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AMSRL-CS-IO-SC 380, 6 Jun 1997

Watertown Arsenal Laboratory
Report No. WAL 739/48
Problem No. R-1.5

8 August 1944

BAYONETS

Metallurgical Examination of Eight M1 Bayonets Submitted by Springfield Armory

OBJECT

To compare the subject bayonets with those previously tested (Report No. WAL 739/37).

SUMMARY OF RESULTS

A comparison with the nine lots (A to I inclusive) of M1 and M1905 bayonets previously tested (Report No. WAL 739/37) indicates the following:

1. The subject bayonets were made of WD1080 steel, as were six of the nine lots previously tested, and were all hardened from pommel to blade point. Only three of the previous lots were so treated.

2. Five subject bayonets which were conventionally quenched and tempered were uniform in hardness throughout their lengths whereas even the best bayonets of the previous lots, all conventionally quenched and tempered, were found to possess zones of lowered hardness in the vicinity of the guard.

3. Zones of lowered hardness similar to those found in the previous bayonets were also found in three of the subject bayonets which were austempered by quenching into molten salt at 540 - 630°F.

4. All of the bayonets previously tested and seven of the eight subject bayonets were found to meet the requirement for blade hardness contained in U.S. Army Specification No. 54-4-1B (Amend. -3). The subject bayonet which failed to meet this requirement was quenched at an inadequate rate in a molten salt bath at 630°F as part of the austempering treatment which it received, and low hardness resulted throughout.

APPROVED:

H. H. ZORNIG
Colonel, Ordnance Dept.
Director of Laboratory

BERNARD S. LEMENT
Associate Metallurgist

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Introduction and Test Procedure

At the request of the Office, Chief of Ordnance, (SPOTS)*, a metallurgical examination was carried out of eight (8) M1 bayonets submitted to this Arsenal by Springfield Armory. These bayonets were manufactured by the American Fork and Hoe Company and heat treated by the American Steel and Wire Company. Bend tests were carried out on the heat treated bayonets by Springfield Armory. The heat treatments and bend test results of the 8 bayonets are given in Table I and in Appendix B respectively. The purpose of the present investigation was to compare the 8 bayonets with those previously tested (Report No. WAL 739/37).

The procedure in this examination consisted of the following steps:

(1) Visual inspection
(2) Chemical analysis
(3) Rockwell "C" hardness surveys
(4) Impact tests
(5) Microexamination

Results and Discussion

1. Visual Inspection

The eight (8) bayonets in the as received condition were found to be stamped on their tangs with the following numbers: 1, 5, 9, 12, 14, 16, 19, and 21. The blade of each bayonet was found to be stamped just below the guard with the following identification: "AFH US".** Bayonet No. 19 was received in two pieces. Breakage occurred in the tang immediately to the rear of the bolster which supports the guard as shown in Figure 1. This location has been previously referred to as the critical section (Report No. WAL 739/37).

2. Chemical Composition

The chemical compositions of the eight bayonets are given in Table II. These bayonets were all made of WD1080 steel and apparently from the same heat.

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* O.O. 474.7/2032 - WTN. 474.8/85 2nd Ind. (See Appendix A).

** Abbreviations for: American Fork and Hoe Company, United States.

3. Hardness Surveys

The results of Rockwell "C" hardness surveys taken on longitudinal sections of the eight bayonets are given in Appendix C and summarized in Table III. The sections chosen included the tang up to the pommel and three inches of the blade as measured from the front of the guard. A typical section is shown in Figure 2. Each section was ground parallel to and for a distance of 3/16" from the flat edge or back side of the blade. Hardness readings were taken 1/4" apart starting at a reference point in line with the front of the guard. In reporting the results of the hardness surveys, the direction of the blade point is noted as positive while the direction of the pommel is noted as negative.

As shown in Table III, Bayonets No. 12, 14, 16, 19, and 21 possess fairly uniform hardness throughout their lengths, whereas Bayonets No. 1, 5, and 9 possess transitional zones of lowered hardness in the region of the guard. The hardness level of both the tang and blade of Bayonet No. 9, Rockwell "C" 43-46 is below that of the other seven bayonets, Rockwell "C" 47-52.

