WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/727

Statistical Basis for Revision of a Ballistic Specification for Acceptance of Helmet Steel

BY

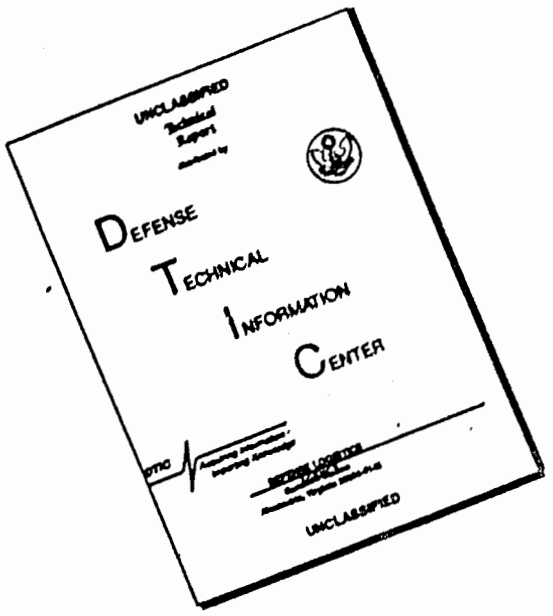
J. F. Sullivan
Asst. Engineer

A. Hurlich
Assoc. Metallurgist

DATE 3 March 1945

WATERTOWN ARSENAL
WATERTOWN, MASS.

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

[redacted]

RESTRICTED

UNCLASSIFIED

WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/727

Partial Report on Problem B-7.3

3 March 1945

Statistical Basis for Revision of a Ballistic Specification for Acceptance of Helmet Steel

1. When U. S. Army Tentative Specification AXS-1170 was originally set up[1] comparatively few ballistic tests of non-magnetic steel of the thickness to be procured had been made. Moreover, the majority of these tests had been made with a soft lead (copper jacketed) cal. .45 bullet which at that time was considered an adequate criterion of service attack.

2. Since that time the caliber .45 M1911 projectile has been modified by the replacement of the gilding metal jacket by copper clad steel and the addition of hardening alloys to the lead core, resulting in a projectile of greater resistance to deformation and, thus, greater penetrative power. Because of the decreased availability of the softer projectiles and in view of the fact that the harder projectiles represented a more realistic simulation of the types of missiles, helmets and body armor are expected to afford protection against, it was recommended[2,3,4] that the harder bullets be used for acceptance testing of steel procured for helmets and body armor. Consequently when steel has been submitted for procurement under Specification AXS-1170, the ballistic requirements of Specification AXS-1346 (as originally established)[5], which stipulates the use of the hard lead (copper-clad-steel jacketed) bullets, have been substituted for those of AXS-1170.

---

1. Ordnance Dept. U. S. Army. Tentative Specification AXS-1170, 10 Jan. 1944. "Steel, Non-Magnetic: Sheet and Strip (for Body Armor)".
2. WAL 710/635, 18 May 1944.
3. Wtn. 400.112/3203, 11 October 1944.
4. Wtn. 471.2/4568, 12 October 1944.
5. Ordnance Dept. U. S. Army. Tentative Specification AXS-1346, 4 August 1944. "Armor; Fragment-Resistant; Plate or Sheet". Table II, Column 3.

[redacted]

3. Inasmuch as these requirements were established on the basis of the rather sparse data which were available at the time of specification, it should not be surprising that they did not accurately forecast the trend of actual production results.

4. Sufficient (approximately 800) results of acceptance testing with the hard bullet have now become available, it is believed, to warrant a valid appraisal with a view toward revising the current prerequisites to the acceptance of Hadfield manganese steel for helmets and body armor. Accordingly, these results have been reviewed and on the basis of a statistical analysis of them new ballistic specification requirements are proposed herewith.

5. The average resistance of plates of each thickness has been determined and these values have been plotted as circles in Figure 1 (the numbers beside the circles are indicative of the number of values included in the determination of the averages). These values follow a linear-to-curvilinear path which is undoubtedly attributable to an inevitable change in the mechanism of penetration as the thickness of the test sheets and the velocity of the projectiles simultaneously increase. The apparent path of these values has been drawn as a solid line in Figure 1.

