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Watertown Arsenal Laboratory
Report No. WAL 739/47
Problem No. R-1.4

2 August 1944

BAYONETS

Metallurgical Examination of Six Lots of T2 Bayonets

OBJECT

To carry out a metallurgical examination of the subject bayonets to determine the following: (a) the material and heat treatment which provides the strongest and most durable bayonet; (b) the effect of hydrogen-copper brazing on the blade near the guard; and (c) how the T2 bayonets compare with the bayonets previously tested (Report No. 739/37).

SUMMARY OF RESULTS

1. The six lots of T2 bayonet blades were found to be made from WD1095 steel instead of three lots from WD1080 steel and three lots from WD1095 steel. Therefore, no comparison can be made on the basis of chemical composition.

2. Results of impact tests give some indication that the full austempering treatment consisting of quenching into molten salt at 550 - 570°F. given to Lots A, D, and E and the partial austempering treatment consisting of quenching into molten salt at 400°F, followed by air cooling and drawing given to Lot B confers greater toughness in T2 bayonets at a hardness level of Rockwell "C" 48 - 51 than the conventional quench and draw treatment given to Lots C and F. All six lots were able to meet the bend test requirements as specified in U.S. Army Specification No. 52-4-1B (Amend. -3). The hardness requirements of this specification were met by bayonets of all six lots, with the exception of three bayonets which received inadequate quenching. Zones of lowered hardness were found in the region of the guards of almost all of the bayonets and were caused by the effect of the added mass of the guard in retarding the rate of heating to and quenching from the hardening temperature.

3. On the whole, the effect of hydrogen brazing on the blade near the guard is not considered detrimental. Cracks originating from the brazed joint were found in the blades of two bayonets and are believed to have resulted from too rapid heating during the brazing operation. The quality of the brazed joints was found to vary

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considerably and improvement in the uniformity of the brazing operation would be desirable to eliminate the following conditions: oxidation, trapped flux, incomplete coverage by braze metal, brazed metal joints of excessive thickness, and cracks in the blade.

4. The six lots of T2 bayonets received as good heat treatment as the best of the nine lots of M1 and M1905 bayonets previously tested (Report No. 739/37). The T2 bayonet represents an improvement over the M1 and M1905 bayonets from the standpoint of simplicity of manufacture and increased strength of blade due to increased section.

Bernard S. Lemont
Associate Metallurgist

APPROVED:

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INTRODUCTION AND TEST PROCEDURE

At the request of the Office, Chief of Ordnance, (SPOTS)*, a metallurgical examination of six lots of T2 bayonets was carried out in an effort to determine the material and heat treatment which provides the strongest and most durable bayonet, the effect of hydrogen-copper brazing on the blade near the guard, and to compare the T2 bayonets with the bayonets previously tested (Report 739/37). The T2 bayonet was developed on a Research and Development contract by the Edison General Electric Appliance Company, Chicago, Illinois, in an effort to obtain a bayonet of higher strength than the M1 bayonet and consists of a blade fabricated from rolled strip, to which the guard and pommel are brazed. Brazing was accomplished by induction heating in an atmosphere of hydrogen to a temperature about 2000°F, the bayonet being held in an appropriate fixture. The T2 bayonet also differs from the M1 bayonet in that the tang is not cut away and the point is so ground as to result in a thicker section.

The following information was received regarding the six lots of T2 bayonets:

<u>Lot</u>	<u>Number of Bayonets in Lot</u>	<u>Steel</u>	<u>Heat Treatment</u>	<u>Heat Treated by</u>
A	3	WD1080	Austempered	American Steel & Wire Co.
B	4	WD1080	Isothermal	Ajax Electric Co.
C	6	WD1080	Quench & Draw	Ludberg Steel Treating Co.
D	4	WD1095	Austempered	American Steel & Wire Co.
E	5	WD1095	Isothermal	Ajax Electric Co.
F	6	WD1095	Quench & Draw	Ludberg Steel Treating Co.

Lots A and D bayonets were treated by heating in a lead bath at 1550°F. for 15 minutes, followed by a quench in a salt bath at 570°F. for 45 minutes. Lot B bayonets were austenitized at 1575°F. for 10 minutes quenched into a molten salt bath at 400°F. for 2 minutes, cooled in air, and drawn in a salt bath at 600°F. for 45 minutes. Lot E bayonets were austenitized at 1575°F. for 10 minutes and quenched into molten salt at 550°F. for 45 minutes. Lots C and F bayonets were heated in a controlled atmosphere furnace for 30 to 40 minutes at 1475°F., quenched singly in oil at 120°F., straightened in a press when cooled to 350-400°F., and drawn for 2 hours at 550-650°F. in an air furnace.

The procedure followed in this investigation involved the following steps:

*O.O. 474.7/2021 - Wtn. 474.8/31 (r) (See Appendix A)

1. Visual inspection of T2 bayonets as received.
2. Specification bend tests of T2 bayonets.
3. Chemical analysis of blade and brazing metal.
4. Impact tests of blades.
5. Hardness surveys of blades and tangs.
6. Shear and impact tests of brazed joints.
7. Microexamination of blades, tangs, and brazed metal joints.

RESULTS AND DISCUSSION

1. Visual Inspection

Results of visual inspection of the six lots of T2 bayonets are given in Table I. A typical T2 bayonet is shown in Figure 1. Identification markings were found on the tang and in most cases on the blade just under the guard of each bayonet. In a few cases, lot designations were found on the guards of the bayonets. Each lot was made up of bayonets both with and without blood grooves. Three bayonets, Nos. D3, D4, and E5, were made with cutting edges 6 to 9" long on their back edges.

Notes were found attached to Bayonets Nos. B2, and D1. The note on Bayonet No. B2 read as follows: "Typical Edgewise Bending with Grooves". Inspection of this bayonet revealed that distortion of the blade occurred in the direction of the back edge. This distortion caused the sides of the blood grooves to assume a bent position and the blade point to be displaced $1/4$ " from its normal position. Inspection of the other bayonets for this type of distortion revealed that in most cases, the displacement was less than $1/16$ ". No correlation apparently exists between the occurrence of distortion and either the presence of blood grooves or the type of heat treatment received by the T2 bayonets. The note on Bayonet No. D1 read as follows: "American Steel & Wire, Lead-Bath Heating, Not Sand Blasted. Note Remaining Lead". As indicated by the note, the presence of lead in globular form was found on this bayonet.

2. Specification Bend Tests

Bend tests of all of the T2 bayonets were carried out in accordance with U.S. Army Specification No. 52-4-1B (Amend.-3). The specification bend test consists of bending a bayonet blade on each side over a curved surface having a radius of 18". Blades taking a set of $1/16$ " in either direction are considered rejectable. The sets incurred in testing the T2 bayonets were all within $1/16$ ", and therefore these bayonets may be considered to have satisfactorily passed the bend test.

