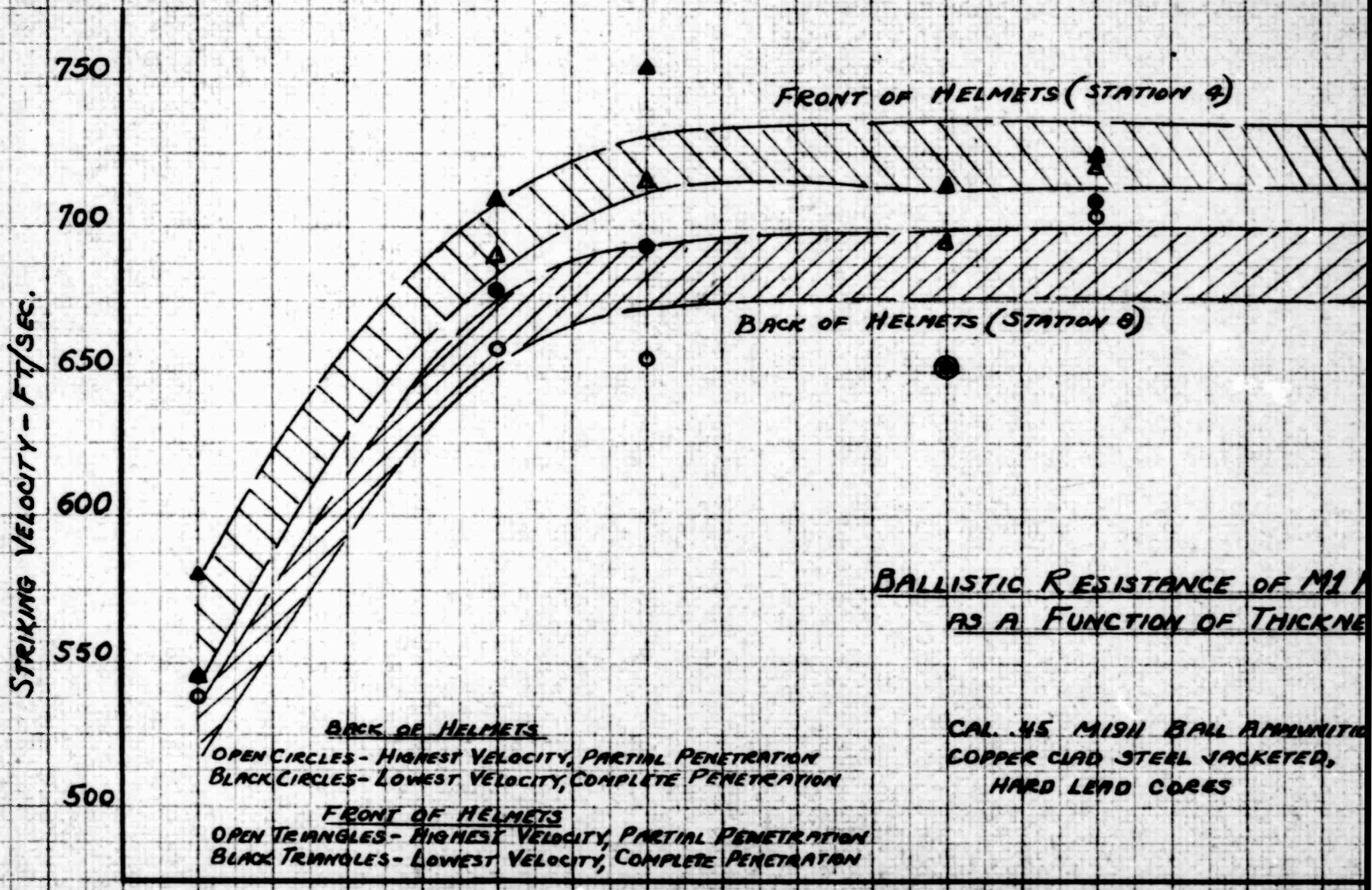
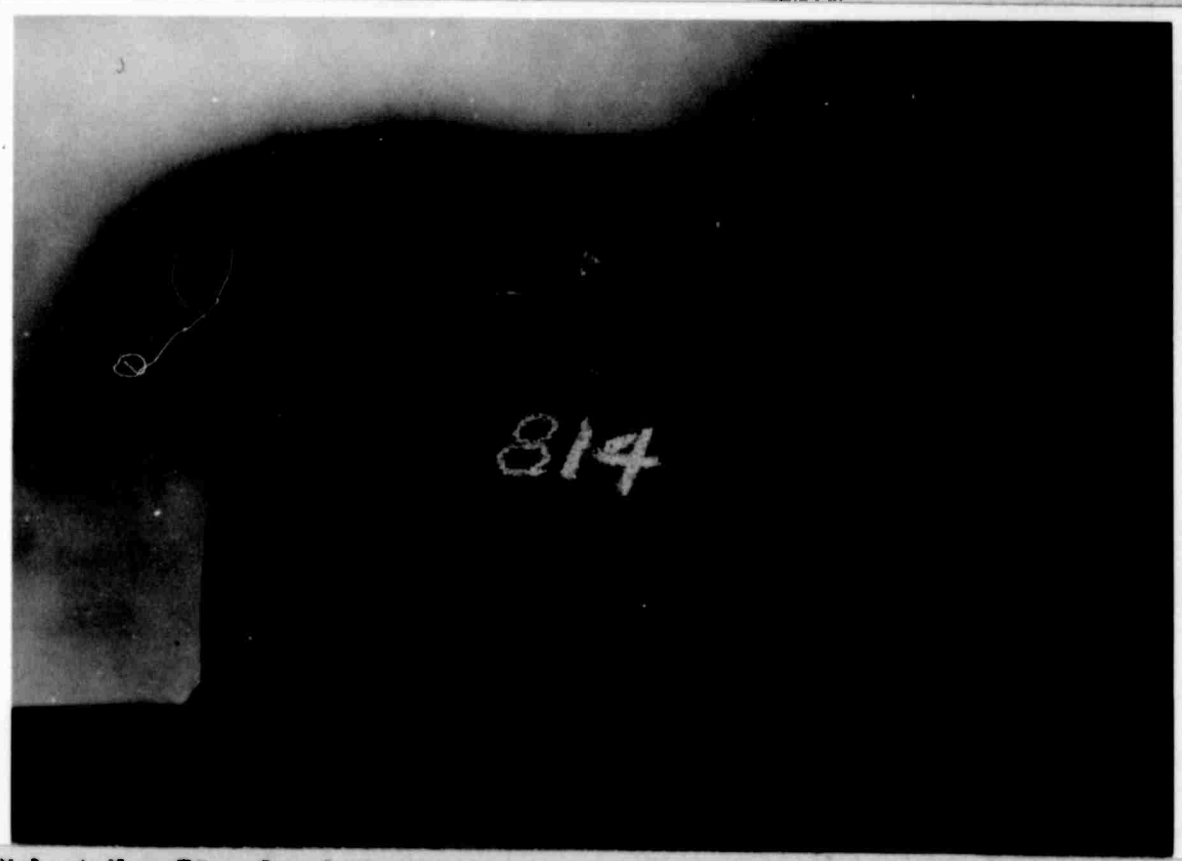