4. Impact Tests

Charpy impact tests were carried out on unnotched specimens (.065 x .700 x 2.0") of the M1 bayonet blades, striking against the .700 x 2.0" side. The results of these tests are given in Table IV. The impact strengths of all with the exception of Bayonet No. 9 were found to be equivalent. The high impact strength of Bayonet No. 9 appears to be due to its low hardness.

5. Microexamination

Typical photomicrographs of the M1 bayonets are shown in Figure 3. The structure of Bayonet No. 1 blade away from the region of the guard, -A-, contains some primary troostite, which indicates that this bayonet was hot quenched at a slow rate from the hardening to the austempering temperature. The structure of the blade in the region of the guard, -B-, contains undissolved pearlite areas and primary troostite, which indicates that a combination of insufficient heating to and a slow rate of hot quenching from the hardening temperature was responsible for the zone of lowered hardness found in this region. The presence of a decarburized layer about .008" in depth, was found at the surface of the tang, -C-, indicating need for better surface protection during either the forging or annealing treatment given to this bayonet.

The structure of Bayonet No. 9 blade, away from the guard, -D-, contains a large amount of primary troostite, which indicates that this bayonet was hot quenched at a very slow rate from the hardening to the austempering temperature. The structure of this blade in the region of the guard is the same as -B-, indicating that a combination of insufficient heating to and a slow rate of hot quenching from the hardening temperature was likewise responsible for the zone of low hardness.

The structure of the tang of Bayonet No. 16 at the critical section where breakage occurred, -D-, is uniform, indicating that the breakage is not associated with poor heat treatment or defective material. The structures of Bayonet No. 16 as well as Bayonets No. 12, 14, 19 and 21 are substantially uniform from pommel to blade point and similar to -E-, indicating a satisfactory heat treatment in each case.

6. General Considerations

The results of examination of the eight M1 bayonets reveal that they were all made of WD1080 steel and hardened from pommel to blade point. Five bayonets which were oil quenched and tempered attained uniform hardness throughout their lengths, whereas the three bayonets which were austempered were found to possess zones of lowered hardness in the region of the guard. One austempered bayonet blade was found to possess a hardness level lower than the range, Rockwell "C" 46 to 52, specified in U.S. Army Specification No. 52-4-1B (Amend. 3). Evidence was found that the three cases of lowered hardness resulted from insufficient heating for hardening and slow rates of quenching from the hardening temperature. These conditions could result from interference to heating and quenching caused by the method of supporting the bayonets during the hardening operation. In the case of Bayonet No. 9, it may be that the temperature of the austempering bath (630°F) was high enough to lower the quenching rate sufficiently to result in lowered hardness. Based on the results of the impact tests, it appears that the austempering treatment and oil quench and temper treatments resulted in bayonet blades of equivalent toughness at a hardness level of Rockwell "C" 48 - 52.

A comparison with the nine lots of M1 and M1905 bayonets previously tested (Lots A to I inclusive - Report No. WAL 739/37) reveals that the subject eight M1 bayonets possess the same chemical composition (WD1080) as Lots A, B, C, D, F and G; that the subject bayonets were all hardened from pommel to blade point whereas only bayonets of Lots A, C and F were so treated; that five of the eight subject bayonets were given a conventional quench and draw treatment whereas all of the lots previously tested were given this treatment; that the five subject bayonets which were quenched and drawn are

uniform in hardness throughout their lengths whereas the bayonets of Lot A which is considered to be the best of the lots previously tested were found to possess zones of lowered hardness in the vicinity of the guard similar to those found in the three subject bayonets that were austempered; that all the bayonets previously tested and seven of the eight subject bayonets were found to meet the requirement for blade hardness contained in U.S. Army Specification No. 52-4-13 (Amend. 3).

TABLE I

HEAT TREATMENTS GIVEN TO EIGHT M1 BAYONETS BY AMERICAN STEEL AND WIRE COMPANY

BAYONET NO.	HEAT TREATMENT
1, 5	Austempered. Heated in lead at 1550°F. for 5 minutes followed by quench into molten salt at 540°F. for 45 minutes.
9	Austempered. Heated in lead at 1550°F. followed by quench into molten salt at 630°F. for 30 minutes.
12, 14	Hot Oil Quench and Temper. Heated in lead at 1550°F. for 5 minutes followed by quench into controlled temperature oil at 250°F. for 1 minute followed by immediate tempering at 630°F. for 30 minutes.
16	Conventional Quench and Temper. Heated in lead at 1550°F. for 5 minutes followed by quenching into oil at 80°F., then drawn in lead at 700°F. for 1 hour.
19, 21	Hot Oil Quench and Temper. Heated in lead at 1550°F. for 5 minutes followed by quench into controlled temperature oil at 250°F. for 1 minute followed by immediate tempering at 700°F. for 30 minutes.

