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REPORT NO. 710/55

EXAMINATION OF SAMPLES  
OF  
LIGHT ARMOR PLATE

BY

R. M. REED

APPENDIX BY

G. J. BONNE

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*Captain Deal  
Oklahoma Nat Guard ✓*

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Report No. 710/55  
Watertown Arsenal

June 17, 1936

Examination of Samples  
of  
Light Armor Plate

References

O. O. 400.111/4298, Neal, Hugh A.  
8th C. A. 400.111/29 - Wtn 400.111/43 dated  
March 1936.

O. O. 400.11/4318, Neal, Hugh A. Wtn 400.11/44  
dated April 1936.

Purpose

The purpose of this investigation was to determine the composition, structure and ballistic properties of the treated samples.

Conclusions

1. The treated samples under consideration were not satisfactory from the point of view of ballistic efficiency and freedom of pronounced cracks and brittleness.

2. The microstructure of the treated samples was typical of case hardened plate which had been quenched from a temperature considerably above the critical range of case and core. Both faces of the plate were case hardened.

3. Chemical analysis of the untreated sample showed it to be a low carbon steel plate.

4. The results of the tests described herewith indicate that the material is not suitable for light armor plate.

History of Samples

Captain Hugh A. Neal, Service Battery, 158th Field Artillery, Commanding, submitted to the Ordnance Officer, Ft. Sam Houston, Texas, as per his letter of March 16, 1936, three samples of armor plate, one untreated and two treated. By direction of the Chief of Ordnance the samples were sent to Watertown Arsenal for test.

According to Captain Neal, letter dated 3/16/36 to the Ordnance Officer, Ft. Sam Houston, Texas, the samples of steel both treated and untreated have been fired on with a service rifle and service ammunition at a distance of twenty yards. Also, in his letter dated 3/25/36 to the Chief of Ordnance, Washington, D. C. Captain Neal states that the plates were not hardened by a case hardened process. The samples submitted were from 5" to 7" in length, about 3" wide and 3/8" thick.

An examination of the treated samples subjected to the ballistic test as mentioned above indicated that the plates lacked toughness and ductility. Circumferential cracks were observed at some areas of impact of the bullet, while on the back face of the plate radial cracks were detected.

No complete penetrations were found on the treated samples, while the untreated sample was easily penetrated by the ammunition used, see Figures 1, 2, 3, 4, 5 and 6.

#### Experimental Procedure

The untreated and treated samples were subjected to spectrographic analysis, chemical analysis, microscopic examination and hardness tests.

Ballistic tests were made on the treated samples using Cal. .30 M1922 A.P. 165 gr., core 87.5 gr., 1900 f/s striking velocity preloaded ammunition at a distance of 100 yards. The samples were mounted on a wooden frame, the back of the plates being unprotected.

## Experimental Results

### 1. Spectrographic analysis

Traces of calcium were detected in the untreated and treated samples.

### 2. Chemical analysis

The results of the chemical analysis made on the untreated sample is as follows:-

<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>W</u>	<u>Va</u>
.19	.42	.025	.034	.012	Nil	.05	Nil	Nil	Nil

### 3. Microscopic Examination

Microscopic examination of the untreated and treated samples is discussed by S. LaBonte in the appendix.

### 4. Brinell Hardness

The Brinell hardness of the samples is given below:-

	Untreated sample	-	121
Treated sample "A"	Case - front	533	
"	"	Case - back	533
"	"	Core -	286
Treated sample "B"	Case - front	533	
"	"	Case - back	533
"	"	Core -	286

## 5. Ballistic Tests

The results of the ballistic test are as follows:

Thickness of plate 3/8"  
Distance from plate to muzzle - 100 yards

<u>Plate No.</u>	<u>Round No.</u>	<u>Striking Velocity</u>	<u>Penetration</u>	<u>Appearance of Back Plate</u>
Treated "A"	1	1900 f/s	Partial	Crack from edge of plate to round 2
	2	1900 f/s	Complete	Large radial cracks on same spot as former impact
Treated "B"	1	1600 f/s	Partial	No bulge, no cracks
	2	1900 f/s	Partial	No bulge, plate cracked into two pieces through area of impact

Note: According to U. S. Army Tentative Specification AXS - 54, Rev. 2, July 31, 1934, paragraph V 2 b, c, the plates lacked sufficient toughness and ductility to be of good quality armor plate. A 3/8" plate should resist Cal. .30 A. P. M1922 ammunition with a striking velocity of 1950 f/s.

### Discussion

Chemical analysis of the material submitted in the untreated state indicates that it is a plain low carbon steel.

Microscopic examination clearly shows that the samples have been case hardened and subsequently quenched from a temperature considerably above the critical range.