FRONT OF HELMETS (STATION 4)
BACK OF HELMETS (STATION 8)
BALLISTIC RESISTANCE OF M1
AS A FUNCTION OF THICKNE
CAL. .45 M1911 BALL AMMUNITI
COPPER CLAD STEEL JACKETED,
HARD LEAD CORES
BACK OF HELMETS
OPEN CIRCLES - HIGHEST VELOCITY, PARTIAL PENETRATION
BLACK CIRCLES - LOWEST VELOCITY, COMPLETE PENETRATION
FRONT OF HELMETS
OPEN TRIANGLES - HIGHEST VELOCITY, PARTIAL PENETRATION
BLACK TRIANGLES - LOWEST VELOCITY, COMPLETE PENETRATION
STRIKING VELOCITY - FT./SEC.
750
700
650
600
550
500
.032
.033
.034
.035
.036
.037
.038
.039
THICKNESS OF BACK OF HELMET (STATION 8) INCHES

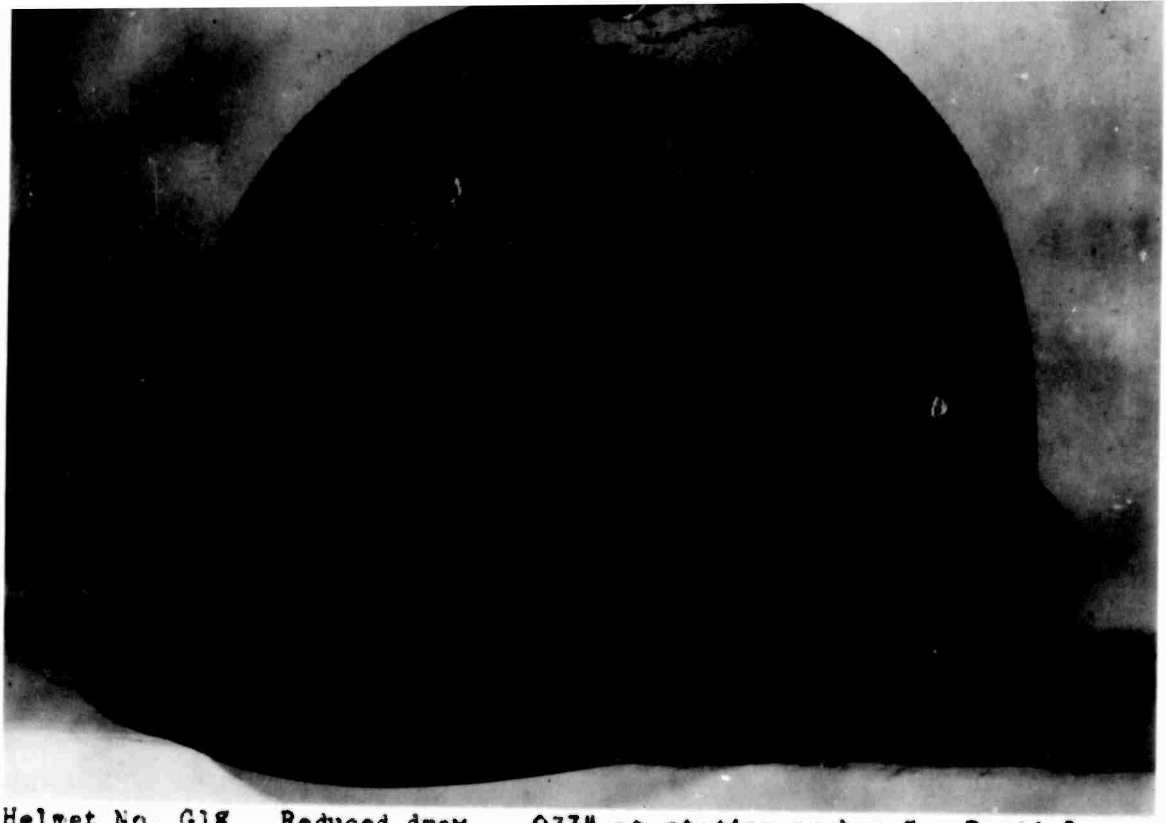
FIGURE 3.

Helmet No. F3. Reduced Draw. 0.034" at Station Number 8. Partial penetration of front (station 4) at 842 ft./sec. Gilding metal jacketed bullet. Diameter of indent - 4.1".



Helmet No. F3. Complete penetration of back (station 8) at 814 ft./sec. Gilding metal jacketed, soft lead bullet. Size of opening - 1.4 x 0.9".