TABLE II

CHEMICAL COMPOSITION

BAYONET NO.	C	Mn	Si	S	P	Ni	Cr	Cu	Mo
1	.85	.60	.25	.034	.012	Trace	.04	.08	Trace
5	.86	.57	.21	.028	.016	"	.05	.08	"
9	.82	.58	.23	.028	.013	"	.04	.08	"
12	.85	.57	.22	.028	.020	"	.03	.07	"
14	.81	.58	.23	.028	.020	"	.04	.07	"
16	.82	.57	.23	.032	.012	"	.03	.08	"
19	.82	.57	.22	.030	.013	"	.03	.08	"
21	.83	.57	.22	.030	.012	"	.04	.07	"

TABLE III

RESULTS OF HARDNESS SURVEYS

BAYONET NO.	HEAT TREATMENT (1)	ROCKWELL "C" HARDNESS LEVEL OF TANG	ROCKWELL "C" HARDNESS AT CRITICAL SECTION	LOCATION OF HARDNESS TRANSITIONAL ZONE IN INCHES	ROCKWELL "C" HARDNESS LEVEL OF BLADE	MINIMUM ROCKWELL "C" HARDNESS AT TRANSITIONAL ZONE
1	Austempered at 540°F.	48 - 52	46	-3/4 to + 1-3/4	48 - 49	38
5	Austempered at 540°F.	50 - 52	46	-3/4 to + 1-3/4	47 - 49	40
9	Austempered at 630°F.	44 - 46	44	-1/2 to + 2	43 - 44	39
12	Oil quenched to 250°F. and tempered at 630°F.	50 - 51	52	None	51 - 52	--
14	Oil quenched to 250°F. and tempered at 630°F.	50 - 52	50	None	51 - 52	--
16	Oil quenched to 80°F. and tempered at 700°F.	48 - 50	48	None	49 - 50	--
19	Oil quenched to 250°F. and tempered at 700°F.	47 - 50	49	None	48 - 49	--
21	Oil quenched to 250°F. and tempered at 700°F.	48 - 50	47	None	49 - 50	--

(1) See Table I. The hardening temperature was 1550°F. in all cases.