Both surfaces of the plate have been case hardened. A treated sample was heated above the critical temperature of the case and core and cooled slowly in order to determine the depth of case, the results of which are as follows:

Depth of Hyper-eutectoid case	.02"
" " Eutectoid case	.01"
" " Hypo eutectoid case	.025"

The results of the Brinell hardness tests are representative of martensitic case hardened low carbon steels.

The results of the ballistic tests showed that the treated plates resisted penetration by armor piercing bullets of the specified caliber and striking velocity, but since the plates lacked the proper toughness, that is, radial cracks developed on the back face by bullet impacts, the plates are not suitable for good quality armor plate.

In one case, plate "B", the impact of an armor piercing bullet with a striking velocity of 1900 F/S cracked the plate into two pieces, indicating the plate was extremely brittle.

Photographs illustrating the brittleness of the plates resulting from the ballistic tests as described by Capt. Neal in his letter of March 16, 1936 to the

Ordnance Officer, Ft. Sam Houston, Texas, are shown in Figs. 3, 4, 5 and 6.

Photographs illustrating the lack of toughness in the plates after the Ballistic tests at Watertown Arsenal, are shown in Figs. 7, 8, 9 and 10.

Recommendations

The results of the tests described above indicate that the treated samples submitted are not suitable for armor plate.

Ref. W. A. Report No. 115/92

Ref. W. A. Report No. 115/93

Respectfully submitted,

*E. L. Reed.*  
E. L. Reed

FIGURE 1.