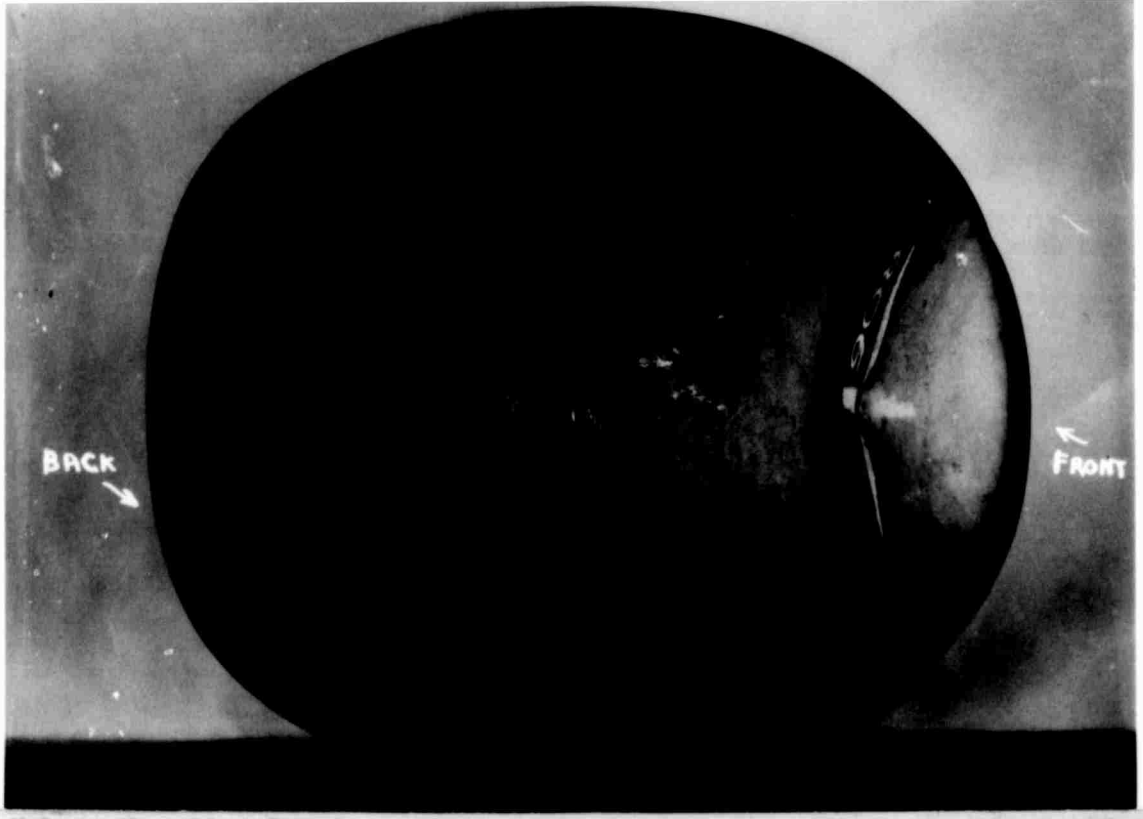
FIGURE 4



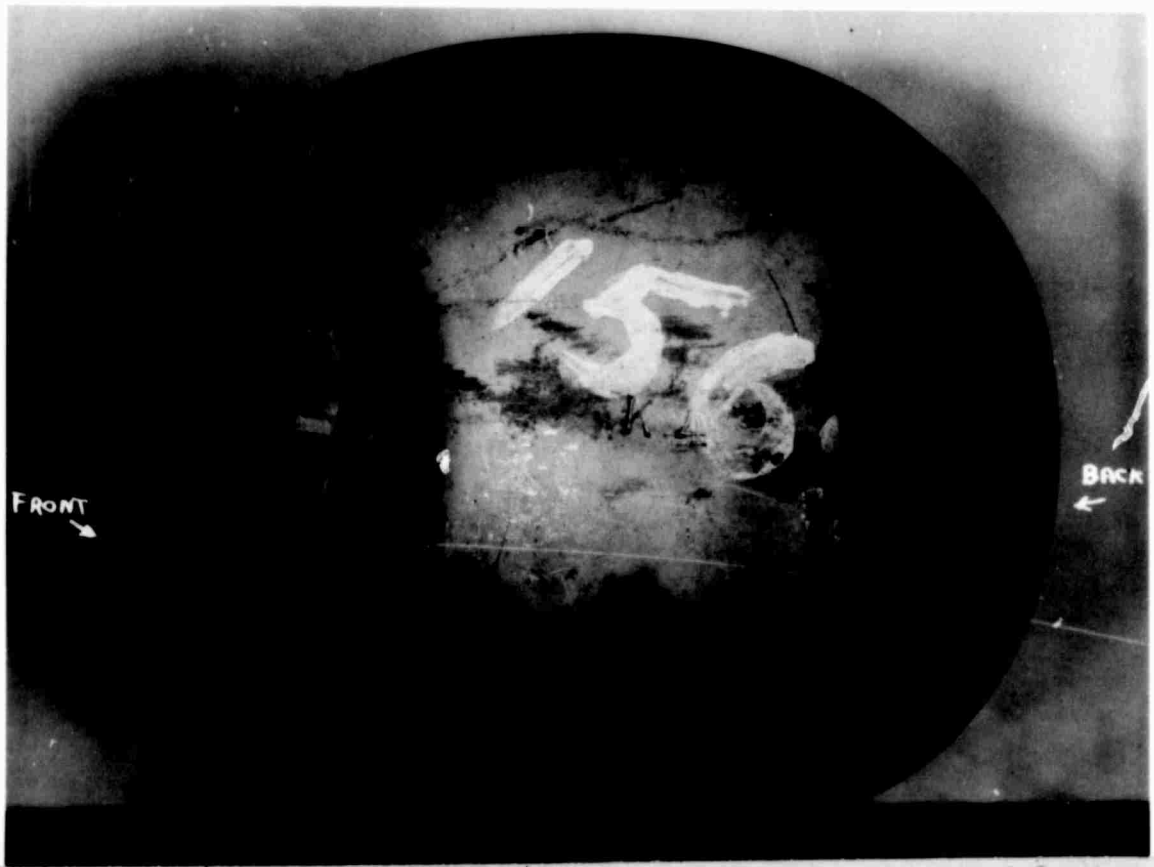
Helmet No. G18. Reduced draw. .037" at station number 8. Partial penetration of front (station 4) at 695 ft./sec. Copper clad steel jacketed, hard lead bullet. Diameter of indent - 3.7".

Helmet No. G13. Reduced draw. .037" at station number 8. Complete penetration of front (station 4) at 781 ft./sec. Copper clad steel jacketed, hard lead bullet. Size of opening - 0.70 x 0.48".

FIGURE 5

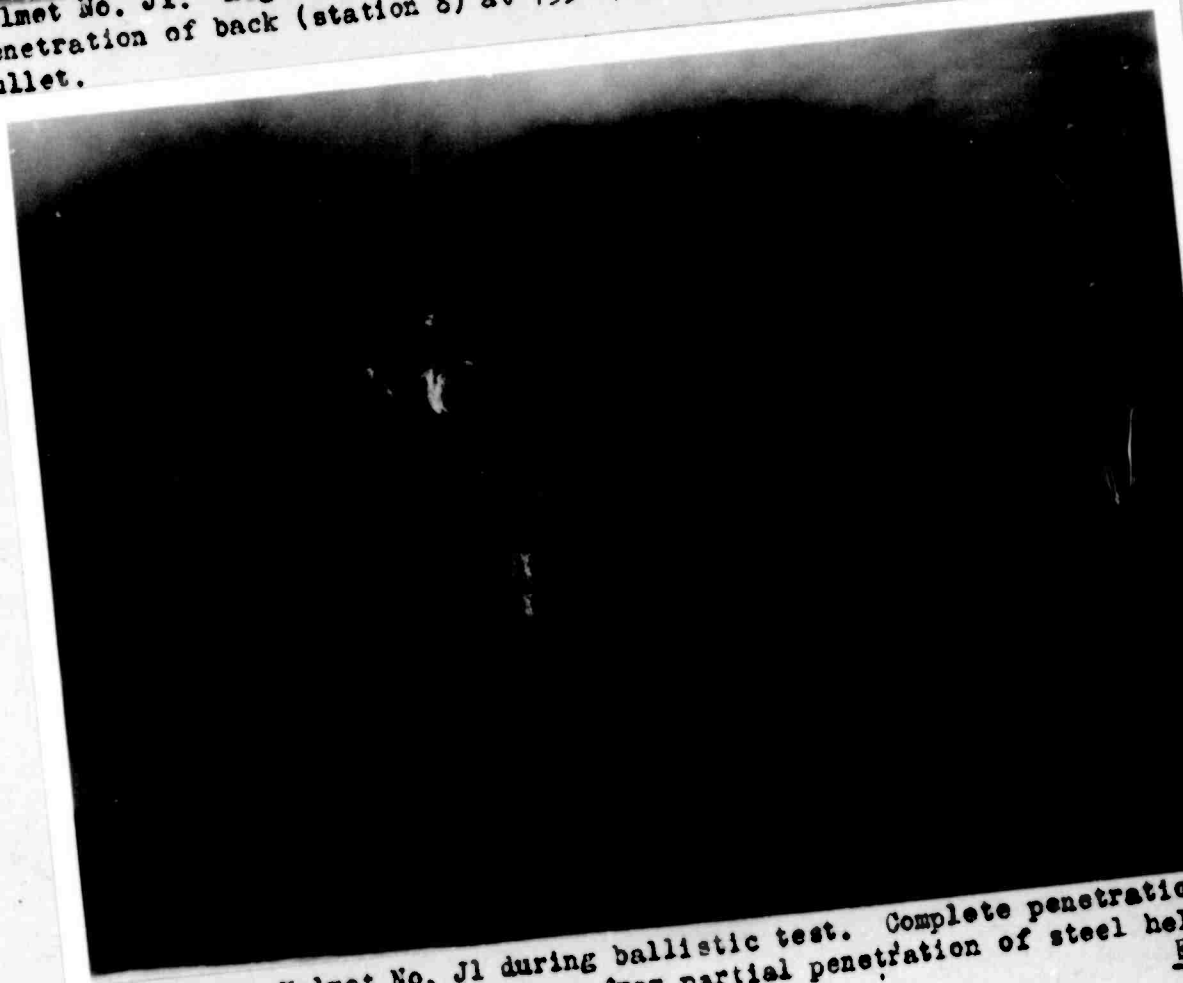


Helmet No. E9. Regular draw, .035" at station number 8. Partial penetration of front (station 4) at 908 ft./sec. Gilding metal jacketed bullet. Complete penetration of back (station 8) at 869 ft./sec.



Helmet No. K4. Regular draw, .040" at station number 8. Partial penetration of front (station 4) at 944 ft./sec. Gilding metal jacketed bullet. Partial penetration of back (station 4) at 899 ft./sec. FIG. 6

Helmet No. J1. Regular draw, .032" at station number 8. Partial penetration of back (station 8) at 755 ft./sec. Gilding metal jacketed bullet.

