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ARMOR SECTION

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Report No. 710/408

METALLOGRAPHIC EXAMINATION OF

3/4" HARD ROLLED HOMOGENEOUS ARMOR PLATE

By

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January 13, 1942

WATERTOWN ARSENAL
WATERTOWN, MASS.

84 10 19 039

Report No. 710/408 January 13, 1942
Watertown Arsenal

Metallographic Examination of

1/4" Hard Rolled Homogeneous Armor Plate

OBJECT

To determine the relation between banding in 1/4" hard homogeneous armor plate as revealed by the sodium picrate etch and ballistic limit.

REFERENCES

1. Letter from E. K. Spring, Henry Disston & Sons, Inc., dated September 15, 1941.

Reply by Lt. Col. S. B. Ritchie, Watertown Arsenal, dated September 18, 1941.

Reply by Lt. Col. S. B. Ritchie, Watertown Arsenal, dated September 19, 1941.

Letter from E. K. Spring, Henry Disston & Sons, Inc., dated September 22, 1941.

2. Disston Report "Metallographic Examination of 1/4" Navy Test Plates" dated September 11, 1941.

3. References to the Sodium Alkaline Picrate Etch in Literature.

The basic correspondence and material pertaining to this report are contained in Appendix A.

CONCLUSIONS

1. Conclusions Nos. 1, 2, 3, and 4 of the Disston report dated September 11, 1941 (see Appendix A) are not borne out by the investigation.

2. The banding revealed by the alkaline sodium picrate etch on the three samples submitted has no relation to the ballistic limit. (See Figures 4 and 5.)

3. A direct relationship between ballistic limit and hardness was found to exist for the three plates submitted for this investigation, the plate with the highest hardness having the highest ballistic limit. (See Figure 11.)

4. The banding revealed by the alkaline sodium picrate etch bears no relationship as regards relative intensity to the banding revealed by an etch in 1% nital, an electrolytic etch in 10% chromic acid, or by a macroetch with Oberhoffer's reagent. (See Figures 1A, 4, 5, 6, and 7.)

5. A good correlation was found between the intensities of the banding produced on all three plates by 1% nital, Oberhoffer's reagent, and an electrolytic etch in 10% chromic acid, the plate with the highest ballistic limit showing the greatest intensity of banding as revealed by these reagents. (See Figures 1A, 6, and 7.) This correlation was not revealed by the sodium picrate etch.

6. In all three plates, the majority of the nonmetallic inclusions, particularly the larger elongated inclusions, are found in the dark etching bands produced by the alkaline sodium picrate etch. (See Figures 20 and 5A.)

7. The bands revealed by both the nital and chromic acid etches also contain the majority of the nonmetallics, but the bands are not as numerous nor as intense as those produced by the alkaline sodium picrate. (See Figures 6 and 7.)

8. The Murakami etch shows a uniform dispersion of faint carbides in all three plates. (See Figure 2A.)

9. It is believed that the intense banding revealed by the alkaline sodium picrate etch on plates Nos. 1, 3, and 5 is not due primarily to carbide segregation.

10. Alkaline sodium picrate is not recommended as a carbide etching reagent for the following reasons:

a. Alkaline sodium picrate does not always blacken the cementite of high chromium content.

b. In manganese bearing steels, alkaline sodium picrate will bring out the distinctive banded appearance of manganese segregation.

c. In silicon steels, an alkaline solution of sodium picrate blackens ferrite containing silicon.

d. Alkaline sodium picrate blackens manganese sulphide inclusions and darkens regions rich in these inclusions and areas higher in manganese.

e. Alkaline sodium picrate etches martensite very readily and may thus lead to false conclusions regarding carbide distribution.

E. L. Reed,
Research Metallurgist.

A. Hurlich,
Jr. Metallurgist.

APPROVED:

G. L. Cox,
Major, Ordnance Dept.,
Acting Director of Laboratory.

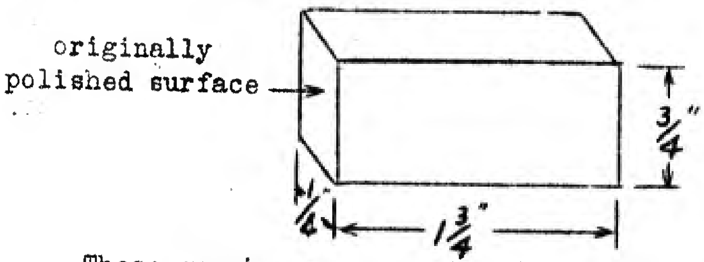
INTRODUCTION

In a report "Metallographic Examination of 1/4" Navy Test Plates" dated September 11, 1941 submitted by the Henry Disston & Sons, Inc., it was shown that banding as revealed by the sodium picrate etch was closely related with the ballistic properties. It was suggested by this company that Watertown Arsenal check these results on the same metallographic samples.