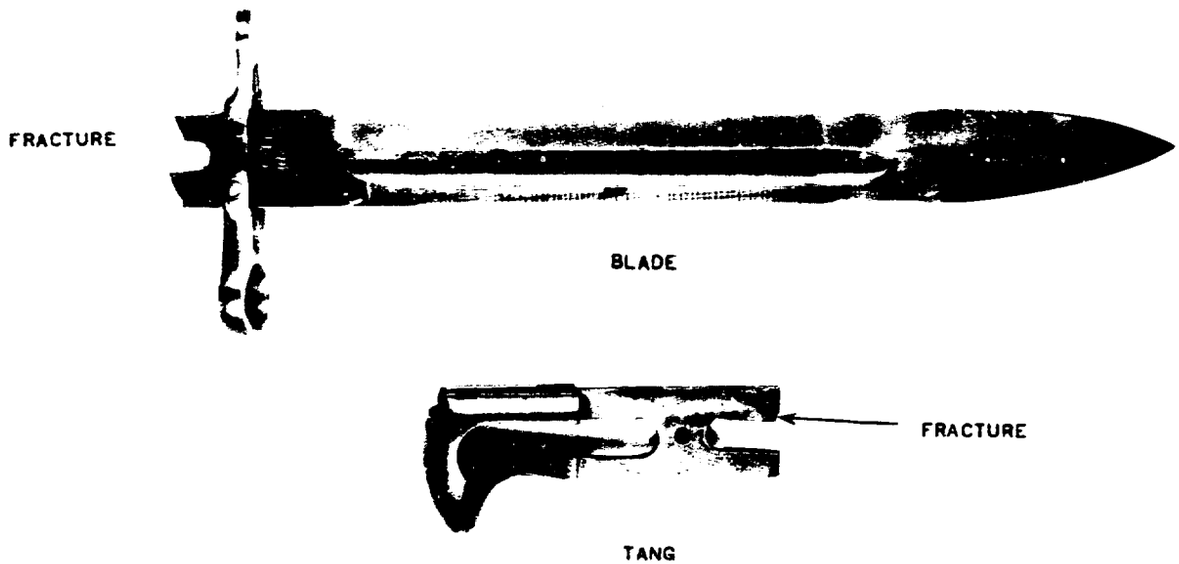
TABLE IV

RESULTS OF IMPACT TESTS OF M1 BAYONET BLADES

BAYONET NO.	HEAT TREATMENT (1)	ROCKWELL "C" HARDNESS	IMPACT STRENGTH, FT.-LBS. (2)
1	Austempered at 540°F.	48 - 49	16
5	Austempered at 540°F.	48 - 49	15
9	Austempered at 630°F.	43 - 44	23
12	Oil Quenched to 250°F. and tempered at 630°F.	51 - 52	14
14	Oil Quenched to 250°F. and tempered at 630°F.	51 - 52	15
16	Oil Quenched to 80°F. and tempered at 700°F.	49 - 50	14
21	Oil Quenched to 250°F. and tempered at 700°F.	49 - 50	15

(1) See Table I. The hardening temperature was 1550°F. in all cases.

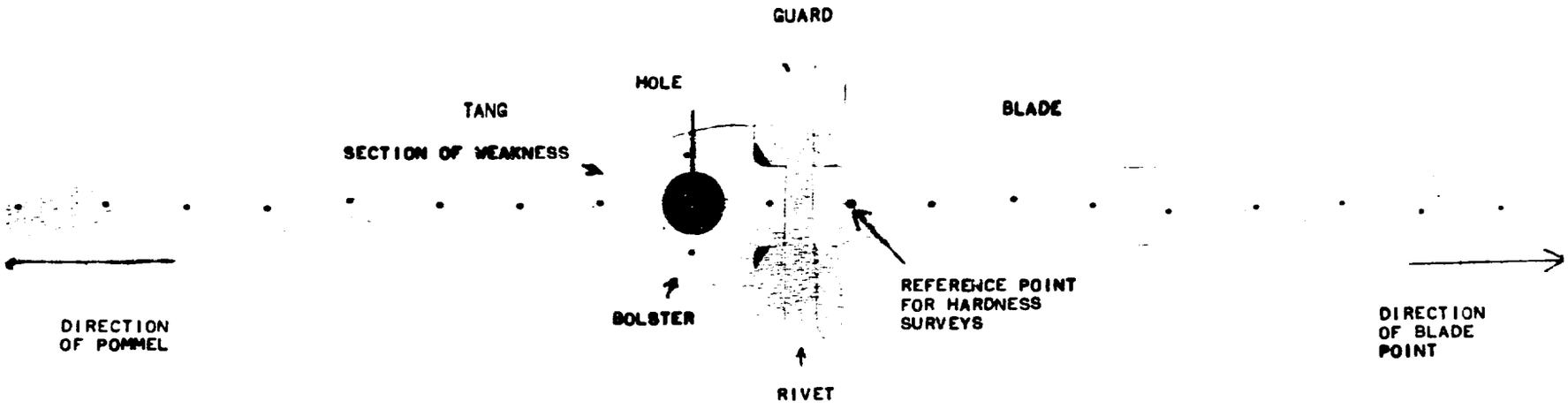
(2) Average of 2 tests.



WATERTOWN ARSENAL

FIGURE 1

PHOTOGRAPH OF BROKEN M1 BAYONET NO. 19 SUBMITTED BY SPRINGFIELD ARMORY
17 MAY 1944 MAG. X 1/2 WTN.693-62



WATERTOWN ARSENAL

FIGURE 1

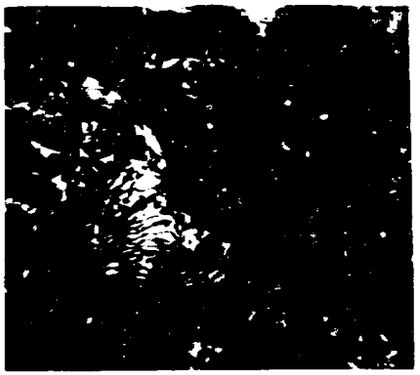
LONGITUDINAL SECTION OF BAYONET IN VICINITY OF GUARD SHOWING HARDNESS SURVEY. ROCKWELL "C" HARDNESS READINGS WERE TAKEN 1/4" APART STARTING AT A REFERENCE POINT IN LINE WITH THE SIDE OF THE GUARD NEAREST THE BLADE POINT.
3 JAN 1944