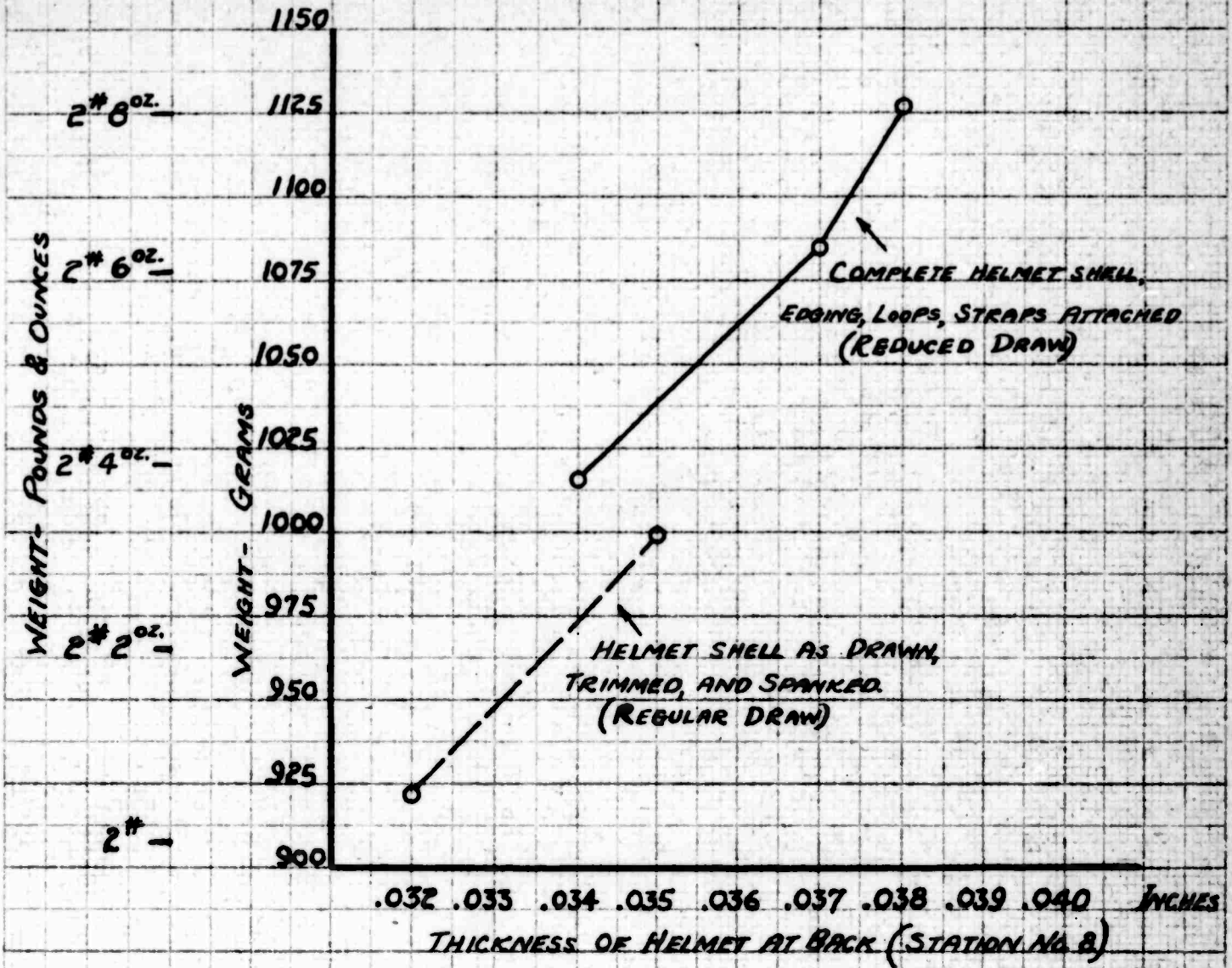


Liner inside Helmet No. J1 during ballistic test. Complete penetratio and extensive cracking resulting from partial penetration of steel hel

Mag.X2/3

Helmet No. J6. Inside view of liner in helmet after ballistic testing.
Complete penetration of front (station 4) at 963 ft./sec. Liner cracked and fragments broken away.
Complete penetration of back (station 8) at 899 ft./sec. Fragment blown out of liner.
Straps covering head were cut away to show the penetrations.
Projectiles - cal. .45 M1911 Ball, gilding metal jacketed, soft lead bullets.

FIGURE 8



RELATIONSHIP BETWEEN THICKNESS AND WEIGHT OF M1 HELMETS.

FIGURE 9.

APPENDIX A

Correspondence

Rewrite/ref
73819

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

Attn:
SPOIS

14 August 1944

Subject: Helmet, Steel M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. Attached herewith in duplicate is shipping order, SAD 4021, covering the shipment of the following helmets to your arsenal for ballistic test:

a. 50 - Helmets, Steel M1 fabricated from steel stock of .044 ± .003 with same depth of draw as current helmets.

b. 50 - Helmets, Steel M1 fabricated from steel stock of .044 ± .003 with 1/4" reduced depth of draw.

c. 50 - Helmets, Steel M1 fabricated from steel stock of .046 ± .003 with same depth of draw of current helmets.

d. 50 - Helmets, Steel M1 fabricated from steel stock of .046 ± .003 with 1/4" reduced depth of draw.

2. Each helmet is to be tagged to indicate the method of fabrication together with the depth of draw and thickness and location of the thinnest section. It is requested that your office determine the ballistic limits on these helmets in an attempt to determine which of the four groups produced the highest ballistic limits. In addition, it is requested that all helmets be fired at a minimum of one shot on the top of the crown in an attempt to determine the maximum depth of indentation without penetration. The purpose of this test is to determine:

a. Whether or not the helmets fabricated with 1/4" reduced depth of draw will give higher ballistic limits.

b. To determine what increase in ballistic efficiency is obtained by fabricating helmets from thicker steel stock.

It is understood that these helmets will be shipped to your arsenal within the next few days from the McCord Radiator & Mfg. Co. After the ballistic determinations have been made, it is requested that your office submit the results by indorsement hereon prior to the memorandum report.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

1 Incl. (in dup.) SAD 4021

Hewitt/ver
73819

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

O.O. 421/3395
Attn: SPOIS

22 November 1944

Subject: Helmet, Steel M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Attn: Major N. A. Matthews

1. Attached herewith are duplicate copies of shipping order, SAD 4241, covering shipment of 10 helmets, Steel M1 (.040 thickness weighing 48 ounces plus or minus two ounces) and 10 Helmets, Steel M1 (.032 thickness at thinnest spot with helmet liner, plastic). It is requested that ballistic limits be made on the 10 helmets weighing 48 ounces plus or minus two ounces and also that ballistic limits be determined on the 10 helmets of .032 thickness with the helmet liner plastic in place. It is requested that the point of impact be at station number 4 and station number 8 located by measuring ½" between stations from the front of the visor on a line in the longitudinal plane of the helmet.

2. On shipping order, SAD 4243, duplicate copies attached, the following material is being forwarded:

20 . . . Helmet Discs (.043 thickness)
20 . . . Helmet Discs (.046 thickness)
20 . . . Helmet Discs (.050 thickness)
20 . . . Helmets, Steel M1 (regular draw thickness .032)
20 . . . Helmets, Steel M1 (regular draw thickness .035)
20 . . . Helmets, Steel M1 (reduced draw thickness .034)
20 . . . Helmets, Steel M1 (reduced draw thickness .037)
20 . . . Helmets, Steel M1 (reduced draw thickness .038)

It is requested that ballistic limits be determined of the flat sheet stock of the thicknesses listed above as well as the ballistic limits of the helmets at the number 4 and 8 stations as described in paragraph 1. This test will supersede that requested in a letter from this office dated 14 Aug. 1944 file OO 421/3260.