6. Since the frequency distribution of the entire population of material of a given thickness cannot very accurately be estimated from the frequency distribution of even a fairly large number of individual values selected from the population, but the frequency distribution of averages of groups of four (or more) samples from a given parent distribution can be fairly accurately estimated from the frequency distribution of averages of groups of four (or more, respectively) samples selected at random from such a parent distribution, the data available concerning the ballistic limits for any given thickness (except where the total number of tests fell below 100) were randomly sampled in groups of four and the average and range (the difference between the highest and lowest value in a group) for each group determined. From the average of such averages and ranges certain limits were estimated within which it can be predicted with reasonable certainty that averages of subsequent groups of four samples selected at random from products of a process with the same degree of control and with the same level of high quality will fall. These limits have been indicated in Figure 1 as dotted lines equidistantly above and below the central trend line.

7. Inasmuch as it has been demonstrated that material of such a high level of quality can be produced with consistency, it is not considered unreasonable to require material submitted in the future to duplicate such performance. With this premise in mind, therefore, the following requirements are proposed:

a. From each lot submitted for acceptance, four ballistic test samples (16½" diameter circles in the case of helmet steel and 12" squares in the case of body armor steel) shall be selected at random. (It is preferred that all four samples selected be of the same thickness, but if the randomness of selection would be jeopardized by so doing, samples of different gage may be taken).

b. The first round fired at each sample should be loaded with a charge calculated to produce a striking velocity approximately 20 feet-per-second in excess of the requirement stipulated in Table I. (This 20 foot differential should insure a striking velocity in excess of the requirement). The velocity of subsequent rounds (if necessary) will be governed by the results of the first round.

c. If the first rounds fired against all four plates result in partial penetrations at velocities above the requirements of Table I, the lot shall be accepted.

d. If the first rounds fired against all four plates result in partial penetrations, but if one or more rounds result in a velocity below the requirements of Table I, firing will be continued on those plates on which a below requirement velocity was obtained until either (1) a partial penetration at a velocity above the requirement is obtained, or (2) a complete penetration at a velocity below the requirement is obtained.

e. If, as a result of the procedure set out in paragraph 7-d, a partial penetration at a velocity above the requirement is obtained on each of the four plates, the lot shall be accepted.

f. If, however, as a result of the procedure set out either in paragraph 7-b or in paragraph 7-d, a complete penetration at a velocity below the requirement is obtained, firing shall continue until the ballistic limit of each of the four samples in the group has been determined.

g. From these ballistic limits the ballistic excess (the difference between the ballistic limit and the requirement) for each sample shall be determined. (If the ballistic limit is lower than the requirement the excess will have a minus value).

h. The average ballistic excess of the group of four samples shall then be determined. If the average has a positive value the lot shall be accepted. If the average has a negative value the lot shall be liable to rejection, subject to a retest of four additional samples selected at random from within the lot.

i. If the procedure of paragraph 7-h calls for the retest of additional samples the ballistic limit and the ballistic excess of each retest sample shall be determined. If the average ballistic excess of the eight samples (four primary samples and four retest samples) has a positive value, the lot shall be accepted. If, however, this average has a negative value the lot shall be rejected.

8. For the purposes of this test and to avoid ambiguity the following definitions are proposed:

a. Complete penetration. Any fair impact of the projectile against the plate which produces a hole in the plate through which light may pass; or, if the projectile remains in the plate, any fair impact which produces a hole in the plate through which the projectile may be seen from the rear of the plate.

b. Partial penetration. Any fair impact of the projectile against the plate which is not a complete penetration.

c. Ballistic limit. The average of two velocities, one of which is the highest giving a partial penetration and the other the lowest giving a complete penetration. The difference between these two velocities shall be not more than 50 feet-per-second and the velocity for the highest partial penetration shall be less than the velocity for the lowest complete penetration.

9. It is considered that incorporation of the foregoing suggestions into any proposed revision of Specification AXS-1170 will assure the acceptance of a greater amount of good quality steel and the rejection of a greater amount of poor quality steel than is assured under the current procedure. The suggestions also provide for a reduction in the number of rounds necessary to be fired to determine the ballistic acceptance status of a lot of steel.

APPRECIATION

10. The authors wish to express their appreciation of the aid given by Mary S. Fitzgerald of this laboratory in compiling the data and computing averages and ranges used in the statistical analysis.

11. Suggestions toward reducing the number of rounds fired during the ballistic tests which were incorporated in the final draft of this report were contributed by Captains W. W. Hewitt and C. A. Anderson of the Office, Chief of Ordnance (Industrial Service, Small Arms Division).