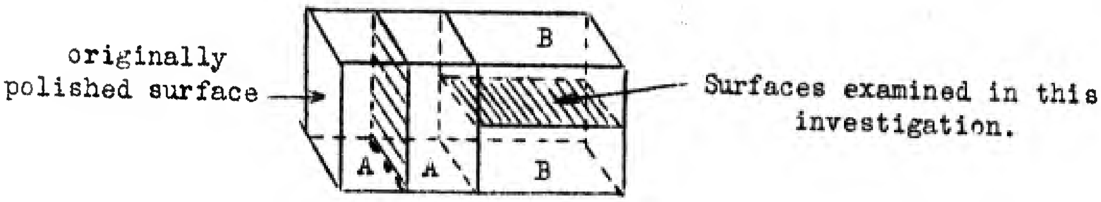
TEST PROCEDURE

A correlation of the microstructures was made after etching the samples in 1% nital, Murakami's reagent, sodium picrate, Oberhoffer's reagent, and an electrolytic etch in 10% chromic acid.

The metallographic samples, 1-3/4"x3/4"x1/4", numbered 1, 3, and 5 from heats 768-1, 1065-2, and 1618-2 respectively were received as shown below:



These specimens were cut and polished as shown below:



Specimens marked with an "A" following the plate number were polished on faces parallel to the originally polished face, and those marked "B" were polished on faces perpendicular to the originally polished face. There were two "A" and two "B" specimens from each plate.

Chemical analyses, hardness values and ballistic properties were reported by the Henry Disston & Sons, Inc.

Vickers Brinell hardness surveys were made on the cross sections of each sample.

RESULTS

1. Chemical Analyses – Reported by Henry Disston & Sons, Inc.

No.	Heat No.	C	Mn	Si	Ni	Cr	Mo	V	Cu	W
1	768-1	.45	.71	.29	.05	1.16	.70	.20	.10	none
3	1065-2	.47	.76	.25	.04	1.24	.66	.27	.10	none
5	1618-2	.48	.69	.33	.06	1.10	.69	.23	.23	none

2. Physical Properties

a. Hardness

	Reported by Disston		Reported by Watertown Arsenal	
No.	Rockwell C	Equivalent Vickers Brinell	Vickers Brinell	Rockwell C
1	53-55	608-649	526	49.5
3	52½	598	513	49.0
5	50-53	551-608	461	45.0

A Vickers Brinell hardness survey made on the cross section of the samples is shown in Figure 11.

3. Ballistic Properties – Reported by Henry Disston & Sons, Inc.

No.	Ballistic Limit Cal. .30 A.P. F/S
1	2001
3	1900
5	1726

Microscopic Examination

1. Alkaline Sodium Picrate Etch

The specimens were etched for 5 minute intervals in an alkaline sodium picrate solution, the temperature being kept just below the boiling point. It was found that a 25 minute etching period (five 5 minute cycles) produced the best degree of etching for both visual and photographic purposes.

Plate No. 5, having a ballistic limit of 1726 f/s, showed the greatest intensity of banding as well as the widest bands. Plate No. 1, with a ballistic limit of 2001 f/s, showed the second greatest intensity of banding, while plate No. 3, having a ballistic limit of 1900 f/s, showed the least intensity of banding as well as the narrowest, shortest and most diffuse bands. (See Figures 4A, B, and C at X100, and Figures 5A, B, and C at X250.)

Figures 2C and 5A illustrate the blackened inclusions of manganese sulphide that are for the greater part segregated in the dark etching bands produced by the alkaline sodium picrate.

At high magnification it appears that the alkaline sodium picrate etches grain boundaries and the martensitic structure as well as the intense banding. (See Figures 2B, C, D, E, F, and 3A, C, and E.)

2. <u>Murakami Etch</u>

The Murakami etch, see Figure 2A, shows no trace of grain boundary carbides in any of the steels.

3. <u>Nital Etch</u>

The nital etch shows a much less degree of intensity of banding than the sodium picrate etch. (See Figure 6A, B, and C at X100.) Plate No. 5, Figure 6C, shows very little banding on a nital etch whereas it had the most severe banding revealed by the picrate etch. Plate No. 1, Figure 6A, shows the most intense banding on the nital etch.