3. Tests of Blades and Tangs

A. Chemical Composition

The chemical compositions of blades representing the six lots of T2 bayonets are given in Table II. The blades of the six lots were all made from WD1095 steel. The basic letter however stated that the blades of Lots A, B, and C were made of WD1080 steel. It is evident that Lots A, B, and C were made from a different heat of WD1095 steel than were lots D, E, and F, since the carbon and manganese contents of the former are slightly lower than the respective contents of the latter, .95 - .97% C and .29 - .31% Mn as compared with .98 - 1.03% C and .44 and .45% Mn.

B. Hardness Surveys

The results of Rockwell "C" hardness surveys taken on longitudinal sections of the T2 bayonets in the vicinity of the guard are given in Appendix B and summarized in Table III. The section 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. Hardness readings were taken 1/4" apart along the tang and blade 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.

The results of Table III show that the hardness levels of most of the T2 bayonet blades fall within the limits specified in U.S. Army Specification No. 52-4-1B (Amend. -3) Rockwell "C" 46-52. The blades of bayonets Nos. A3, B4, and F2 possess a hardness level of Rockwell "C" 41-43 which is below the lower specification limit. The hardness levels of the T2 bayonet tangs are all within Rockwell "C" 40 to 53. Most of these tangs are nonuniform in hardness, varying as much as 10 points from pommel to guard. Transitional zones of lowered hardness were found to exist in the vicinity of the guard of all with the exceptions of Bayonets Nos. B4, E2 and E4. These zones all fall in a region extending from 1" in back of the guard (pommel direction) to 1-1/2 inches in front of the guard (blade point direction). The minimum hardnesses found in these zones are in the range of Rockwell "C" 38-44.

C. Impact Tests

Impact tests were carried out on two sizes of un-notched specimens (.150 x .250 x 2.0" and .075 x .300 x 2.0") of the T2 bayonets, and the results of these tests are given in Table IV. In view of the variation in hardness of these

specimens, the results for each lot are reported as average impact strengths at various hardness levels. Due to the fact that the same hardness levels do not exist in all six lots, direct comparisons of impact strength at all hardness levels in the range of Rockwell "C" 41 to 54 are not possible. However, at a hardness level of Rockwell "C" 48-51, the results appear to indicate that the impact strengths of Lots C and F which were given a quench and draw treatment are lower than those of Lots A, B, D, and E which were given either full or partial austempering treatments.

D. Microexamination

Photomicrographs of T2 bayonet blades selected as representative of the six lots are shown in Figure 3. The structure of Bayonet A1 blade, -A-, indicates a uniform austempering treatment and is typical of Lots A and D blades. The structure of Bayonet B2 blade, -B-, indicates that the isothermal treatment given to Lot B bayonets may be considered as a partial austempering treatment. The structure of Bayonet E3 blade, -C-, is coarser than that of Bayonet A1 blade, -A-, although Lots A, D, and E bayonets received approximately the same austempering treatment. The structure of Bayonet F4 blade, -D-, indicates a uniform quench and temper treatment and is typical of Lots C and F blades. The structures of Bayonet blades A3, B4, and F2 (-E-, -F-, and -G- respectively) all reveal that a slow quenching rate was responsible for the low hardness of these blades.

The structure of F4 Bayonet blade adjacent to the guard consists of tiny untransformed pearlite areas and a large amount primary troostite, -H-. This indicates that this portion of the blade did not reach the operating temperature of the heating bath and was quenched at a slower rate than either the tang or the remainder of the blade. Similar microstructures were found at the same location of the bayonets of all six lots. It appears that the added mass of the brazed on guard lowers both the rate of heating and quenching of the adjacent portion of the T2 bayonet blade and results in the transitional zones of lowered hardness revealed by the hardness surveys. A similar condition could occur if the means used to support the bayonets during heating and quenching gave an added mass effect.

4. Examination of Brazed Joints

A. Chemical Composition

The approximate chemical composition of the braze metal used to join the guards to the blades of T2 bayonets is as follows:

<u>Cu</u>	<u>Zn</u>	<u>Ni</u>
96.8	3.0	0.2

This composition falls outside of the limits of purity generally desired for copper braze metal and does not correspond to any of the commercial brazing alloys, indicating that both Zn and Ni are present as impurities in the copper.

B. Shear Tests

1. Comparison Between Brazed and Riveted Joints

Tests to determine the shear strength of the brazed joints were carried out by placing the bayonet guard on two supports parallel to the 1 inch wide sides of the blade and applying a load to the blade in the direction of its length until separation of the blade and guard occurred. Similar tests were carried out on the riveted joints of M1 bayonets for purpose of comparison. Values of shear load necessary to cause separation between the guards and blades are reported in Table V for three T2 bayonets and three M1 bayonets. The results reveal that the brazed joints of both T2 Bayonets C6 and F3 withstood a shear load approximately four times greater than the riveted joints of the M1 bayonet. However, the shear load withstood by T2 Bayonet F6 is approximately one-half that of the M1 bayonets, indicating that the strength of the brazed joints may vary considerably. A comparison of shear strengths reveals that the ability of copper brazed joints to withstand greater shear loads than the riveted joints is due to the much larger shear area involved.

2. Examination of Brazed Joints Exposed by Shear Test

Results of visual and microscopic examination of the brazed joints of the three T2 bayonets subjected to shear tests are given in Table V. It was found that the low shear strength of T2 Bayonet F6 was due to excessive oxidation of the brazed metal joint. Evidence of trapped flux was also found in the joint.

C. Impact Tests

1. Results of Test

Qualitative impact tests were carried out on the brazed joints of twenty-four T2 bayonet sections. The area of the brazed joint tested was approximately $1/4"$ x $1/2"$ in dimensions or approximately one-fourth of the total brazed joint area which holds the guard to the blade of a T2 bayonet. The impact tests were carried out by holding the blade portion in a vise and striking the guard portion with a series of blows using a one pound hammer. The intensities of blows employed correspond to what may be roughly considered as a light tap, half the striking force of an average individual, and the full striking force of an average individual;

and were reported as light, medium and heavy blows respectively. If a series of light blows failed to cause breakage, the intensity was increased to medium blows, and finally to heavy blows, where necessary.

The results of the impact tests are given in Table VI. Two tests were made on each bayonet section. In all tests it was found possible to knock off the guard portion from the blade. In 29 tests, light blows sufficed; in 14 tests, medium blows; and in 3 tests, heavy blows.