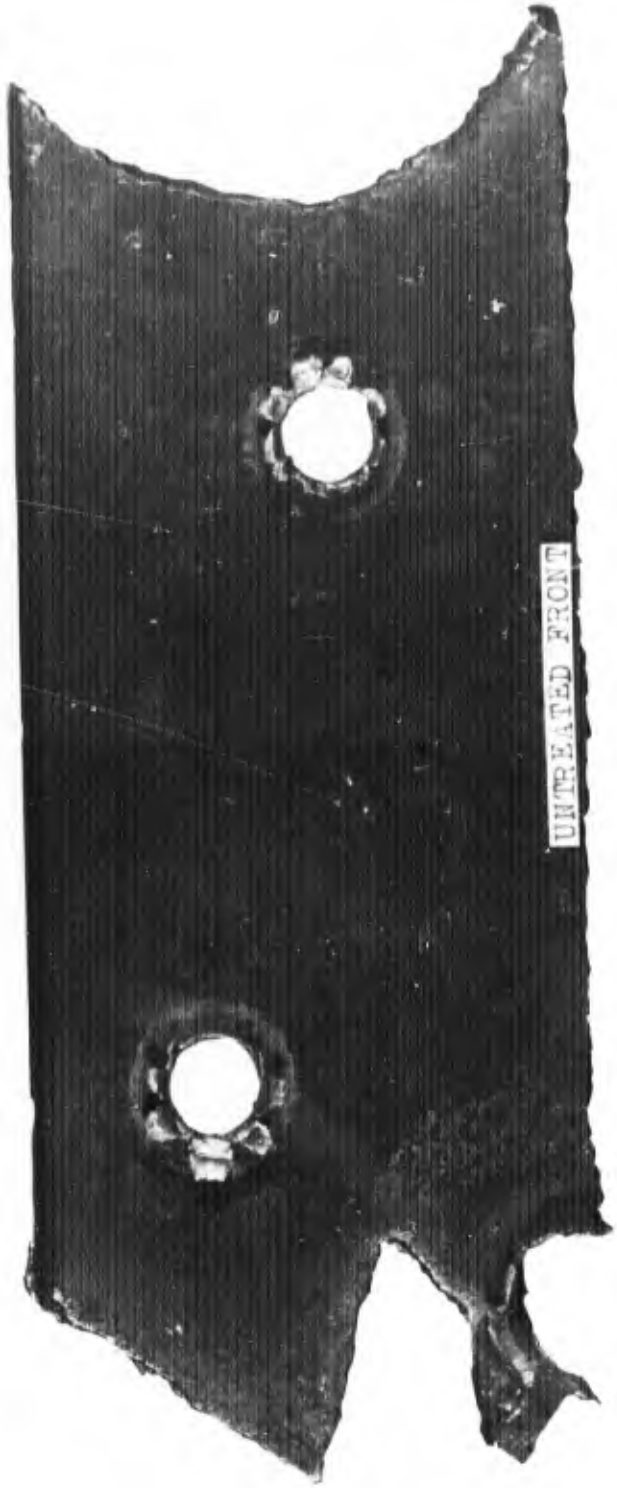
Untreated Sample

Front Face

Brinell Hardness 121

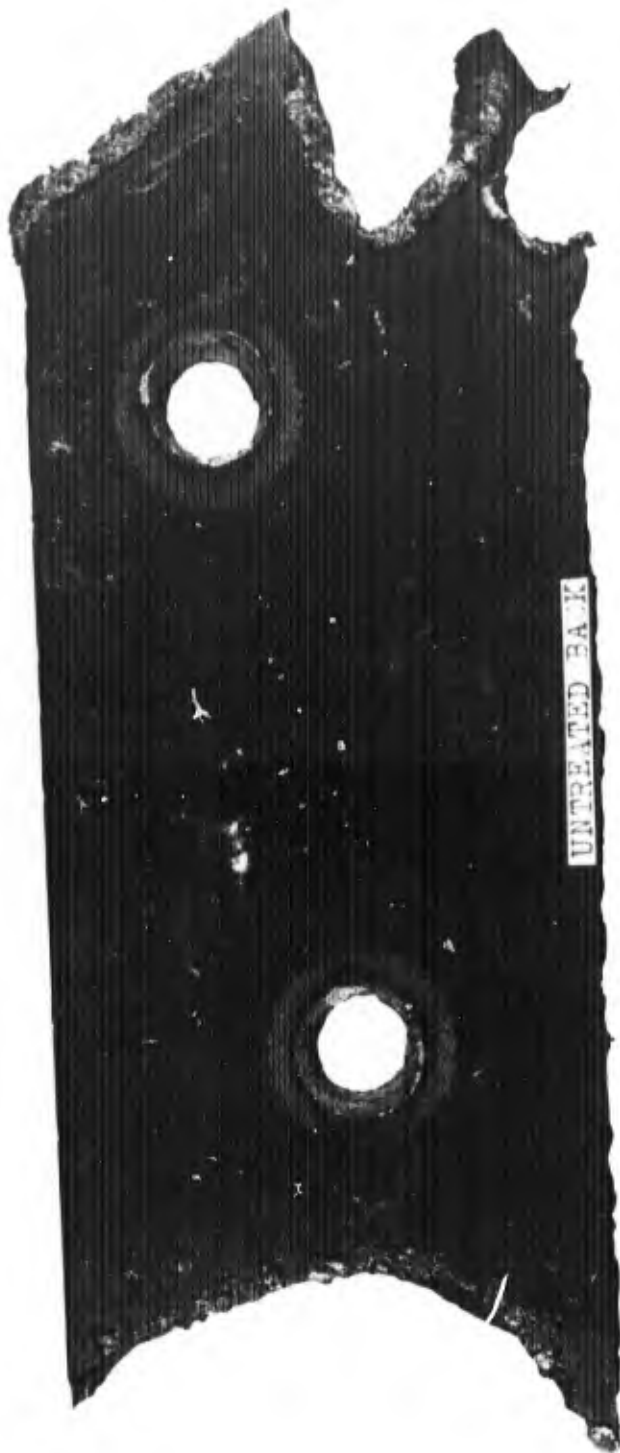
Fired at with a service rifle and  
service ammunition, at a distance of 20  
yards.

Ref:- Capt. Neal's letter dated  
March 16, 1936, to Ordnance Officer,  
Fort Sam Houston, Texas.



ORDNANCE DEPT U.S.A.  
WATERDOWN ARSENAL  
4-6-36 710-1R4

FIGURE 2.  
Untreated Sample  
Back Face



UNTREATED BACK



ORDNANCE DEPT. U.S.A.

4-6-36 <sup>WINDY</sup> ARSENAL

710-185

FIGURE 3.

Treated Sample "A"