4. <u>Electrolytic Etch - 10% Chromic Acid</u>

An electrolytic etch in 10% chromic acid will reveal carbide banding and also banding due to segregations of higher carbon martensite. And as in the case of the nital etch, the banding revealed by the chromic acid is not nearly as severe as that produced by the picrate. (See Figure 7A, B, and C.) Note, in both Figures 6 and 7, the segregation of nonmetallics in the banded areas.

DISCUSSION

In order to obtain additional information concerning the use of alkaline sodium picrate, sections of Disston heats Nos. 1830 and 1843 were etched in this reagent. Figure 8A, X100, shows the heavily banded region about 1/8" wide across the midsection of heat No. 1830 containing .23 carbon, 4.88 nickel, .30 molybdenum, .09 vanadium after a 25 minute etch in alkaline sodium picrate. (See Watertown Arsenal Report No. 710/407.)

The rest of the cross section showed very faint banding. Figure 8B, X100, is typical of the whole cross section of another Disston heat 1843 of similar composition. These results appear to confirm the results obtained from the nital etch on these same specimens. (See Figure 9A and B.)

Figure 10A, X100, shows another region of the midsection of heat No. 1830 containing severe banding. Figure 10B, X1000, shows a tendency towards segregation of carbides in the grain boundaries in the matrix of the metal while Figure 10C, X1000, shows the high carbon concentration found in the bands. Again these results very closely check those previously obtained with the nital etch.

When alkaline sodium picrate is used alone it may often lead to erroneous conclusions, but when used in conjunction with etching reagents whose specific effects are well understood the use of alkaline sodium picrate may help confirm the conclusions previously arrived at, such as in heats 1830 and 1843. There are cases, such as are well illustrated by plates Nos. 1, 3, and 5, where banding resulting from some other cause than carbide segregation will cause considerable confusion.

It is because the alkaline sodium picrate reagent will respond to so many metallographic factors that this reagent is not recommended for use in the study of banding in armor plate. (See references to the sodium picrate etch in literature in Appendix A.)

Vickers Brinell Hardness Surveys

Vickers Pyramid hardness surveys made across the cross sections of the plates afford an explanation for the difference in ballistic limits obtained upon these plates. The plate with the highest ballistic limit had the highest hardness, while the plate with the lowest ballistic limit had the lowest hardness. (See Figure 11.)

Figure 1

A Plates Nos. 1A, 3A, and 5A.

Most intense banding in plate No. 1 and least intense in plate No. 5.

Oberhoffer Etch X3 MA-3798

B. Typical distribution of nonmetallics in plate No. 3B. All plates exhibit about the same concentration and distribution of inclusions.

Unetched. X25 MA-3797

Figure 9

A. Heat 1830

Banded region 1/8" wide in middle of cross section of plate.

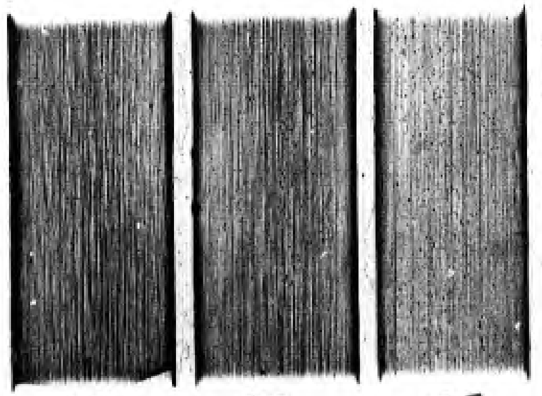
Etched in 1% Nital X100 MA-3772

B. Heat 1843

Uniform microstructure throughout plate.