2. Examination of Brazed Joints After Impact Tests

Visual examination was made of the brazed joints after impact tests and estimates of the percentage of the joint area covered by brazed metal are given in Table VI. These percentages vary from 10 to 100% for joints which required light blows; 50 to 100% for joints which require medium blows; and 80 to 90% for joints which required heavy blows. Estimates were also made of the percentage of each joint area oxidized during the brazing operation. These percentages vary from 0 to 90% for joints which required light blows; 0 to 30% for joints which required medium blows, and 0 to 10% for joints which required heavy blows during the impact tests. Microscopic examination revealed the presence of trapped flux in most of the joints which required light blows; whereas in most of the joints which required either medium or heavy blows, little or no evidence of trapped flux was found. On the whole, the impact strengths of the brazed joints appear to depend on their quality as judged by coverage of braze metal, amount of oxidation, and presence of trapped flux.

D. Microexamination of Longitudinal Sections of Brazed Joints

The results of microexamination of the brazed joints between blade and guard of the longitudinal sections used for hardness surveys are given in Table VII. Photomicrographs illustrating the conditions indicated in Table VII are shown in Figures 4 and 5. The thickness of brazed joint was found to be fairly uniform in each of more than half of the joints examined. The maximum thicknesses of all the brazed joints were found to be in the range of .0005" to .0060". A typical example of a uniform brazed metal joint is shown in Figure 4, -A-. In Bayonets Nos. B1 and E5, the braze metal penetrated along the grain boundaries of the blade, -B- and -C-. This indicates that a higher temperature was reached and probably applied during the brazing of guards to these bayonets than in the case of the others. Cracks which connect with the brazed joints were found in the blades of Bayonets Nos. B1 and E5, -B- and -D-. These cracks were found to be almost completely filled with braze metal, which indicates that they were present during the time the braze metal was in a molten state and could penetrate. The absence of any decarburization in the vicinity of the cracks, Figure 5, -A-, is an indication that these cracks did not exist prior to

the brazing operation. In view of the foregoing evidence, it is believed that the cracks in the blades resulted from too rapid a heating rate during the brazing operation. The high carbon content of the blades would be expected to render them susceptible to cracking during rapid heating.

Examples of poor joints found in those bayonets indicated in Table VI as possessing voids to an appreciable extent are shown in Figures 5, -B- and -C-. Evidence of oxidation was found in the guard near the brazed joint, indicating the need for more adequate protection against oxidation during the brazing operation. The absence of braze metal at the corners between blade and guard, -C-, was observed in several bayonets. In most cases, however, a considerable amount of braze metal was found at the corners as shown in the case of Bayonet B1, -D-. The crack in the blade of this bayonet, shown in -D-, originated at the corner of the blade and guard and is believed to have resulted from too rapid heating during the brazing operation.

5. General Considerations

A. Comparison of Material

Since each of the six lots of T2 bayonet blades was found to be made of WD1095 steel, a comparison between WD1080 and WD1095 steel cannot be made on the basis of the results of this investigation. However, it is generally recognized that WD1080 steel is potentially capable of developing greater hardenability and toughness than WD1095 steel. On the other hand, WD1095 steel is potentially capable of developing greater ability to maintain keenness of cutting edge. In view of the greater importance of hardenability and toughness as compared with ability to maintain keenness of cutting edge in determining the service life of bayonets, WD1080 is considered superior to WD1095 steel for this application.

B. Comparison of Heat Treatments

Each of the heat treatments given to the T2 bayonets enabled them to meet the bend and hardness requirements specified in U.S. Army Specification No. 52-4-1B (Amend. -3), although the hardness levels of three out of all the blades tested were found to be slightly below the lower specified limit, Rockwell "C" 46. An inadequate rate of quenching from the hardening temperature was found to be mainly responsible for the cases of low hardness in the blades. However, it should be realized that the low hardenability of WD1095 steel is responsible for the critical nature of the quenching rate.

Although the results of the impact tests are not conclusive, the indications are that Lots C and F which were given

a quench and draw treatment possess lower toughness than do the other lots at a hardness level of Rockwell "C" 48-51. Greater toughness would be expected in Lots A, B, D, and E because of the fact that they received full or partial austempering treatments which are known to impart greater toughness than the conventional quench and draw treatment at the hardness level mentioned. On the basis of the tests made it appears the austempering treatment does not result in sufficient increased toughness to merit a change in the currently used quench and draw treatment.

C. Effect of Hydrogen-Copper Brazing on Blade Near Guard

On the whole, the effect of the brazing operation on the blade near the guard is not considered detrimental. The cracks found in the blade which originated from the brazed joint of two bayonets could be eliminated if better control of the rate of application of heat was exercised during the brazing operation. The cracks found in the blade are less serious than ordinary cracks in view of the fact that they are filled with braze metal which would be expected to retard their further propagation. The brazed-on guard affects the adjacent blade by acting to slow down the rate of heating and quenching this region of the blade. The lowered hardness which results would not be considered detrimental provided that the minimum value is above about Rockwell "C" 40. By selection of proper hardening temperature and time of heating and quenching uniformly, adequate hardness should result in the region of the guard.

D. Quality of Brazed Metal Joints

The quality of the brazed metal joints between the blade and guard was found to vary considerably and improvement in the uniformity of the brazing operation would be desirable. The shear tests indicated that brazed joints could be made which would be able to resist shear loads four times greater than riveted joints. The impact tests revealed varying degrees of brittleness of these joints which are associated with oxidation, incomplete coverage by brazing metal, and trapped flux. The ability of the brazed joints to withstand impact loads in actual service conditions cannot be judged from the impact tests in view of the fact that the area of brazed joint is four times as great in actual bayonets as in the impact test specimens.

The variation in maximum thicknesses of brazed joints was found to be appreciable. It is generally accepted that the optimum thickness is .001 to .002" for the best strength properties.

E. Comparison of T2 Bayonets with the M1 and M1905 Bayonets previously tested (Report No. WAL 739/70).

A comparison with M1 and M1905 Bayonets previously tested reveals that the T2 Bayonets possess the same composition as Lot Nos. I-8, I-11, and I-16 M1905 bayonets manufactured by Springfield Armory in 1908, 1911, and 1916 respectively; that the T2 bayonets were all hardened from pommel to blade point whereas only bayonets of Lots A, C, and F manufactured by the Pal Blade and Union Fork and Hoe Company were so treated; that only two lots of T2 Bayonets were given a quench and draw treatment whereas all of the lots previously tested were given this treatment. As compared with M1 bayonets of Lots A, C, and F for uniformity of hardness from pommel to blade point, the T2 bayonets may be considered as good as Lot A, the best of the three, and better than Lots C and F because of the higher minimum values of hardness found in the transitional zones. On the whole, the T2 bayonets represent an improvement over the M1 bayonets from the standpoint of simplicity of manufacture and increased strength of blade due to increased section. However, further improvement in the T2 bayonets could be expected from use of WD1080 steel, greater uniformity of brazing operation, and greater care in heat treatment.