3. The purpose of these ballistic determinations is to determine whether or not the slight changes in curvature and design of the helmet will increase the ballistic characteristics. It is requested that these ballistic determinations be expedited and a report be made by indorsement of the results.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

2 Incls.
SAD 4241
SAD 4243

APPENDIX B

Identification and Weights of Helmets

Weights of Helmets

Helmet Nos: D1-D20. Regular draw. 0.032" thick at back (station No. 8). In drawn, trimmed, and spanked condition. No edging and loops, unpainted.

Helmet No.	Lift No.	Carnegie-Illinois Heat No.	Weight		
			Grams	Pounds	Ounces
D1	73340	200597	915	2	1/4
D2	"	"	887	1	15-1/4
D3	"	"	910	2	1/8
D4	"	"	917	2	3/8
D5	"	"	893	1	15-5/8
D6	"	"	942	2	1-1/4
D7	"	"	906	2	--
D8	73341	"	976	2	2-3/8
D9	73340	"	928	2	7/8
D10	"	"	925	2	5/8
D11	"	"	931	2	7/8
D12	"	"	932	2	7/8
D13	"	"	908	2	1/8
D14	"	"	910	2	1/8
D15	"	"	921	2	1/2
D16	"	"	933	2	7/8
D17	"	"	936	2	1
D18	"	"	933	2	7/8
D19	"	"	922	2	1/2
D20	"	"	912	2	1/8
		Average	922 ± 13 grams	2Lbs.	1/2 ± 1/2 ounce

Helmet Nos: E1-E20. Regular draw. 0.035" thick at back (station No. 8). In drawn, trimmed, and spanked condition. No edgings and loops, unpainted.

Helmet No.	Lift No.	Carnegie-Illinois Heat No.	Weight Grams	Weight Pounds	Weight Ounces
E1	73336	210557	993	2	3
E2	"	"	999	2	3-1/4
E3	73341	200597	993	2	3
E4	"	"	1011	2	3-5/8
E5	"	"	1008	2	3-5/8
E6	"	"	1003	2	3-3/8
E7	"	"	1014	2	3-3/4
E8	73336	210557	998	2	3-1/4
E9	73341	200597	980	2	2-5/8
E10	73336	210557	997	2	3-1/8
E11	73341	200597	1032	2	4-3/8
E12	"	"	998	2	3-1/4
E13	"	"	996	2	3-1/8
E14	"	"	1000	2	3-1/4
E15	"	"	1006	2	3-1/2
E16	"	"	978	2	2-1/2
E17	73340	200597	963	2	2
E18	73341	200597	1006	2	3-1/2
E19	"	"	1013	2	3-3/4
E20	"	"	988	-	--
		Average	999 ± 10 grams	2 lbs.	3-1/4 ± 3/8 ounces

Helmet Nos: F1-F20. Reduced draw. .034" thick at back (station No. 8). Helmets in finished condition, edgings and loop attached and painted. Helmets drawn from 0.045" thick discs.

Helmet No.	McCord Corp. No.	Weight		
		Grams	Pounds	Ounces
F1	517	1003	2	3-3/8
F2	528	1023	2	4-1/8
F3	516	997	2	3-1/8
F4	485	1011	2	3-5/8
F5	510	997	2	3-1/8
F6	499	--	-	--
F7	524	1022	2	4-1/8
F8	484	1037	2	4-5/8
F9	495	1047	2	4-7/8
F10	472	1013	2	3-3/4
F11	489	1030	2	4-3/8
F12	452	1017	2	3-7/8
F13	469	998	2	3-1/4
F14	487	1023	2	4-1/8
F15	491	1023	2	4-1/8
F16	502	1018	2	3-7/8
F17	519	1006	2	3-1/2
F18	521	1045	2	4-7/8
F19	473	1003	2	3-3/8
F20	506	996	2	3-1/8
	Average	1016 ± 13 grams	2 Lbs.	3-7/8 ± 1/2 ounces

Helmet Nos: G1-G20. Reduced draw. 0.037" thick at back (station No. 8). Helmets in finished condition, edgings and loops attached and painted. Helmets drawn from 0.047" thick discs.

Helmet No.	McCord Corp. Co.	Weight		
		Grams	Pounds	Ounces
G1	954	1095	2	6-3/4
G2	992	1093	2	6-5/8
G3	934	1083	2	6-1/4
G4	1008	1128	2	7-3/4
G5	952	1106	2	7
G6	928	1103	2	7
G7	929	1111	2	7-1/4
G8	1004	1097	2	6-3/4
G9	875	1102	2	6-7/8
G10	956	1113	2	7-1/4
G11	964	1068	2	5-1/2
G12	887	1078	2	6
G13	1006	1058	2	5-1/4
G14	996	1056	2	5-1/4
G15	925	1110	2	7-1/4
G16	--	1086	2	6-1/4
G17	935	1103	2	7
G18	888	1095	2	6-3/4
G19	994	1108	2	7-1/8
G20	--	1108	2	7-1/8
		Average 1085 ± 18 grams	2Lbs.	6-1/4 ± 5/8 ounces

Helmet Nos: H1-H20. Reduced draw. .038" thick at back (station No.8). Helmets in finished condition, edgings and loop attached and painted. Helmets drawn from 0.049 - 0.050" thick discs.

Helmet No.	McCord Corp. No.	Weight		
		Grams	Pounds	Ounces
H1	—	1114	2	7-3/8
H2	1271	1128	2	7-3/4
H3	1309	1112	2	7-3/8
H4	1346	1136	2	8
H5	1377	1133	2	7-7/8
H6	1363	1149	2	8-5/8
H7	1307	1150	2	8-5/8
H8	1379	1146	2	8-1/2
H9	1338	1124	2	7-3/4
H10	1279	1131	2	7-7/8
H11	1376	1118	2	7-1/2
H12	1270	1113	2	7-3/8
H13	1339	1123	2	7-3/4
H14	1285	1106	2	7
H15	1354	1120	2	7-1/2
H16	1364	1130	2	7-3/4
H17	1353	1123	2	7-3/4
H18	1361	1135	2	8
H19	1333	1106	2	7
H20	1277	1148	2	8-5/8
		Average 1127 ± 11 grams	2 Lbs.	7-3/4 ± 3/8 ounces

Helmet Nos: J1-J10. Regular draw. .032" thick at back (station No. 8). Helmets fitted with plastic liners. Helmets trimmed and spanked. No edgings and loops attached, unpainted.

Helmet No.	Steel Source	Thickness Front (Station No. 4)	Thickness Back (Station No. 8)	Weight of Helmet Shell Grams	Weight of Liner Grams
J1	Carnegie	.035	.032	986	278
J2	"	.034	.032	931	275
J3	"	.032	.032	910	280
J4	"	.033	.032	900	281
J5	Sharon	.035	.032	960	287
J6	"	.035	.032	943	283
J7	"	.035	.032	941	280
J8	"	.035	.032	943	278
J9	"	.034	.032	927	276
J10	Carnegie	.034	.032	959	278
				Ave. 940 ± 18 grams 2 Pounds, 1-1/4 ± 5/8 ounces	280 ± 3 grams 9-7/8 ± 1/8 ounces

Helmet Nos: K1-K10: Regular draw. 0.040" thick at back (station No. 8). Edging, loops, and suspension holder attached, unpainted. Helmets drawn from 0.051 - 0.052" thick discs.