MAGNIFICATION X 2
WTN.693-60

FIGURE 2

PICRAL —A— X1000

BAYONET NO. 1 BLADE. BAINITE, PRIMARY TROOSTITE, AND CARBIDES

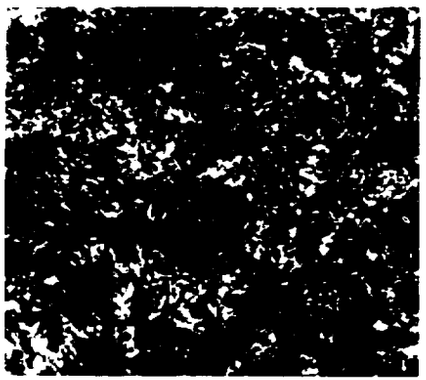


PICRAL —B— X1500

BAYONET NO. 1 BLADE NEAR GUARD. TINY PEARLITE AREAS, PRIMARY TROOSTITE, AND CARBIDES.

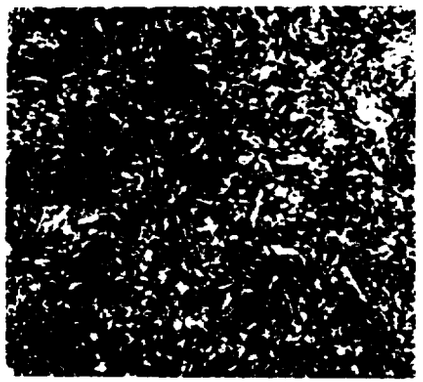
PICRAL —C— X100

BAYONET NO. 1 TANG AT SURFACE. DECARBURIZED LAYER ABOUT .008" IN DEPTH.



PICRAL —D— X1000

BAYONET NO. 9 BLADE. BAINITE, PRIMARY TROOSTITE, AND CARBIDES.



PICRAL —E— X1000

BAYONET NO. 19 CRITICAL SECTION, TEMPERED MARTENSITE AND CARBIDES.

WTN.639-7009

FIGURE 3. PHOTOMICROGRAPHS OF MI BAYONETS

FIG. 3

APPENDIX A

WTN. 474.8/85
O.O. 474.7/2032
Attn: SPOTS
S.A. 474.7/402

2nd Indorsement

Flanagan/es
73174

Army Service Forces, Ordnance Department, Washington 25, D. C., 11 May 1944

To: Commanding Officer, Watertown Arsenal, Watertown 72, Mass.

1. Reference is made to Watertown Arsenal Laboratory Experimental Report No. 739/37.

2. It is requested that subject bayonets be given micro examination, similar to those tested under report listed above, in order that a comparison may be made between these bayonets and ones previously tested.

By order of the Chief of Ordnance:

RENE' R. STUDLER
Colonel, Ord. Dept.
Assistant

APPENDIX B

RESULTS OF BEND TESTS PERFORMED ON EIGHT M1 BAYONETS BY SPRINGFIELD ARMORY

6" BEND TEST

BAY-ONET NO.	To Right				To Left				LOCATION OF BEND OR BREAK. (DIST. FROM GUARD.
	1/16" Set		1/2" Set		1/16" Set		1/2" Set		
	DIST.(1) INCHES	FORCE(2) LBS.	DIST. INCHES	FORCE LBS.	DIST. INCHES	FORCE LBS.	DIST. INCHES	FORCE LBS.	
12	1-7/16	10	4-3/4	36	2	15	4-5/8	35½	In Blade 5"
16	3-13/16	20	5	43	2-5/8	19	4-1/2	33½	In Blade 1-3/4"
21	3-1/16	26	4-5/8	34	2-3/4	20	4-1/4	31½	In Blade 4½"
				4" BEND TEST					
1	1-9/16	19	3-1/8	36	1-7/8	24	3-1/8	37	In Blade 1-3/4"
9	1-1/2	22	2-5/8	29½	1-3/8	19	2-1/2	29	In Blade 2-1/2"
14	1-15/16	27	3-1/4	45	2-1/8	32	3-1/4	35	In Blade 1"
				1" BEND TEST					
5	11/16	45	1-3/4	72	5/8	40	1-1/2	70	In Blade 3/4"
19	7/8	65	Broke	68	7/8	60	----	--	In Handle 1/2"

(1) Distance = Circular displacement in inches of arc at pommel.