TABLE I

RESULTS OF INSPECTION OF SIX LOTS OF T2 BAYONETS

Lot	No.	Blood Grooves	Identification on Blade Just Under Guard	Identification on Guard	Identification on Tang	Amt. and Direction of Distortion in Plane of Blade in In. (1)
A	1	Present	None	A	Hotpoint 1944 80	0
	2	"	"	"	Hotpoint 1944 80	1/16 B
	3	Absent	Hotpoint A 1944	None	80	0
B	1	Present	Hotpoint B 1944	"	80 18	0
	2	"	None	B	Hotpoint 1944	1/4 B
	3	Absent	Hotpoint B 1944	None	80 15	1/16 F
C	1	"	Hotpoint C 1944	None	80 6	1/16 B
	2	"	"	"	Hotpoint 1944	"
	3	Present	"	"	80	1/16 B
D	1	"	Hotpoint D 1944	"	Hotpoint 1944 80	Not Inspected
	2	"	"	"	Hotpoint 80 1944	"
	3	Absent	"	"	80	0
E	1	"	Hotpoint E 1944	"	95	1/16 F
	2	"	"	"	95	1/32 F
	3	Present	"	"	95	1/32 F
F	1	"	"	"	95 2	0
	2	"	"	"	95	3/32
	3	Absent	"	"	95	0

* Possesses 6" back cutting edge.

** Possesses 9" back cutting edge.

(1) Direction of distortion is as follows: B --- toward back edge. F -- toward front cutting edge.

TABLE I (Cont'd.)

RESULTS OF INSPECTION OF SIX LOTS OF T2 BAYONETS

(1)

Lot No.	Blood Grooves	Identification on Blade Just Under Guard	Hotpoint F 1944	Identification on Guard	Identification on Tang	Amt. and Direction of Distortion in Plane of Blade in In.
F 1	Absent	"	"	None	95	Not Inspected
2	"	"	"	"	95	"
3	"	"	"	"	95	1/16 B
4	Present	"	"	"	95	Not Inspected
5	"	"	"	"	95	"
6	"	"	"	"	95	3/32 B

* Possesses 6" back cutting edge.

** Possesses 9" back cutting edge.

(1) Direction of distortion is as follows:

B -- toward back edge

F -- toward front cutting edge.

TABLE II

CHEMICAL COMPOSITION

<u>Lot</u>	<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>
A	.95	.29	.21	.011	.013	Trace	.21	Trace	Trace
B	.97	.32	.19	.011	.012	Trace	.13	Trace	Trace
C	.96	.31	.23	.012	.012	Trace	.20	Trace	Trace
D	1.00	.45	.17	.033	.028	Trace	.09	Trace	Trace
E	.98	.44	.16	.029	.026	Trace	.02	Trace	Trace
F	1.03	.44	.19	.030	.026	Trace	.02	Trace	Trace

TABLE III

RESULTS OF HARDNESS SURVEYS TAKEN ON LONGITUDINAL SECTIONS OF
SIX LOTS OF T2 BAYONETS

Lot	No.	Rockwell "C" Hardness Level of Tang	Rockwell "C" Hardness Level of Blade	Location of Hardness Tran- sitional Zone in Inches		Minimum Rock- well "C" Hard- ness of Tran- sitional Zone
				Minus	Plus	
A	1	43 - 46	47 - 49	1/4	to 1-1/2	39
A	2	42 - 47	49 - 50	1/4	to 1-1/4	38
A	3	40 - 43	41 - 43	1/4	to 1/4	38
B	1	47 - 49	47 - 49	0	to 1/2	43
B	2	42 - 53	53 - 54	3/4	to 3/4	42
B	3	48 - 50	48 - 49	1/4	to 1/4	35
B	4	41 - 43	42 - 43	Absent		--
C	1	42 - 50	47 - 49	1/4	to 3/4	38
C	2	40 - 51	50 - 52	1/2	to 1	39
C	4	51 - 52	52 - 53	1/4	to 1/4	44
C	5	42 - 52	51 - 52	1/2	to 1/2	38
D	1	44 - 50	51 - 52	1	to 1	41
D	2	45 - 50	50 - 51	1/2	to 1/2	43
D	3	45 - 50	49 - 50	1/2	to 3/4	42
D	4	49 - 53	49 - 50	1/4	to 1-1/4	44
E	1	46 - 48	48 - 49	1/4	to 1/4	44
E	2	45 - 47	45 - 46	Absent		--
E	3	45 - 48	47 - 48	1/4	to 3/4	42
E	4	45 - 48	47 - 48	Absent		--
E	5	45 - 47	45 - 46	1/2	to 2	40
F	1	46 - 50	48 - 49	1/4	to 3/4	42
F	2	43 - 51	42 - 43	3/4	to 1-1/2	39
F	4	42 - 51	50 - 51	1/2	to 1-1/4	41
F	5	43 - 50	50 - 51	1/2	to 1-1/4	40

TABLE IV

RESULTS OF IMPACT TESTS OF T2 BAYONETS

<u>.150 x .350 x 2.0" Specimens</u>				<u>.075 x .700 x 2.0" Specimens</u>		
Lot	Rc 41-43	Rc 45-47	Rc 48-51	Rc 52-54	Rc 48-51	Rc 52-54
	Ft.-Lbs.	Ft.-Lbs.	Ft.-Lbs.	Ft.-Lbs.	Ft.-Lbs.	Ft.-Lbs.
A	53 ⁽⁵⁾	-----	-----	-----	20 ⁽²⁾	-----
B	40 ⁽⁴⁾	30 ⁽²⁾	28 ⁽³⁾	-----	-----	9 ⁽²⁾
C	-----	-----	21 ⁽²⁾	22 ⁽⁴⁾	-----	13 ⁽⁴⁾
D	-----	-----	29 ⁽³⁾	26 ⁽¹⁾	16 ⁽²⁾	-----
E	-----	34 ⁽⁷⁾	-----	-----	18 ⁽⁴⁾	-----
F	47 ⁽²⁾	-----	16 ⁽⁶⁾	-----	-----	6 ⁽²⁾

Numbers in parentheses indicate number of specimens tested at each hardness level.