Helmet No.	McCord Corp. No.	Weight - grams
K1	1622	1243
K2	1597	1257
K3	1584	1248
K4	1565	1256
K5	1592	1249
K6	1576	1253
K7	1602	1260
K8	1520	1213
K9	1482	1248
K10	1608	1287

Ave. 1251 ± 10 grams

2 Pounds,

12-1/4 ± 3/8 ounces

APPENDIX C

Ballistic Results

Part I - Ballistic Tests of Hadfield Steel Sheet
Part II - Ballistic Tests of M1 Helmets

PART I

Ballistic Tests of Hadfield Steel Sheets

16½" Diameter Discs

Plate Nos: A1, A2, A3, A4. Lift No. 73286, Heat No. 200594, Carnegie-Illinois Steel Corp.

Thickness: 0.043"

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E. C. 24704X (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores.

Range: 25 ft.

Plate No. A1

Round No.	Striking Velocity ft./sec.	Result on Plate
1	976	PP, Medium bulge
2	1045	PP, Large bulge
3	1084	PTP, Disregard, hit 3/4" from round #2
4	1068	PP, Large bulge
5	1091	PP, Large bulge
6	1101	PP, Large bulge
7	1108	PTP, 1.7" x 1.6" opening

Ballistic Limit - 1105 ft./sec.

Plate No. A2

Round No.	Striking Velocity ft./sec.	Result on Plate
1	1038	PP, Large bulge
2	lost	PP, Large bulge
3	1076	PP, Large bulge
4	1100	PTP, 1.5" x 0.9" opening

Ballistic Limit - 1088 ft./sec.

Plate No. A3

Round No.	Striking Velocity ft./sec.	Result on Plate
1	lost	PP, Large bulge
2	1108	PP, Large bulge
3	1128	PP, Large bulge
4	1146	PTP, 1.4" x 0.7" opening

Ballistic Limit - 1137 ft./sec.

Plate No. A4

Round No.	Striking Velocity ft./sec.	Result on Plate
1	1092	PP, Large bulge
2	1120	PP, Large bulge
3	1128	PP, Large bulge
4	1146	PP, Large bulge
5	1158	PTP, 1.3" x 0.6"opening

Ballistic Limit - 1152 ft./sec.

Plates Nos: A5, A6, A7, A8. Lift No. 73286, Heat No. 200594, Carnegie-Illinois Steel Corp.

Thickness: 0.043"

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal, Copper-clad steel jacketed, hard lead cores.

Range: 25 ft.

Plate No. A5

Round No.	Striking Velocity ft./sec.	Result on Plate
1	986	PTP, 1.0"x 0.9" opening
2	864	PP, Medium bulge
3	960	PTP, 1.0"x0.9" opening
4	927	PTP, Disregard, hit 1/2" from Round 3
5	917	PP, Large bulge

Ballistic Limit - 939 ft./sec.

Plate No. A6

Round No.	Striking Velocity ft./sec.	Result on Plate
1	916	PP, Medium bulge
2	922	PP, Medium bulge
3	951	PTP, 1.2" x 1.0"opening

Ballistic Limit - 937 ft./sec.

Plate No. A7

Round No.	Striking Velocity ft./sec.	Result on Plate
1	937	PP, Medium bulge
2	942	PTP, 1.0" x 0.45"opening

Ballistic Limit - 940 ft./sec.

Plate No. A8

Round No.	Striking Velocity ft./sec.	Result on Plate
1	989	PTP, 0.5" x 0.5" opening
2	916	PP, Medium bulge
3	969	PP, Large bulge

Ballistic Limit - 979 ft./sec.

Plate Nos: B1, B2, B3, B4. Lift No. 73327, Heat No. 210557, Carnegie-Illinois Steel Corp.

Thickness: 0.046"

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E.C. 24704X (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores.

Range: 25 ft.

Plate No. B1

Round No.	Striking Velocity ft./sec.	Result on Plate
1	1093	PP, Large bulge
2	1120	PP, Large bulge
3	lost	PP, Large bulge
4	1146	PP, Large bulge
5	1178	PTP, 1.0" x 0.8" opening

Ballistic Limit - 1162 ft./sec.

Plate No. B2

Round No.	Striking Velocity ft./sec.	Result on Plate
1	1127	PP, Large bulge
2	1167	PTP, 1.2" x 1.0" opening

Ballistic Limit - 1147 ft./sec.

Plate No. B3

Round No.	Striking Velocity ft./sec.	Result on Plate
1	1145	PTP, 1.2" x 0.7" opening
2	1100	PP, Large bulge

Ballistic Limit - 1123 ft./sec.

Plate No. B4

Round No.	Striking Velocity ft./sec.	Result on Plate
1	1109	PP, Large bulge
2	1135	PP, Large bulge
3	1167	PTP, 0.8" x 0.7" opening

Ballistic Limit - 1151 ft./sec.

Plate Nos: B5, B6, B7, B8. Lift No. 73286, Heat No. 200594, Carnegie-Illinois Steel Corp.

Thickness: 0.046"

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal. Copper-clad steel jacketed, hard lead cores.

Range: 25 ft.

Plate No. B5

Round No.	Striking Velocity ft./sec.	Result on Plate
1	939	PP, Medium bulge
2	990	PP, Large bulge
3	996	PTP, 1.1" x 0.8" opening

Ballistic Limit - 993 ft./sec.

Plate No. B6

Round No.	Striking Velocity ft./sec.	Result on Plate
1	997	PP, Large bulge
2	1023	PTP, 0.9" x 0.8" opening

Ballistic Limit - 1010 ft./sec.

Plate No. B7

Round No.	Striking Velocity ft./sec.	Result on Plate
1	996	PP, Medium bulge
2	1028	PTP, 0.9" x 0.9" opening

Ballistic Limit - 1012 ft./sec.

Plate No. B8

Round No.	Striking Velocity ft./sec.	Result on Plate
1	lost	PP, Medium bulge
2	1030	PP, Medium bulge
3	1034	PTP, 1.0" x 0.6" opening

Ballistic Limit - 1038 ft./sec.

PART II

Ballistic Tests of M1 Helmets

Helmet Nos: D1 to D10. Lift No. 73340, Heat No. 200597, Carnegie-Illinois Steel Corp. Regular draw. 0.032" thick at back (station No. 8).

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E.C. 24704X (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores.

Range: 25 ft.

Helmet No.	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
D1	1013	PTP, 1.3"x0.9"opening	lost	PP, diam.of indent-3.9"
D2	912	PTP, 1.5"x1.2"opening	783*	PTP,1.2"x1.0"opening
D3	856*	PTP, 1.4"x1.0"opening	752	PP,diam.of indent-4.5"
D4	754	PP, diam.of indent-4.4"	782*	PP,diam.of indent-4.1"
D5	859*	PTP,1.05"x0.95"opening	801*	PTP,1.4"x1.0"opening
D6	828*	PP, diam.of indent-4.4"	765*	PP, diam.of indent-4.0"
D7	842*	PTP, 1.3"x1.15"opening		
D8	830*	PP, diam.of indent-4.3"		

Ballistic Limit - 836 ft./sec. Front of Helmet

Ballistic Limit - 783 ft./sec. Back of Helmet

*Impacts at velocities within ± 25 ft./sec. of ballistic limits.

Helmet Nos: D11 to D20. Lift No. 73340, Heat No. 200597, Carnegie-Illinois Steel Corp. Regular draw. 0.032" thick at back (station No. 8).