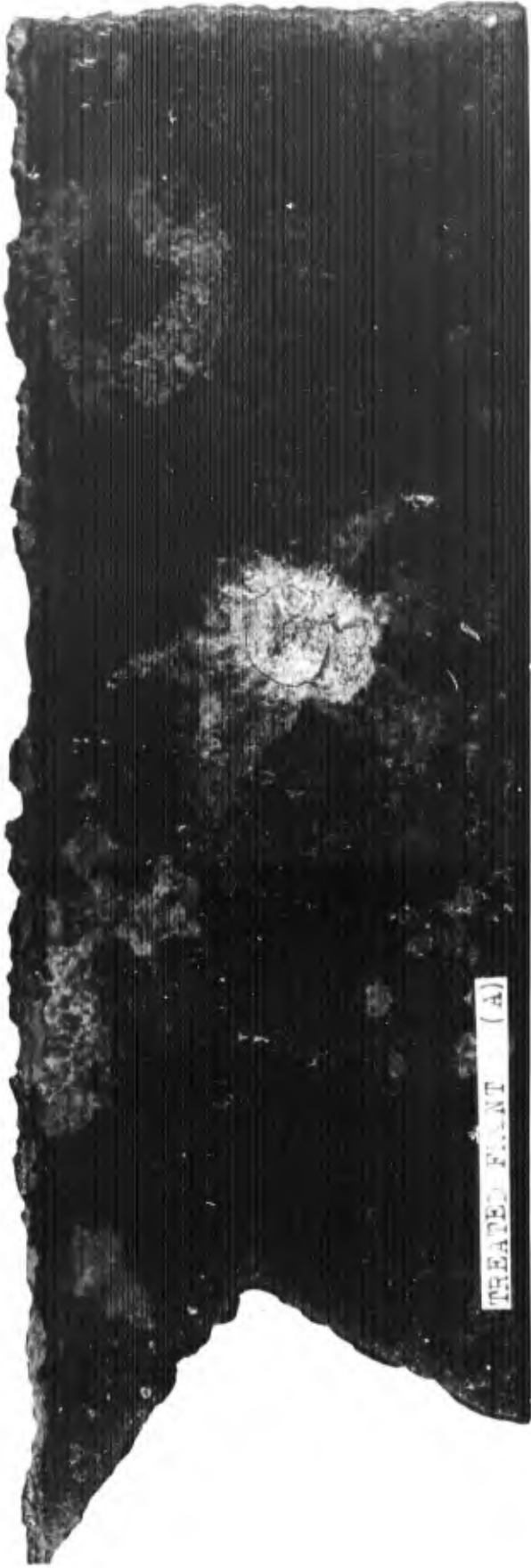
Front Face

Brinell Hardness case-front-533

Brinell Hardness core -286

Fired at with a service rifle and service  
ammunition at a distance of 20 yards.

Ref:- Capt. Neal's letter dated March 16,  
1936 to Ordnance Officer, Fort Sam Houston,  
Texas.



TREATED FABRIC (A)

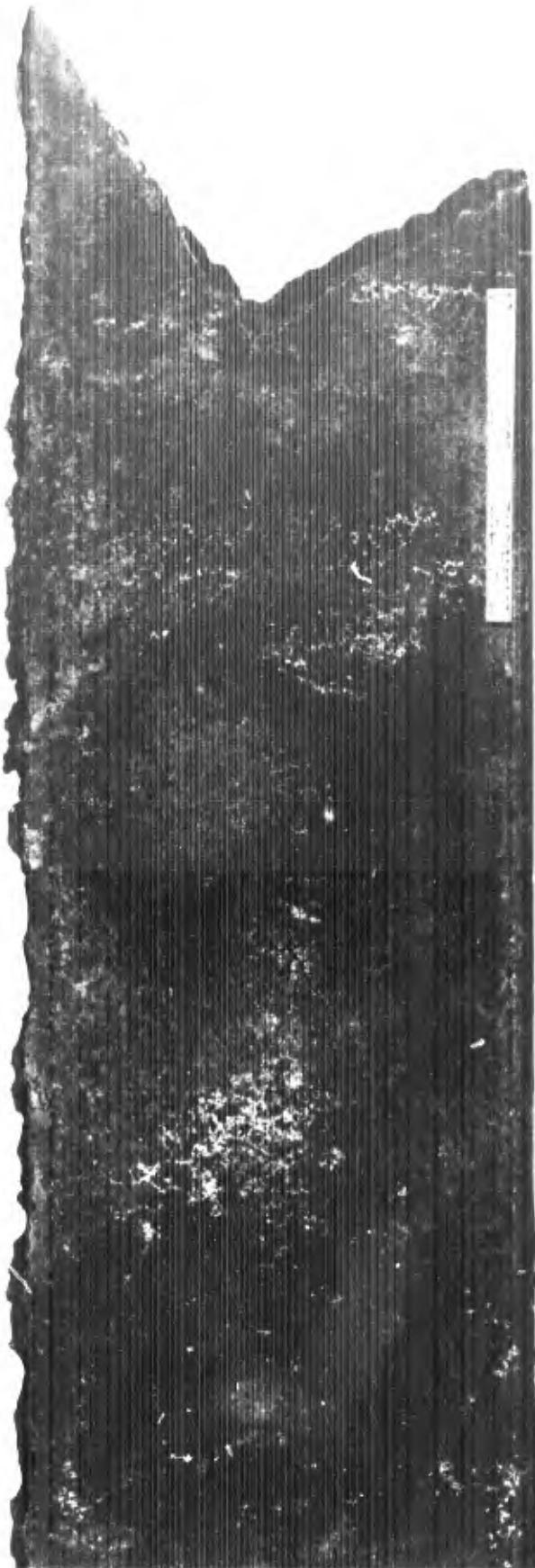


ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL

4-6-36 710-186

FIGURE 4.  
Treated Sample "A"  
Back Face

Brinell Hardness case-front-533  
Brinell Hardness core -286



INCHES  
3  
2  
1  
ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL  
5-6-61 731-14

FIGURE 5.