TABLE V

RESULTS OF SHEAR TESTS OF ATTACHMENT BETWEEN GUARD AND BLADE OF T2 AND M1 BAYONETS

Bayonet No.	Type of Attachment	Area of Shear Action sq. in.	Shear Load lbs.	Shear Strength lbs./sq.in.	Estimated Per- centage of Joint Area Covered by Braze Metal	Estimated Percentage of Joint Area Oxidized *	Occur- rence of Trapped Flux
T2	Brazed Joint	0.50	9,600	19,200	80/90	20/10	Present
T2	" "	0.50	10,450	20,900	80/100	0	"
T2	" "	0.50	1,700	3,400	0/40	100/60	"
M1	Held by two rivets	0.03	2,400	80,000	---	---	---
M1	Held by two rivets	0.03	2,200	73,000	---	---	---
M1	Held by two rivets	0.03	2,450	85,000	---	---	---

*Estimates for two joints are reported.

TABLE VI
RESULTS OF IMPACT TESTS OF BRAZED JOINTS OF T2 BAYONETS

Lot	No.	Intensity of Hammer Blow Necessary to Cause Breakage *	Estimated Percentage of Joint Area Covered by Braze Metal *	Estimated Percentage of Joint Area Oxidized *	Occurrence of Trapped Flux
A	1	Light, ---	50/20	50/80	Present
A	2	" , Light	70/80	20/10	"
A	3	" "	90/100	10/0	"
B	1	" "	80/90	40/70	"
B	2	Medium, Heavy	70/90	30/10	"
B	3	" , Medium	80/100	0/0	"
B	4	Light, Light	90/90	10/0	Absent
C	1	Medium, Heavy	60/80	0/0	"
C	2	" , Medium	80/90	10/0	"
C	4	" , "	80/90	10/10	"
C	5	Light, Light	60/70	20/10	"
D	1	" "	40/80	10/10	Present
D	2	" "	10/80	90/20	"
D	3	" -----	40/10	50/90	"
D	4	" , Light	70/80	50/0	"

* Estimates for two joints are reported.

TABLE VI (Cont'd.)

RESULTS OF IMPACT TESTS OF BRAZED JOINTS OF T2 BAYONETS

Lot	No.	Intensity of Hammer Blow Necessary to Cause Breakage *	Estimated Percentage of Joint Area Covered by Braze Metal *	Estimated Percentage of Joint Area Oxidized *	Occurrence of Trapped Flux
E	1	Light, Light	60/70	30/20	Present
E	2	" , Medium	80/90	10/0	Absent
E	3	" , Light	50/80	40/10	Present
E	4	" , Medium	60/80	30/0	"
E	5	" , Light	70/80	30/10	"

* Estimates for two joints are reported.

TABLE VII

RESULTS OF MICROEXAMINATION OF COPPER BRAZED JOINTS BETWEEN GUARD AND BLADE AT LONGITUDINAL SECTION OF 17 T2 BAYONETS

Lot No.	Maximum Thickness of Brazed Joint in Inches*	Uniformity of Thickness of Brazed Joint	Percent of Voids at Joint	Number of Corners at Which Voids Exist	Number of Cracks Present at Joint	Approximate Size of Cracks in Inches	Occurrence of Grain Boundary Penetration of Blade by Braze Metal
A 1	.0025, ---	Fairly Uniform	23	2	0	---	None
A 3	.003, .001	"	25/33	4	0	---	"
B 1	.003, .004	Nonuniform	0/0	0	2	.015, .027	Substantial
B 2	.001, .0015	Fairly Uniform	8/0	0	0	---	Slight
B 3	.002, .0015	"	0/0	0	0	---	None
B 4	.001, .002	"	0/0	0	0	---	Slight
C 1	.003, .002	"	8/8	0	0	---	"
C 5	.003, .004	Nonuniform	17/0	0	0	---	None
D 1	.0028, .001	"	38/17	4	0	---	"
D 3	.002, -----	Fairly Uniform	42	2	0	---	"
D 4	.001, .0015	Nonuniform	33/23	4	0	---	"
E 1	.001, .0018	"	78/38	1	0	---	"
E 3	.0015, .001	Fairly Uniform	15/23	2	0	---	"

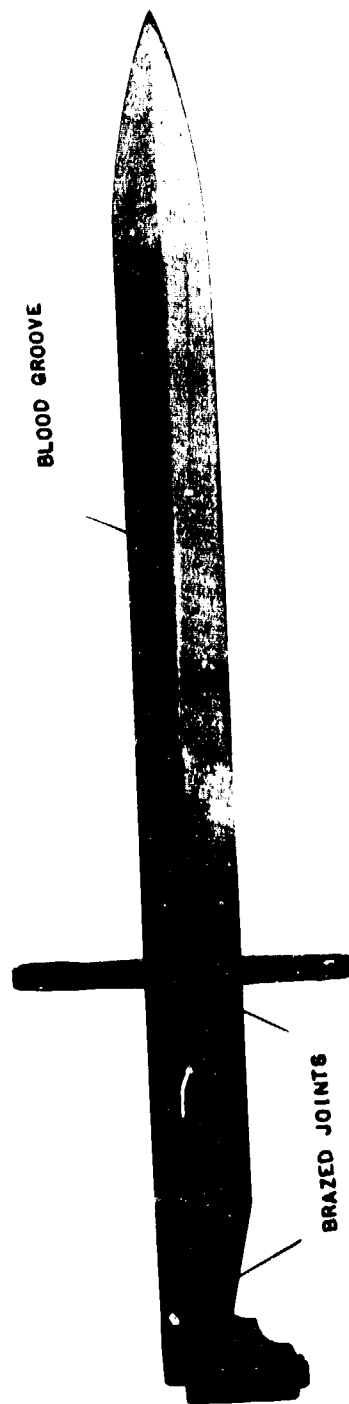
*Results for two joints are reported.

TABLE VII (Cont'd.)