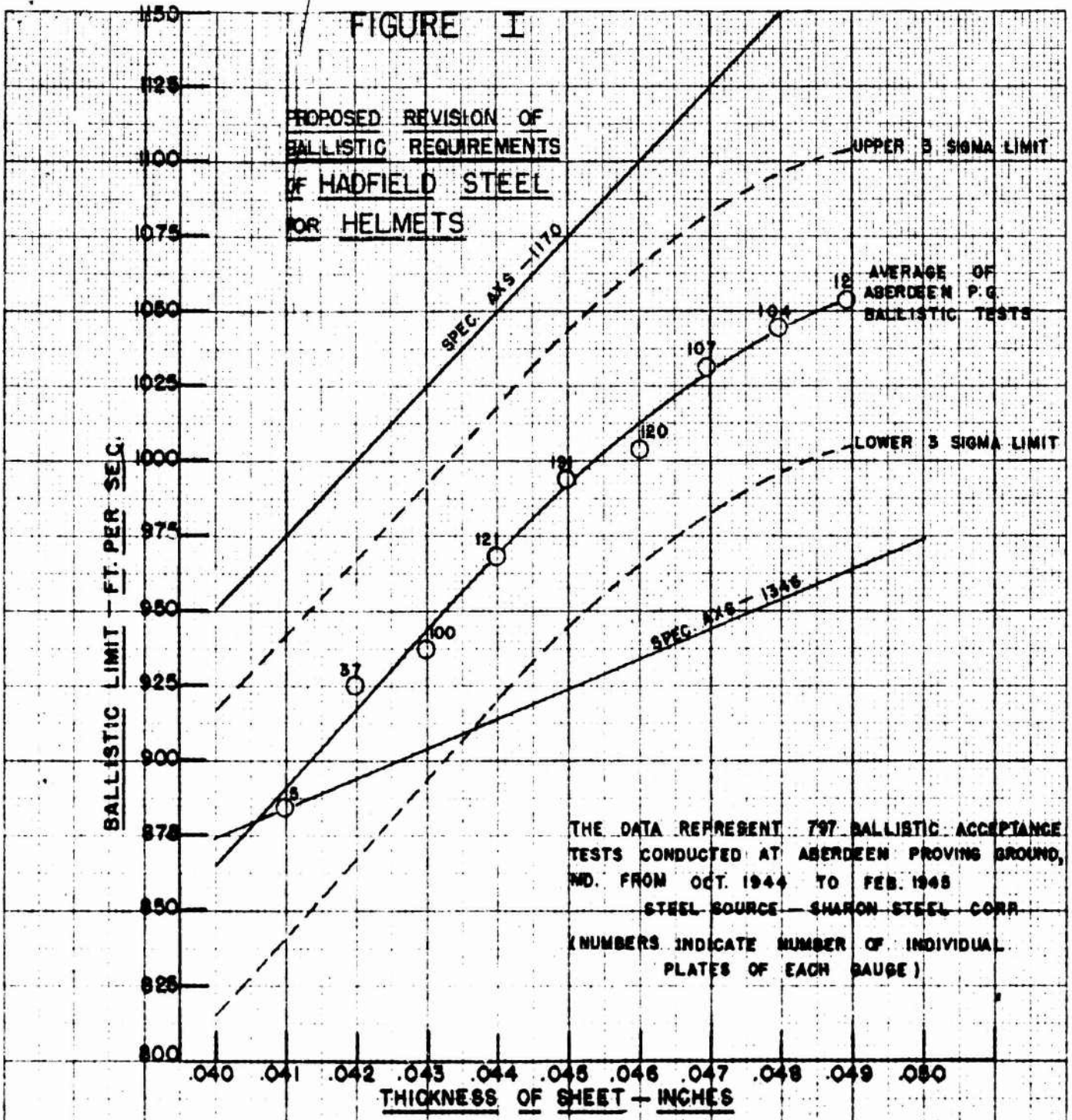
J. F. Sullivan
Asst. Engineer

A. Hurlich
Assoc. Metallurgist

APPROVED

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

FIGURE I



PROPOSED REVISION OF BALLISTIC REQUIREMENTS

(FOR SAMPLING AND TESTING PROCEDURES SEE PARAGRAPHS 7 AND 8 OF WATERTOWN ARSENAL MEMORANDUM REPORT NO. WAL 710/727. 3MARCH 1944.)

F.J.H. 3-3-45

TABLE I

THICKNESS INCHES	REQUIRED MINIMUM BALLISTIC LIMIT (LOWER 3 σ VALUES)
.040	815
.041	840
.042	865
.043	895
.044	920
.045	945
.046	965
.047	985
.048	995
.049	1005
.050	1015