(2) Force = Pounds registered on 100 lb. spring scale fastened at breech end (threads) of M1 Rifle barrel and pulled in direction continuously at right angles to the barrel.

APPENDIX C

ROCKWELL "C" HARDNESS SURVEYS OF EIGHT M1 BAYONETS

BAYONET NO.	DISTANCE FROM FRONT OF GUARD IN INCHES*													
	-2½	-2	-1½	-1	-3/4	-½	-1/4	0	+1/4	+½	+ 3/4	+1	+1½	+2
1	48.0	49.5	51.5	52.0	46.5	44.5	43.0	42.5	39.5	38.5	39.0	40.0	44.5	49.5
5	51.5	51.5	51.5	50.5	46.0	46.5	44.5	43.5	41.5	40.5	41.5	41.5	44.5	49.5
9	44.5	46.0	45.5	45.5	44.5	42.5	41.5	39.5	39.5	39.5	39.5	39.0	42.5	44.5
12	50.5	50.5	50.5	51.5	52.5	48.5	51.5	51.5	51.5	51.5	52.5	51.5	52.5	51.5
14	50.5	51.5	52.5	52.5	50.5	50.5	51.5	52.0	50.5	52.5	51.0	49.5	51.0	52.5
16	48.5	50.5	49.5	49.5	48.5	47.5	48.0	48.5	47.5	48.0	49.0	47.5	49.5	50.5
19	50.5	48.5	48.0	47.5	49.0	47.0	47.5	47.5	47.5	49.5	49.5	46.5	49.5	48.5
21	48.5	49.0	49.5	48.5	47.0	48.0	49.5	48.5	48.5	48.5	47.5	48.5	50.5	48.5

* Direction of blade point is positive; direction of pommel is negative.

DEPARTMENT OF THE ARMY
UNITED STATES ARMY RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21005-5066

REPLY TO
THE ATTENTION OF

AMSRL-CS-IO-SC (380) 6 June 1997

MEMORANDUM FOR Defense Technical Information Center, 8725 John J. Kingman Road Suite 0944, Ft. Belvoir, VA 22060-6218

SUBJECT: Cancellation of Distribution Restrictions for Watertown Arsenal Laboratory Reports

1. References:

a. AD-B962 643, Watertown Arsenal Laboratory Report No. WAL 320/29, "Bayonet Blades, Investigation of WD 10-80 Steel for Use in Bayonet Blades", 19 January 1944.

b. AD-B962 712, Watertown Arsenal Laboratory Memorandum Report No. WAL, 739/87, "The Metallurgical Examination of a Japanese Samurai Sword", by J. I. Blum, 25 September 1946.

c. AD-B962 710, Watertown Arsenal Laboratory Report No. WAL 739/47, "Bayonets, Metallurgical Examination of Six Lots of T2 Bayonets", 2 August 1944.

d. AD-B962 687, Watertown Arsenal Laboratory Report No. WAL 739/48, "Bayonets, Metallurgical Examinaton of Eight M1 Bayonets Submitted by Springfield Armory", 8 August 1944.

e. AD-B962 689, Watertown Arsenal Laboratory Report No. WAL 739/37, "Bayonets, Metallurgical Examination of Bayonets of Commercial and Springfield Armory Manufacture", 5 April 1944.

2. Our Laboratory has reviewed the reference reports and has approved them for public release; distribution is unlimited. Request that you annotate your records and mark the documents with distribution statement A in accordance with DOD Directive 5230.24.

3. Our action officer is Mr. Douglas J. Kingsley, telephone 410-278-6960

P. Ann Brown
P. ANN BROWN
Chief, Security/CI Branch
ARL, APG