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal, Copper-clad steel jacketed, hard lead cores.

Range: 25 ft.

Helmet No.	Front of Helmet (Station No. 4) Striking Velocity ft./sec.	Front of Helmet (Station No. 4) Result on Helmet	Back of Helmet (Station No. 8) Striking Velocity ft./sec.	Back of Helmet (Station No. 8) Result on Helmet
D11	609	PTP, 1.0"x0.5"opening	538*	PP, diam. of indent-3.4"
D12	546*	PP, 1.2"x0.5"opening	545*	PTP, 1.0"x0.5"opening
D13	604	PTP, 1.0"x0.7"opening		
D14	581*	PTP, 1.0"x0.6"opening		
D15	541*	PP, diam. of indent-3.6"		
D16	541*	PP, diam. of indent-3.7"		
D17			lost	PP, diam. of indent-3.7"
D18			535*	PP, diam. of indent-3.6"
D19			625	PTP, 1.0"x0.5"opening
D20			521*	PP, diam. of indent-3.5"

Ballistic Limit - 564 ft./sec. Front of Helmet

Ballistic Limit - 542 ft./sec. Back of Helmet

Helmet Nos: E1 to E10. Lift Nos. 73336 and 73341. Heat Nos. 210557 and 200597. Carnegie-Illinois Steel Corp. Regular draw. 0.035" thick at back (station No. 8).

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E.C.24704X (Evansville Ordnance Plant) gilding metal jackets, soft lead cores.

Range: 25 ft.

Helmet No.	Front of Helmet (Station No. 4) Striking Velocity ft./sec.	Front of Helmet (Station No. 4) Result on Helmet	Back of Helmet (Station No. 8) Striking Velocity ft./sec.	Back of Helmet (Station No. 8) Result on Helmet
E1	880	PP, Disregard, 1¼" low	832	PP, diam. of indent-4.1"
E2	893*	PP, diam. of indent-4.4"	902	PTP, 1.4"x1.4" opening
E3	951	PTP, 1.4"x1.15" opening	lost	PP, diam. of indent-4.4"
E4	914*	PTP, 1.4"x1.1" opening	882**	PP, diam. of indent-4.2"
E5	889*	PP, diam. of indent-4.4"	887	PTP, 1.5"x1.3" opening
E6	888*	PP, diam. of indent-4.4"	898	PTP, 1.4"x1.0" opening
E7	lost	PP, diam. of indent-4.4"	854*	PP, diam. of indent-4.3"
E8	908*	PP, diam. of indent-4.6"	868*	PTP, 1.3"x1.2" opening
E9	908*	PP, diam. of indent-4.7"	869*	PTP, 1.2"x1.15" opening
E10	935*	PTP, 1.25"x1.10" opening	842*	PP, diam. of indent-4.2"

Ballistic Limit - 911 ft./sec. Front of Helmet

Ballistic Limit - 861 ft./sec. Back of Helmet

**Disregarded because complete penetrations occurred at 14 and 13 ft./sec. lower.

Helmet Nos: E11 - E20. Lift Nos. 73335 and 73341, Heat Nos. 210557 and 200597, Carnegie-Illinois Steel Corp. Regular Draw. 0.035" thick at back (station No. 8).

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition, Frankford Arsenal. Copper-clad steel jacketed, hard lead cores.

Range: 25 feet

Helmet No.	Front of Helmet (Station No. 4) Striking Velocity ft./sec.	Result on Helmet	Back of Helmet (Station No. 8) Striking Velocity ft./sec.	Result on Helmet
E11	772	PTP, 1.0"x0.9" opening	655*	PP, diam. of indent-3.5"
E12	658	PP, diam. of indent-3.6"	796	PTP, 1.1"x0.7" opening
E13	769	PTP, 0.90"x.70" opening	723	PTP, 1.0"x0.6" opening
E14	754*	PTP, 1.0x0.7" opening	649*	PP, diam. of indent-3.5"
E15	667	PP, diam. of indent-3.7"	754	PTP, 1.4"x0.7" opening
E16	716*	PP, diam. of indent-4.0"	717	PTP, 1.1"x0.7"opening
E17	--	----	693*	PTP, 1.9"x0.5" opening

Ballistic Limit - 735 ft./sec. Front of Helmet

Ballistic Limit - 674 ft./sec. Back of Helmet

Helmet Nos: F1 - F10. Reduced draw. 0.034" thick at back (station No. 8). Helmets in finished condition, edging and loops attached and painted.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition, Lot E.C. 24704X (Evansville Ordnance Plant) gilding metal jackets, soft lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
F1	851*	PP, diam. of indent-4.6"	--	----
F2	868*	PTP, 1.4"x1.0" opening	809*	PTP, 1.3"x1.0"opening
F3	842*	PP, diam. of indent-4.1"	814*	PTP, 1.4"x0.9" opening
F4	847*	PP, diam. of indent-4.4"	877	PTP, 1.3"x1.05" opening
F5	832	PP, diam. of indent-4.5"	825	PTP, 1.05"x0.9" opening
F6	838	PP, diam. of indent-4.2"	767*	PP, diam. of indent-4.0"
F7	857*	PP, diam. of indent-4.4"	773*	PP, diam. of indent-4.3"
F8	902**	PP, diam. of indent-4.5"	lost	PTP, 1.5"x1.2" opening
F9	915	PTP, 1.1"x0.75" opening	814*	PTP, 1.2"x1.1" opening
F10	880*	PTP, 1.0"x1.0" opening	859	PTP, 1.1"x0.9" opening
	Ballistic Limit - 863 ft./sec. Front of Helmet		Ballistic Limit - 791 ft./sec. Back of Helmet	

** Disregarded because complete penetrations occurred at 22 and 34 ft./sec. lower velocities.

Helmet Nos: F11 - F20. Reduced draw. 0.034" thick at back (station No. 8). Helmets in finished condition edgings and loops attached and painted.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal. Copper-clad steel jacketed, hard lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
F11	lost	PTP, 0.6"x0.5" opening	635	PP, diam. of indent-4.7"
F12	604	PP, diam. of indent-3.8"	616	PP, diam. of indent-3.7"
F13	614	PP, diam. of indent-3.8"	706	PTP, 0.9"x0.7" opening
F14	709*	PTP, 0.75"x0.5" opening	679*	PTP, 1.20"x0.7" opening
F15	691*	PP, diam. of indent-3.9"	658*	PP, diam. of indent-3.8"
F16	638	PP, diam. of indent-3.75"		
	Ballistic Limit - 700 ft./sec. Front of Helmet		Ballistic Limit - 669 ft./sec. Back of Helmet	

Helmet Nos: G1 - G10. Reduced draw. 0.037" thick at back (station No. 8). Helmets in finished condition, edgings and loop attached and painted.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E. C. 24704X (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
G1	944*	PP, diam. of indent-4.5"	908	PP, diam. of indent-4.25"
G2	951*	PP, diam. of indent-4.5"	958*	PTP, 1.3"x1.0" opening
G3	961*	PTP, 1.35"x1.25" opening	lost	PTP, 1.2"x1.1" opening
G4	952*	PP, diam. of indent-4.5"	927*	PP, diam. of indent-4.2"
G5	lost	PTP, 1.3"x1.2" opening	904	PP, diam. of indent-4.3"
G6	963*	PTP, 1.4"x1.2" opening	883**	PTP, 1.3"x1.3" opening
G7	951	PP, diam. of indent-4.4"	965*	PTP, 1.4"x1.0" opening
G8			905	PP, diam. of indent-4.3"
G9			904	PP, diam. of indent-4.3"
	Ballistic Limit - 956 ft./sec. Front of Helmet		Ballistic Limit - 943 ft./sec. Back of Helmet	