Treated Sample "B"

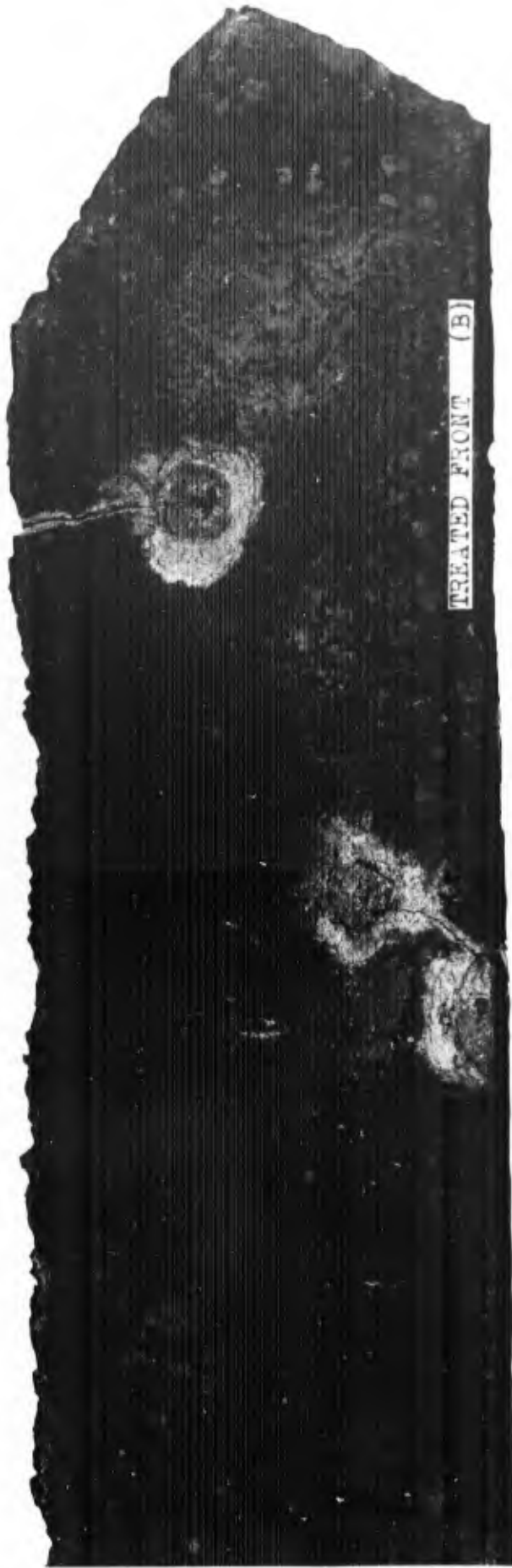
Front Face

Brinell Hardness case-front-533

Brinell Hardness core -286

Fired at with a service rifle and  
service ammunition at a distance of 20  
yards.

Ref:-Capt. Neal's letter dated March  
16, 1936 to Ordnance Officer, Fort Sam Houston,  
Texas.



TREATED FRONT (B)



ORDNANCE DEPT U.S.A.  
WATER TOWN ARSENAL

4-6-36 710-188

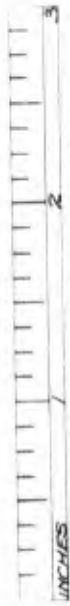
FIGURE 6.

Treated Sample "B"

Back Face

Brinell Hardness case-front-533

Brinell Hardness core -286



ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL  
4-6-66 710-189

FIGURE 7.

Treated Sample "A"

Front Face

After Ballistic Test (Watertown Arsenal)

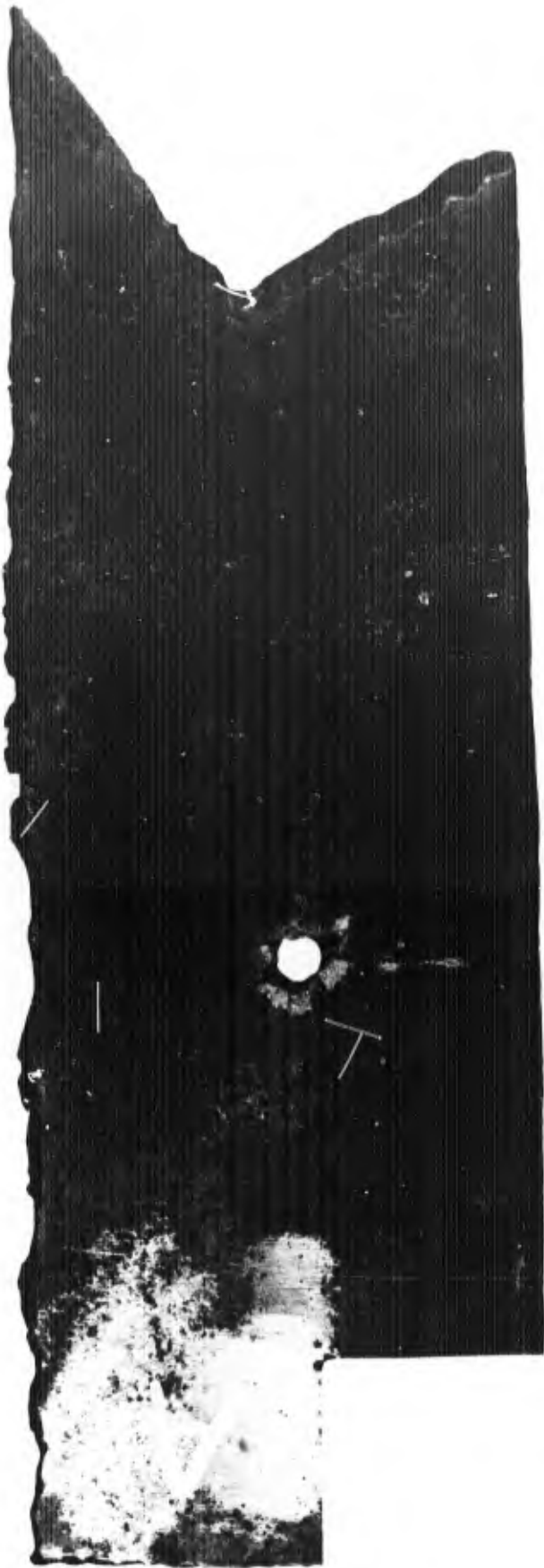
Distance from muzzle to plate 100  
yards ammunition cal .30 A.P. M 1922,  
1900 F/S striking velocity, preloaded.



ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL

#A Front 5-5-36 710-222

FIGURE 8.  
Treated Sample "A"  
Back Face



ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL

#A Back 5-6-36 710-223

FIGURE 9.

Treated Sample "B"

Front Face

After Ballistic Test (Watertown Arsenal)

Distance from muzzle to plate 100 yards,  
ammunition cal. .30 A.P. M 1922, 1600 F/S  
and 1900 F/S striking velocity, preloaded.



0061

0061-

1600

B



ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL

#B Front 5-6-36 710-224

FIGURE 10.  
Treated Sample "B"  
Back Face



ORDNANCE DEPT U.S.A.  
WATERTOWN ARSENAL

#E Back 5-6-36 710-225

B

APPENDIX

Microscopic Examination  
of Untreated and Treated  
Samples

By

S. La Bonte

FIGURE U

Untreated Specimen, U.

1.) X100 Typical area of specimen, showing ferrite and pearlite indicating an annealed low carbon (approximately 20 carbon).

MA 367

2.) X1000 Shows structure of the pearlite.

MA 368

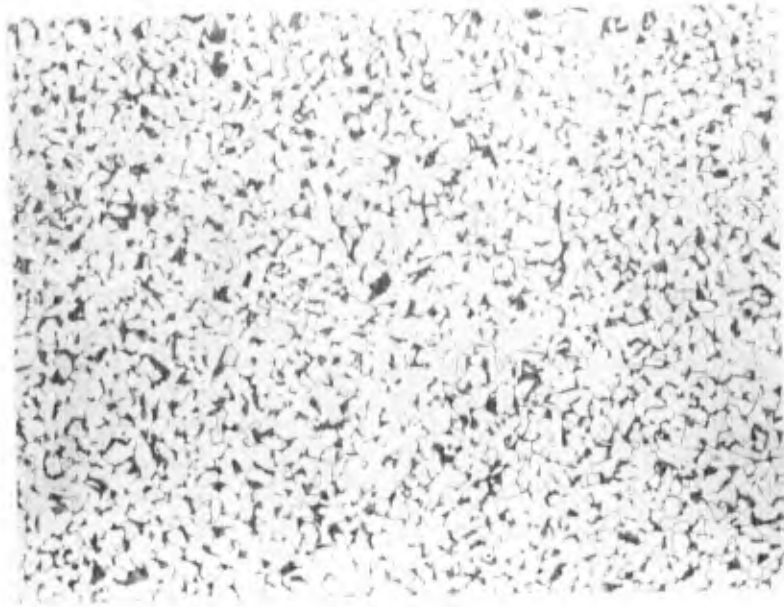


FIGURE A.

Treated Specimen - A & B

1.) X100 (A) - Case, typical of both sides and specimens showing very coarse martensite. This should be very brittle, chip and crack easily.

MA 369

2.) X100 (A) - Core, typical of both specimens. Coarse grained martensitic troostite.