RESULTS OF MICRO EXAMINATION OF COPPER BRAZED JOINTS BETWEEN GUARD AND BLADE AT LONGITUDINAL
SECTION OF 17 T2 BAYONETS

Lot No.	Maximum Thickness of Brazed Joint in Inches	Uniformity of Thickness of Brazed Joint	Percent of Voids at Brazed Joint	Number of Corners at Which Voids Exist	Number of Cracks Present at Joint	Approximate Size of Cracks in Inches	Occurrence of Grain Boundary Penetration of Blade by Braze Metal
E 5	.005, .006	Nonuniform	3/17	0	2 large 4 small	.026, .035 .013 max.	Substantial
F 1	.0025, .003	Fairly Uniform	0/0	0	0	---	None
F 2	.0005, .001	"	0/0	0	0	---	"
F 4	.004, .0025	"	0/17	0	0	---	"

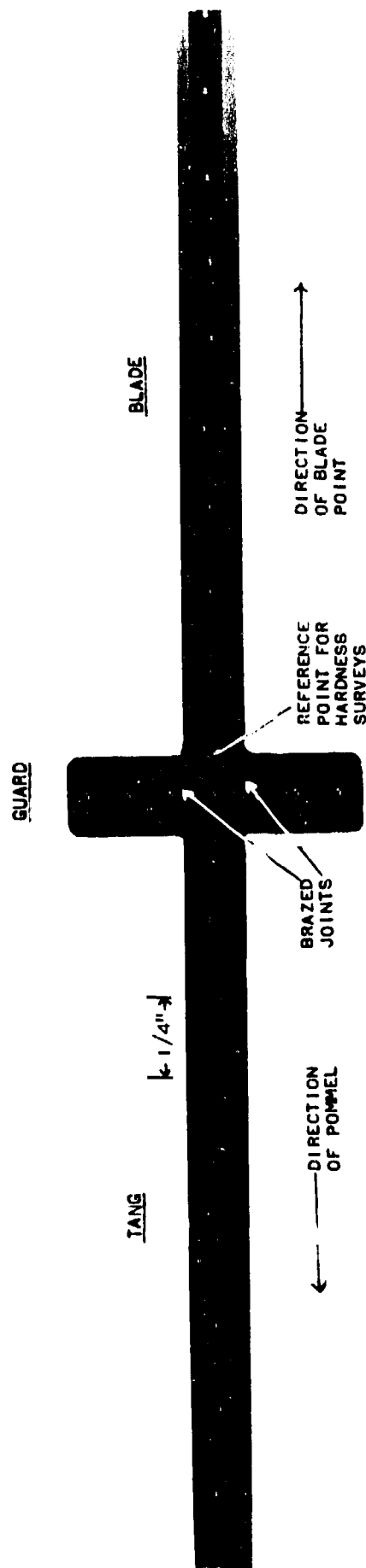
*Results for two joints are reported.



WATERTOWN ARSENAL

FIGURE 1

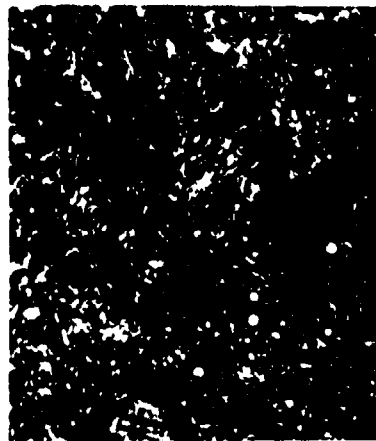
PHOTOGRAPH OF T2 BAYONET SHOWING LOCATION OF BRAZED JOINTS AND BLOOD GROOVE
29 JULY 1944
MAG. X $\frac{1}{2}$
VTN.693-63



WATERTOWN ARSENAL

FIGURE 2

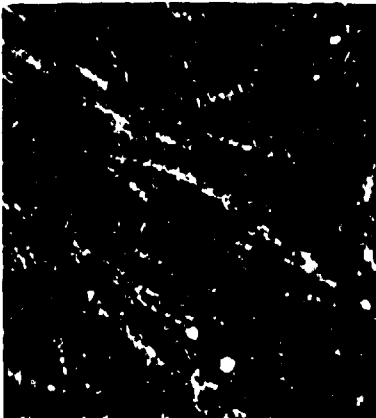
LONGITUDINAL SECTION OF T2 BAYONET IN VICINITY OF GUARD SHOWING HARDNESS SURVEY.
 ROCKWELL "C" HARDNESS READINGS WERE TAKEN $\frac{1}{4}$ " APART ALONG BLADE AND TANG. MAG. X 2
 29 JULY 1944 WTN.003-65



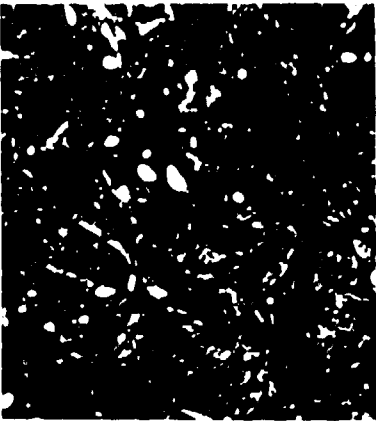
PICRAL -A- X1500
BAYONET A1 BLADE. BAINITE AND CARBIDES.



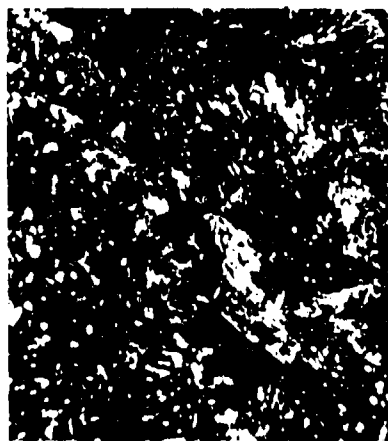
PICRAL -B- X1500
BAYONET B2 BLADE. BAINITE, TEMPERED MARTENSITE, AND CARBIDES.



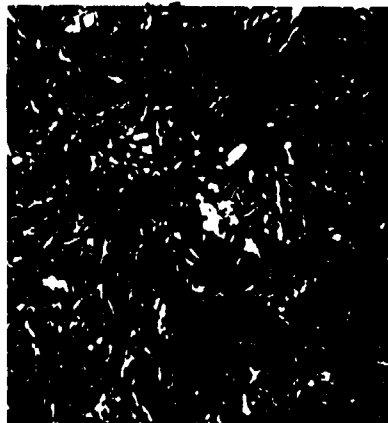
PICRAL -C- X1500
BAYONET E3 BLADE. ACICULAR BAINITE AND CARBIDES.



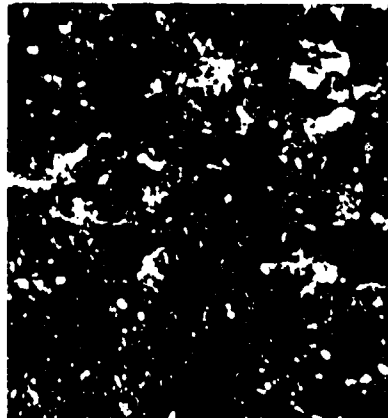
PICRAL -D- X1500
BAYONET F4 BLADE. TEMPERED MARTENSITE, AND CARBIDES.



PICRAL -E- X1500
BAYONET A3 BLADE. BAINITE, PRIMARY TROOSTITE, AND CARBIDES



PICRAL -F- X1500
BAYONET B4 BLADE. PRIMARY TROOSTITE AND CARBIDES PRESENT



PICRAL -G- X1500
BAYONET F2 BLADE. PRIMARY TROOSTITE, AND CARBIDES.