**Disregarded because partial penetrations occurred at 44, 22, and 21 ft./sec. higher velocities.

Helmet Nos: G11 - G20. Reduced draw. 0.037" thick at back (station No. 8). Helmets in finished condition, edgings and loops attached and painted.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal. Copper-clad steel jacketed, hard lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
G11	909	PTP, 0.83"x0.47" opening	673**	PP, diam. of indent-3.7"
G12	822	PTP, 0.65"x0.50" opening	685	PTP, 1.0"x0.6" opening
G13	781	PTP, 0.70"x0.48" opening	703	PTP, 0.85"x0.52" opening
G14	lost	PTP, 0.80"x0.45" opening	716	PTP, 0.62"x0.47" opening
G15	lost	PTP, 1.4"x0.5" opening	652*	PP, diam. of indent-3.5"
G16	713*	PTP, 1.2"x0.5" opening	652*	PTP, 1.4"x0.50" opening
G17	693*	PP, diam. of indent-3.7"	643*	PP, diam. of indent-3.5"
G18	695*	PP, diam. of indent-3.7"	--	----
	Ballistic Limit - 705 ft./sec. Front of Helmet		Ballistic Limit - 652 ft./sec. Back of Helmet	

**Disregarded because complete penetration occurred at 21 ft./sec. lower velocity.

Helmet Nos: H1 - H10. Reduced draw. 0.038" thick at back (station No. 8). Helmets in finished condition, edging and loops attached and painted.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E.C. 24704X (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
H1	969*	PTP, 1.6"x1.2" opening	939**	PP, diam. of indent-4.3"
H2	960*	PP, diam. of indent-4.4"	963	PTP, 1.3"x1.05" opening
H3	965*	PP, diam. of indent-4.4"	950	PTP, 1.3"x0.9" opening
H4	991*	PTP, 1.1"x1.1" opening	899	PTP, 1.3"x1.0" opening
H5	lost	PP, diam. of indent-4.2"	893	PTP, 1.3"x1.2" opening
H6	942*	PP, diam. of indent-4.3"	919	PTP, 1.3"x1.0" opening
H7	996	PTP, 1.35"x1.25" opening	871	PP, diam. of indent-4.1"
H8			930	PTP, 1.2"x1.1" opening
H9			909	PTP, 1.1"x1.05" opening
H10			862	PP, diam. of indent-4.1"
	Ballistic Limit - 967 ft./sec. Front of Helmet		Ballistic Limit - 882 ft./sec. Back of Helmet	

**Disregarded because complete penetrations occurred at velocities of 46, 40, and 20 ft./sec. lower velocities.

Helmet Nos: H11 - H20. Reduced draw. 0.038" thick at back (station No. 8). Helmets in finished condition, edging and loops attached and painted.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal. Copper-clad steel jacketed, hard lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
H11	722*	PP, diam of indent-3.7"	735	PTP, 1.0"x0.8" opening
H12	808	PTP, 1.1"x0.9" opening	705*	PP, diam. of indent-3.6"
H13	754**	PP, diam. of indent-3.85"	781	PTP, 0.75"x0.72" opening
H14	735*	PTP, 0.7"x0.5" opening	709*	PTP, 1.0"x0.5" opening
H15	lost	PTP, 1.5"x0.6" opening	721*	PTP, 0.7"x0.5" opening
H16	745*	PTP, 1.4"x0.7" opening	694*	PP, diam. of indent-3.5"
H17	643	PP, diam. of indent-3.5"		
H18	lost	PP, disregarded		
H19	723*	PTP, 1.4"x0.5" opening		
H20	735*	PTP, 0.95"x0.6" opening		
	Ballistic Limit - 723 ft./sec. Front of Helmet		Ballistic Limit - 707 ft./sec. Back of Helmet	

** Disregarded because complete penetration occurred at 31, and 19 ft./sec. lower velocities.

Helmet Nos: J1 - J10. Regular draw. 0.032" thick at back (station No. 8). 0.035" thick at front (station No. 4). Helmets fitted with plastic helmet liners.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E.C. 247044 (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores and Frankford Arsenal, copper-clad steel jacketed, hard lead cores.

Range: 25 feet.

Helmet No. (Soft Lead Bullets)	Front of Helmet (Station No. 4) Striking Velocity ft./sec.	Result on Helmet
J1	862	PP. diam. of indent-4.1"
J5	916*	PP. diam. of indent-4.3"
J6	963	PTP. 1.6"x1.3" opening
J7	924*	PTP. 1.0"x0.95" opening

Ballistic Limit - 920 ft./sec.
Front of Helmet

(Copper-clad steel-jacketed hard lead bullets)

J2	643*	PTP. 1.0"x0.5" opening
J8	723	PTP. 1.4"x0.5" opening
J9	525	PP. diam. of indent-3.1"
J10	599*	PP. diam. of indent-3.3"

Ballistic Limit - 621 ft./sec
Front of Helmet

Helmet No. (Soft Lead Bullets)	Back of Helmet (Station No. 8) Striking Velocity ft./sec.	Result on Helmet
J1	755	PP. diam. of indent-4.0"
J2	765*	PP. diam. of indent-3.9"
J5	942	PTP. 1.4"x0.7" opening
J6	899	PTP. 0.5"x0.48" opening
J7	887	PTP. 1.3" x0.8" opening
J8	lost	PTP. 0.95"x0.5" opening
J9	851	PTP. 0.95"x0.80" opening
J10	807*	PTP. 1.2"x0.6" opening

Ballistic Limit - 786 ft./sec.
Back of Helmet

Helmet Nos: K1 - K5. Regular draw. 0.040" thick at back (station No. 8). Produced from sheets 0.051" - 0.052" thick.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Lot E.C. 27404X (Evansville Ordnance Plant) gilding metal jacketed, soft lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
K1	999	PTP, 1.8"x1.3" opening	937*	PTP, 1.8"x1.35" opening
K2	969*	PTP, 1.3"x1.0" opening	832	PP, diam. of indent-3.8"
K3	933*	PP, diam. of indent-4.1"	851	PP, diam. of indent-3.9"
K4	944*	PP, diam. of indent-4.1"	899*	PP, diam. of indent-4.0"
K5			897*	PP, diam. of indent-3.9"
	Ballistic Limit - 957 ft./sec. Front of Helmet		Ballistic Limit - 918 ft./sec. Back of Helmet	

Helmet Nos: K6 - K10. Regular draw. 0.040" thick at back (station No. 8). Produced from sheets 0.051" - 0.052" thick.

Projectiles: Caliber .45 M1911 Pistol Ball Ammunition. Frankford Arsenal. Copper-clad steel jacketed, hard lead cores.

Range: 25 feet.

	Front of Helmet (Station No. 4)		Back of Helmet (Station No. 8)	
Helmet No.	Striking Velocity ft./sec.	Result on Helmet	Striking Velocity ft./sec.	Result on Helmet
K6	818	PTP, 1.0"x0.9" opening	638	PP, diam. of indent-3.3"
K7	726*	PTP, 1.1"x0.7" opening	673*	PP, diam. of indent-3.4"
K8	673	PP, diam. of indent-3.5"	lost	PP, diam. of indent-3.3"
K9	705*	PP, diam. of indent-3.5"	755	PTP, 1.2"x0.7" opening
K10			691*	PTP, 1.2"x0.7" opening
	Ballistic Limit - 716 ft./sec. Front of Helmet		Ballistic Limit - 682 ft./sec. Back of Helmet	