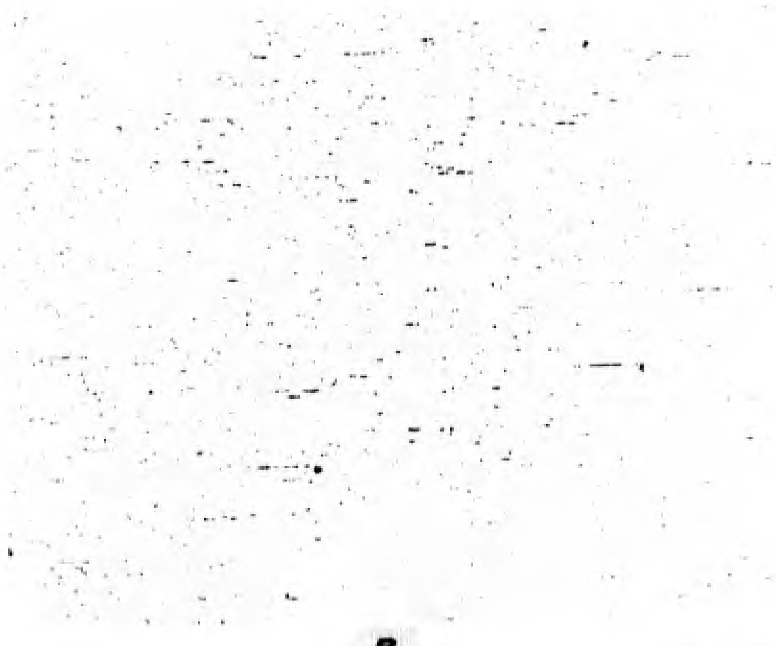
Etched in 1% Nital. X100 MA-3824

FIGURE 1.



1A 3A 5A

A.



B.

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Figure 2

A. Plate No. 3B.

Carbide distribution typical of all plates.

Murakami Etch X1000 MA-3775

B. Plate No. 1A

Banding and microstructure revealed by alkaline sodium picrate.

Etched for 20 minutes (4 5-minute cycles).
X1000 MA-3776

C. Plate No. 3A

Blackened inclusions of manganese sulfide segregated in banded zone.

Etched for 20 minutes in alkaline sodium picrate (4 5-minute cycles). X1000 MA-3777

D. Plate No. 3A

Typical banded region. Tendency towards spheroidal structure.

Etched for 20 minutes in alkaline sodium picrate (4 5-minute cycles). X1000 MA-3782

E. Plate No. 5A

Banded structure. Grain boundaries revealed by alkaline sodium picrate.

Etched for 20 minutes (4 5-minute cycles).
X1000 MA-3779

F. Plate No. 5A

Banded structure typical of plate.

Etched for 20 minutes in alkaline sodium picrate (4 5-minute cycles). X1000 MA-3780

FIGURE 2.