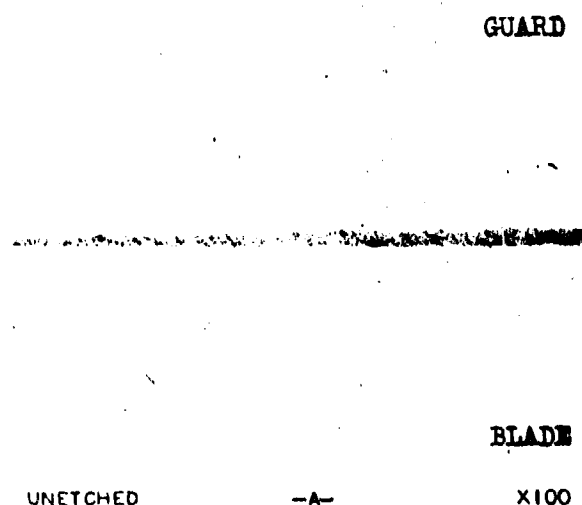


PICRAL -H- X1500
BAYONET F3 BLADE. ADJACENT TO GUARD. PEARLITE AREAS, AND CARBIDES.

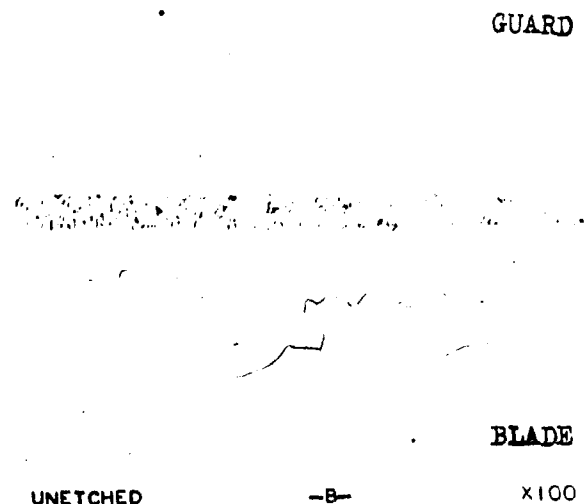
FIG. 3 PHOTOMICROGRAPHS OF T2 BAYONET BLADES.

WTN.639-6694

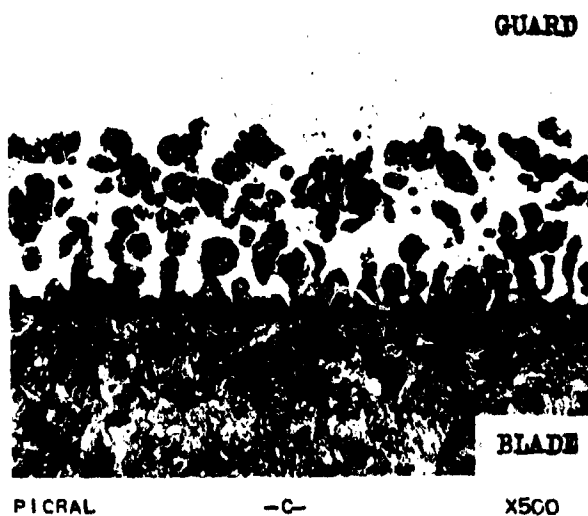
F. 1.



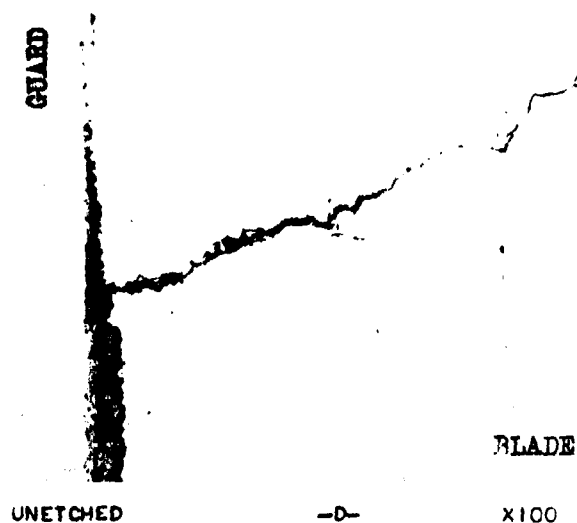
UNETCHED -A- X100
BAYONET F2 JOINT. UNIFORM BRAZE METAL LAYER .001" IN THICKNESS.



UNETCHED -B- X100
BAYONET E5 JOINT. NETWORK FORM OF BRAZE METAL ON BLADE SIDE. CRACKS PRESENT IN BLADE.



PICRAL -C- X500
BAYONET E5 JOINT. PENETRATION OF BRAZE METAL ALONG GRAIN BOUNDARIES OF BLADE.



UNETCHED -D- X100
BAYONET E5 JOINT. CRACK FILLED WITH BRAZE METAL EXTENDS .026" IN BLADE.

FIGURE 4. PHOTOMICROGRAPHS OF BRAZED METAL JOINTS BETWEEN BLADE AND GUARD OF T2 BAYONETS
WTN,639-6995



PICRAL -A- X500
BAYONET E5 JOINT. CRACK FILLED WITH
BRAZE METAL IN BLADE. NO DECARBURIZATION
IN VICINITY OF CRACK.



UNETCHED -B- X500
BAYONET E1 JOINT. CONSIDERABLE VOIDS
PRESENT. OXIDES PRESENT IN GUARD.



UNETCHED -C- X100
BAYONET E1 JOINT. ANSENCE OF BRAZE
METAL AT CORNER. OXIDES PRESENT IN
GUARD.



UNETCHED -D- X100
BAYONET B1 JOINT. CORNER FILLED WITH
BRAZE METAL. CRACK EXISTS IN BLADE.

FIGURE 5. PHOTOMICROGRAPHS OF BRAZED METAL JOINTS BETWEEN BLADE AND GUARD OF T2 BAYONETS
WTN.639-6996 FIG. 5

APPENDIX A

RESTRICTED

WAR DEPARTMENT

OFFICE OF THE CHIEF OF ORDNANCE

Flanagan/es

O.O. No. 474.7/2021

Washington, D. C.

73174

Attention of
SPOTS

Subject: Directive for Test of Bayonets T2

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Attn: Colonel Zornig

1. Reference is made to letter from this office dated 25 November 1943, O.O. 474.7/1702 and Report No. W.A.L. 739/37 dated 5 April 1944.