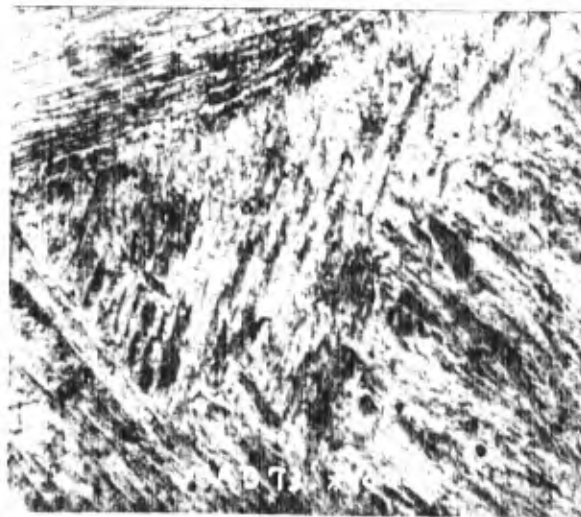
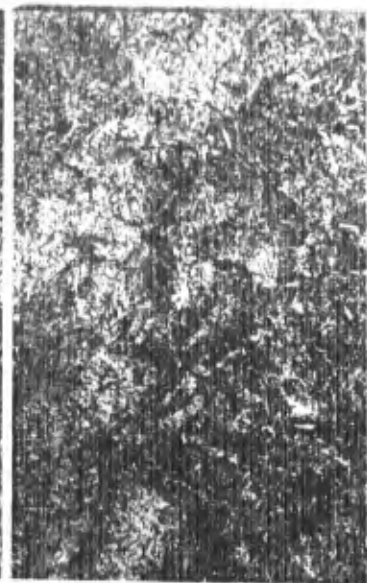
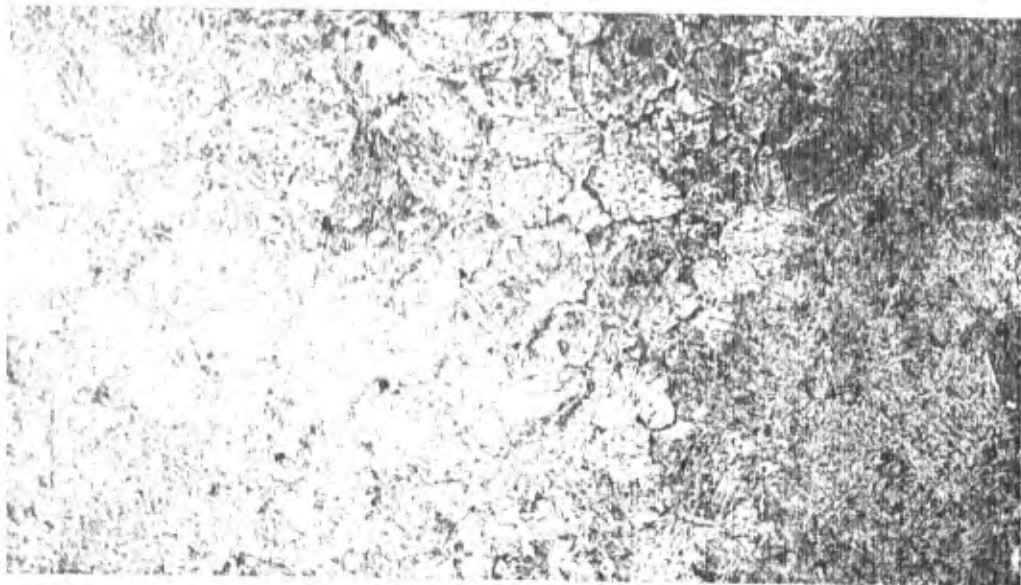
MA 372

3.) X1000 (A) - Case, showing at high power typical needles of martensite with the  $60^\circ$  angle. Evidence of sementite at the far right.

MA 374

4.) X1000 (A) - Core, pseudo-martensitic structure with both  $60^\circ$  and  $90^\circ$  angles formed by needles of ferrite.