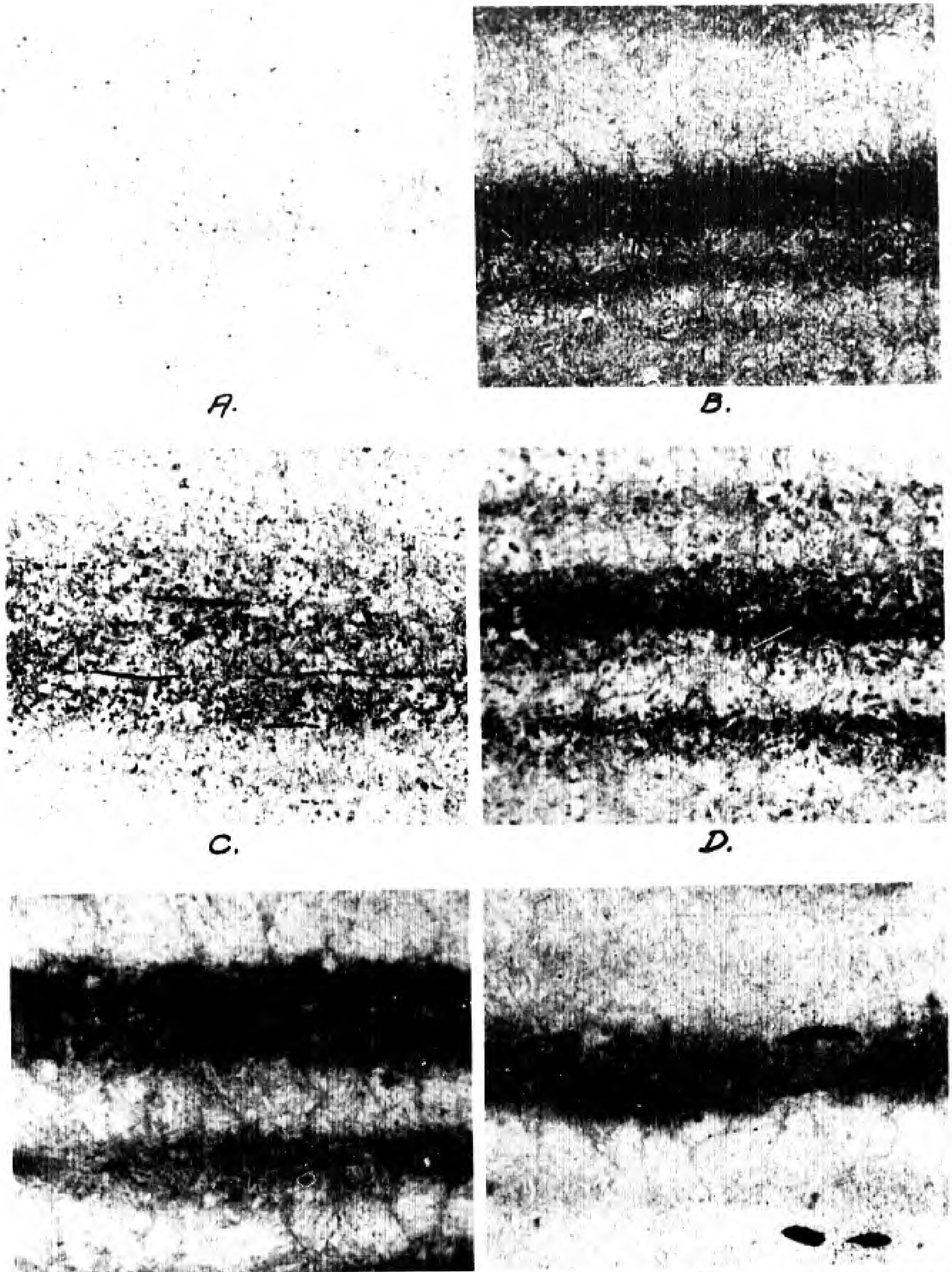

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Figure 3

A. Plate No. 1A

Typical banded structure. Microstructure and grain boundaries etched.

Etched for 25 minutes in alkaline sodium picrate (5 5-minute cycles) X1000 MA-3781

B. Plate No. 1A

Martensitic microstructure and band.

1% Nital Etch X1000 MA-3793

C. Plate No. 3A

Banded region with spheroidized appearance.

Etched for 25 minutes in alkaline sodium picrate (5 5-minute cycles) X1000 MA-3783

D. Plate No. 3A

Fine grained martensite.

1% Nital Etch X1000 MA-3792

E. Plate No. 5A

Intense banding typical of this plate. Tendency towards etching of grain boundaries.

Etched for 25 minuted in alkaline sodium picrate (5 5-minute cycles) X1000 MA-3784

F. Plate No. 5A

Martensite, coarser and less homogeneous than that of plates Nos. 1 and 3.

1% Nital Etch X1000 MA-3791

FIGURE 3.