2. Forwarded this date by Shipping Order No. SPOTS 10-5840 are twelve (12) Bayonets, T2 representing a partial shipment of some twenty-five (25) bayonets. The remainder will be forwarded upon receipt from the facility. Break down is as follows:

- 3 each "C" with blood groove
- 3 each "F" with blood groove
- 3 each "C" without blood groove
- 3 each "F" without blood groove

These bayonets have been developed on a Research and Development contract by the Edison General Electric Appliance Company in an effort to obtain a bayonet of higher strength than the M1 bayonet. It should be noted that this design incorporates a blade fabricated from rolled strips instead of a forging. The guard and pommel are brazed to the blade, the tang is not cut away and the point is ground differently to afford a thicker section. Bayonets are stamped with a letter on blade or guard indicating steel and heat treatment and a sheet listing this code is inclosed.

3. It is requested that your Arsenal undertake a study of these sample bayonets in an effort to determine the material and heat treatment which provides the strongest and most durable bayonet, a determination of the effect of hydrogen-copper brazing on the blade near the guard, and a comparison of the T2 bayonet with the bayonets tested in report cited in 1st paragraph. It is further requested this action be expedited.

By order of the Chief of Ordnance:

/s/t

Rene' R. Studler
Colonel, Ord. Dept.
Assistant.

2 Incls.

- #1 S.O. #SPOTS 10-5840
- #2 Code on Hotpoint Bayonets

RESTRICTED

APPENDIX A (Cont'd)

DC40

HOTPOINT BAYONETS

IDENTIFICATION OF STEEL AND HEAT TREATMENT

<u>Symbol</u>	<u>Steel</u>	<u>Heat Treatment</u>
A	WD1080	Austempered, American Steel & Wire Co.
B	WD1080	Isothermal, Ajax Electric Company
C	WD1080	Quench and Draw, Lindberg Steel Treating Co.
D	WD1095	Austempered, American Steel & Wire Co.
E	WD1095	Isothermal, Ajax Electric Company
F	WD1095	Quench and Draw, Lindberg Steel Treating Co.

Edison General Electric Appliance Co., Inc.
Chicago, Illinois

March 7, 1944

APPENDIX B

ROCKWELL "C" HARDNESS SURVEYS OF LONGITUDINAL SECTIONS OF TANGS AND BLADES IN VICINITY OF GUARDS
OF SIX LOTS OF T2 BAYONETS

Lot	No.	Tang					Front of Guard					Blade				
		-2 1/2"	-2"	-1 1/2"	-1"	-3/4"	-1"	-1/4"	0"	+1/4"	+1"	+3/4"	+1"	+1 1/2"	+2"	+3"
A	1	44.5	43.5	43.5	46.5	43.5	43.5	39.5	41.5	43.5	43.5	42.5	44.5	49.5	49.5	47.5
	2	47.5	44.5	43.5	42.5	42.5	42.5	38.5	39.5	43.5	43.5	43.5	46.5	49.5	49.5	49.5
	3	42.5	40.5	42.5	48.5	44.5	42.5	40.0	38.5	42.5	41.5	40.5	41.5	42.5	42.5	41.5
B	1	48.5	48.0	48.5	48.5	48.5	49.5	48.5	43.5	44.5	48.5	49.5	48.5	49.5	48.5	46.5
	2	51.5	50.5	50.5	52.5	47.5	42.0	43.0	47.5	50.5	51.5	53.5	54.0	54.5	53.5	54.0
	3	49.5	48.5	47.5	49.5	50.5	48.5	35.0	43.0	48.5	48.5	49.5	49.5	49.5	48.5	48.5
	4	43.5	42.5	41.5	42.5	43.5	43.5	42.5	41.5	42.5	41.0	40.5	41.5	42.5	43.0	43.5
C	1	51.5	52.5	52.5	53.0	52.5	42.5	38.5	41.5	45.5	45.5	47.5	43.5	47.5	49.0	49.0
	2	52.0	49.5	50.5	52.0	50.0	40.5	39.5	43.5	45.5	48.5	51.5	52.0	50.5	51.0	51.0
	4	51.0	52.0	51.5	52.0	52.0	52.5	45.5	44.5	51.5	52.0	52.0	53.0	51.5	51.5	51.5
	5	51.5	51.5	52.5	51.5	53.0	44.0	38.5	41.0	45.5	50.5	51.0	51.5	51.5	51.5	51.5
		44.5	50.5	50.5	41.5	45.0	44.5	42.5	42.5	44.5	46.5	48.5	50.5	52.0	51.5	51.0
D	1	50.5	49.5	50.5	49.5	49.5	45.5	43.5	43.5	46.5	49.5	50.5	50.5	50.5	50.5	49.5
	2	50.5	50.5	49.5	49.5	47.5	45.5	42.5	43.5	45.5	46.5	49.5	50.5	50.5	49.5	49.5
	3	52.5	52.5	52.5	53.0	53.0	49.5	44.5	45.0	46.5	45.5	46.5	47.0	50.0	50.0	50.0
	4	47.5	45.5	47.5	48.5	47.5	46.5	44.5	45.5	48.5	48.5	48.5	43.5	49.0	49.5	48.5
E	1	47.0	45.5	45.5	46.0	45.5	45.5	44.5	43.0	45.5	46.0	46.5	46.5	46.0	45.5	46.5
	2	48.5	47.5	47.5	46.5	47.5	45.5	43.5	42.5	45.5	45.5	47.5	47.5	47.5	48.5	48.5
	3	45.5	47.5	46.5	48.0	48.5	47.5	45.5	45.5	48.5	43.5	47.5	48.5	47.5	46.5	47.5
	4	46.5	46.5	46.5	45.5	47.5	47.5	46.5	46.5	46.5	42.5	40.5	40.5	42.5	45.5	46.5
	5	46.5	49.5	49.5	50.5	50.5	49.5	43.5	42.5	42.5	42.5	43.5	43.5	49.5	48.5	49.0
F	1	45.5	51.5	51.5	50.5	48.5	43.5	39.5	43.0	40.5	39.5	39.5	39.0	41.5	43.0	43.0
	2	45.5	50.5	51.5	50.5	51.5	45.5	42.5	41.5	43.5	42.5	43.5	45.5	51.5	50.5	51.0
	4	50.5	50.5	51.5	50.5	49.5	43.5	42.5	42.5	44.5	40.5	42.5	44.5	51.0	50.5	51.0
	5	50.5	50.5	51.5	50.5	49.5	43.5	42.5	42.5	44.5	40.5	42.5	44.5	51.0	50.5	51.0
		46.5	49.5	49.5	50.5	50.5	49.5	43.5	42.5	42.5	42.5	43.5	43.5	49.5	48.5	49.0

UNCLASSIFIED



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 843~~, 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 Examination 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