MA 373



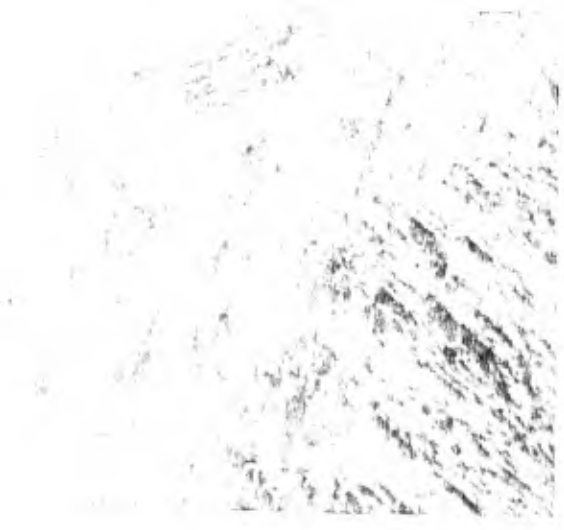
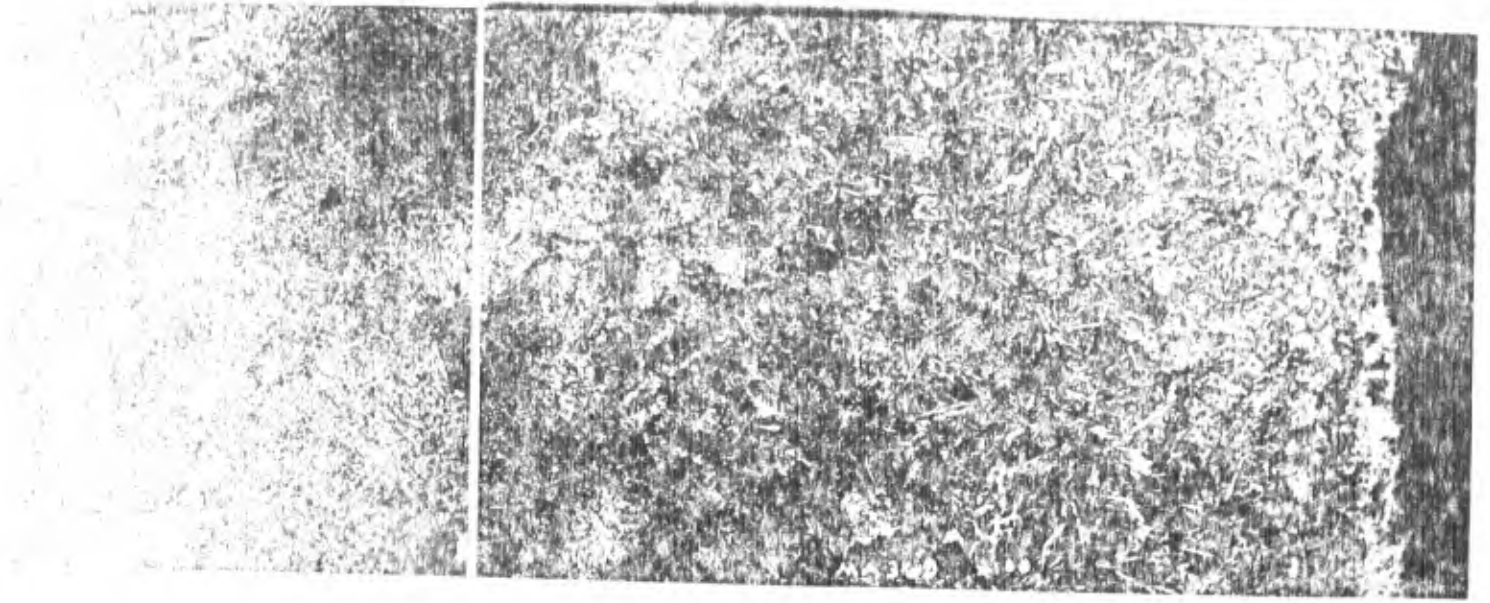


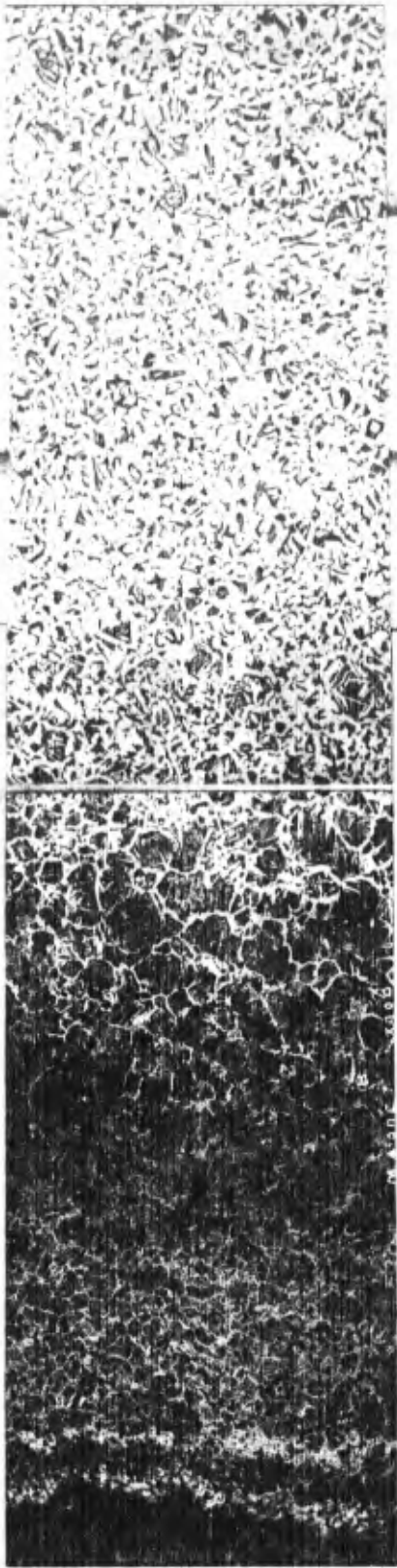
FIGURE B.

Specimen B after annealing. Previous to Watertown Arsenal treatment this specimen showed the same properties as specimen A in Fig. A.

1.) X100. - Panorama showing that the case had been carburized.

Hyper-Eutectoid----	.02 in.
Eutectoid-----	.0075 in.
Hypo-Eutectoid----	<u>.0325</u>
Total case	.06 in.

A soft skin of about .005 in. is probably due to residual scale.



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