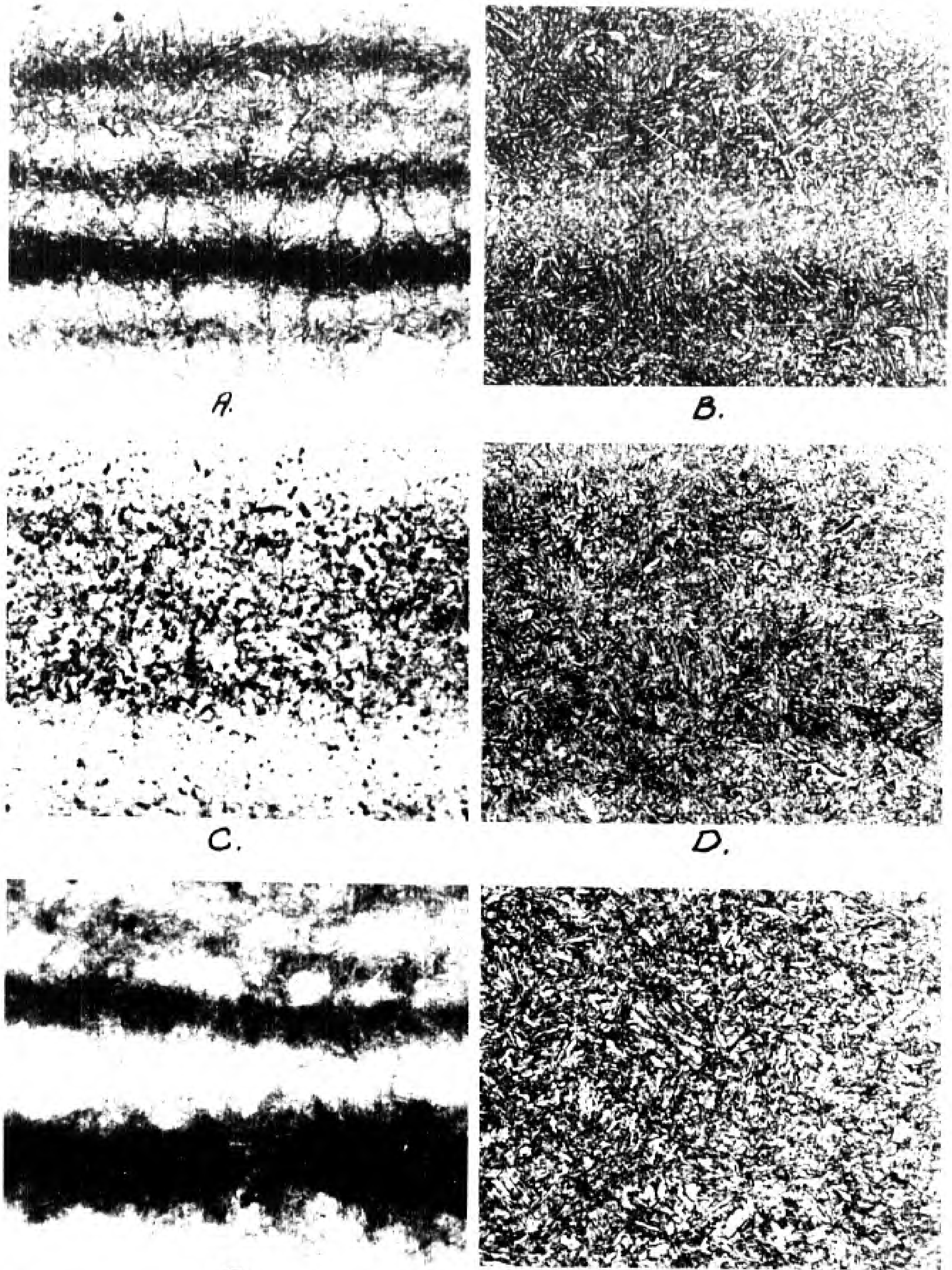


Figure 4

A. Plate No. 1A

Ballistic Limit 2001 f/s. Relatively severe banding with long and wide bands showing great contrast with the matrix.

Etched for 25 minutes in alkaline sodium picrate.
X100 MA-3788

B. Plate No. 3A

Ballistic Limit 1900 f/s. Less severe banding than in plate No. 1. Shorter bands exhibiting less contrast with the matrix and narrower than in plate No. 1.

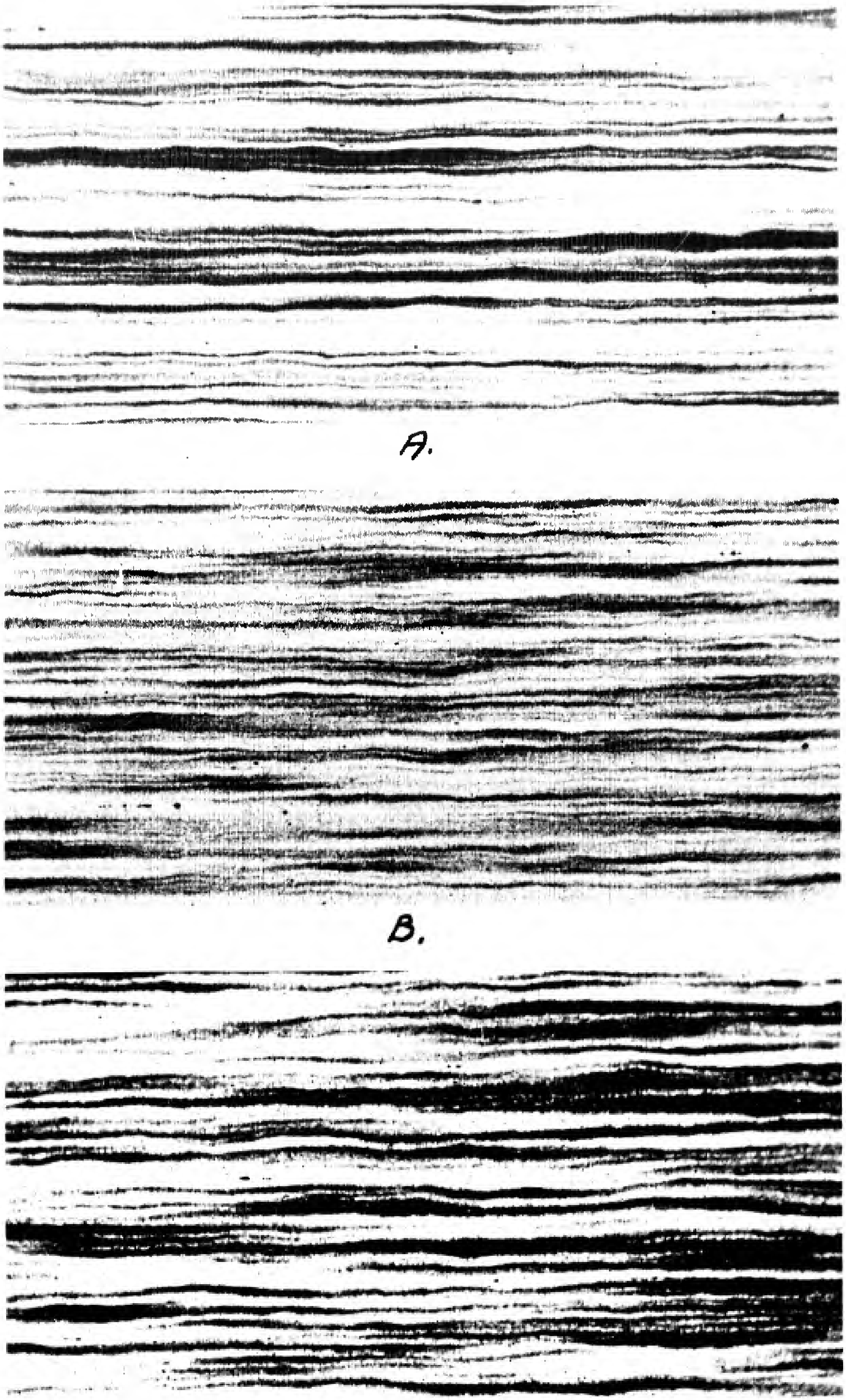
Etched for 25 minutes in alkaline sodium picrate.
X100 MA-3789

C. Plate No. 5A

Ballistic Limit 1726 f/s. Most severe banding of the three plates. Heavy, long, and intense banding. Dark bands are widest and blackest.

Etched for 25 minutes in alkaline sodium picrate.
X100 MA-3790

FIGURE 4.



A.

B.

C.

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Figure 5

A. Plate No. 1A

Typical banding found in this plate. Arrows point to blackened inclusions of manganese sulfide generally found in the dark etching bands.

Etched for 25 minutes in alkaline sodium picrate.
X250
MA-3787

B. Plate No. 3A

The least severe banding in the three plates is found in plate No. 3.

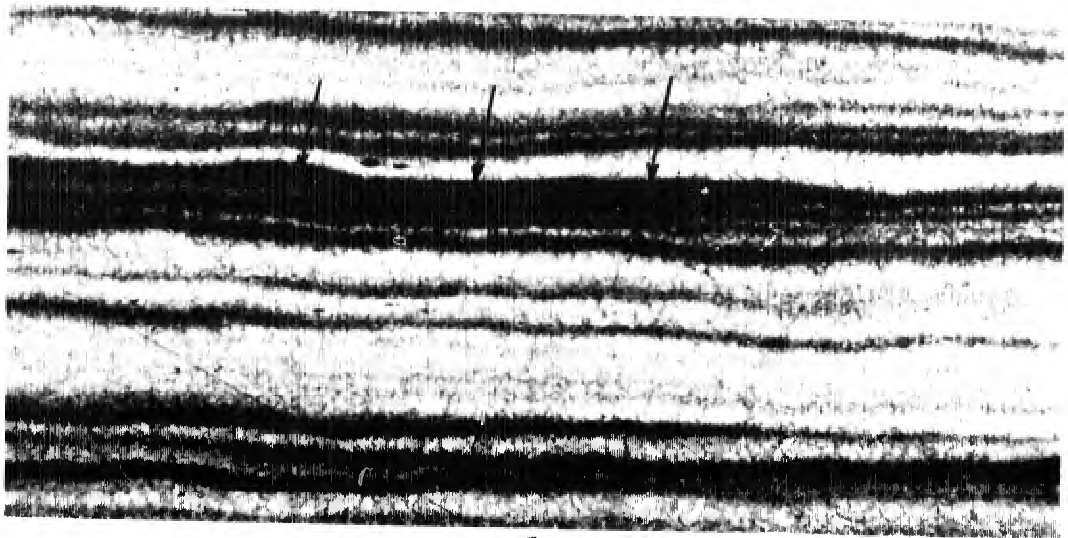
Etched for 25 minutes in alkaline sodium picrate.
X250
MA-3786

C. Plate No. 5A

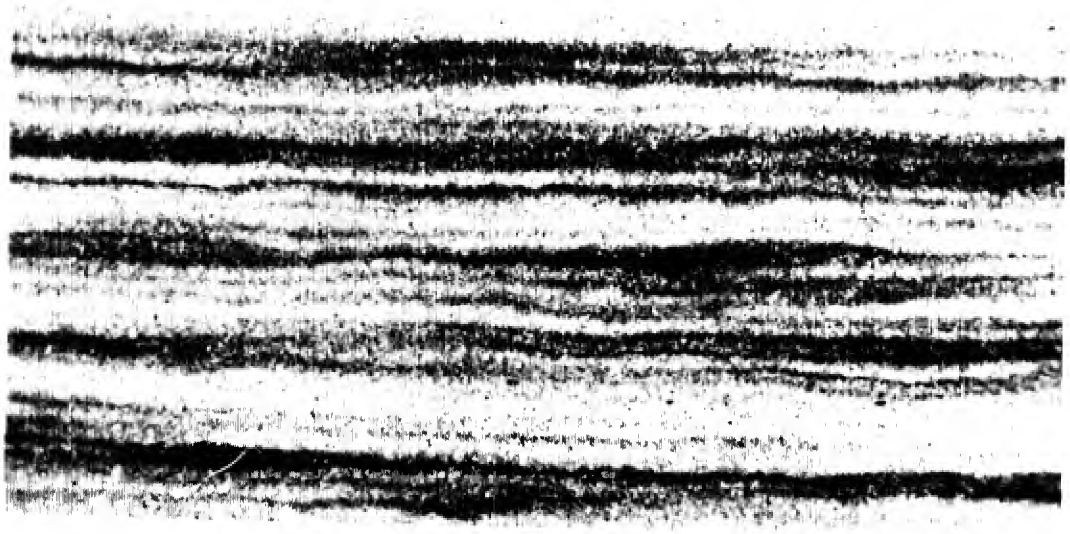
Most severe banding is found in plate No. 5. Very heavy, wide black bands.

Etched for 25 minutes in alkaline sodium picrate.
X250
MA-3785

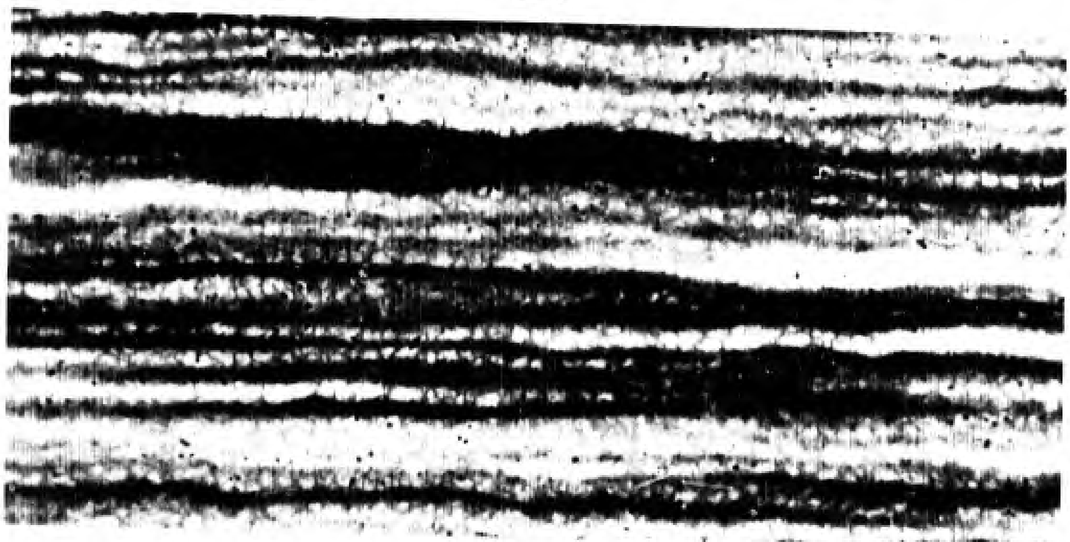
FIGURE 5.



A.



B.



C.

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Figure 6

A. Plate No. 1A

Typical banding occurring in plate No. 1. Arrows point to nonmetallics generally found in the light etching bands. These light etching bands are etched black by alkaline sodium picrate.

Etched in 1% Nital. X100 MA-3796

B. Plate No. 3A

Less severe banding than in plate No. 1. Bands are narrower and have less contrast with the matrix than in the case of plate No. 1.

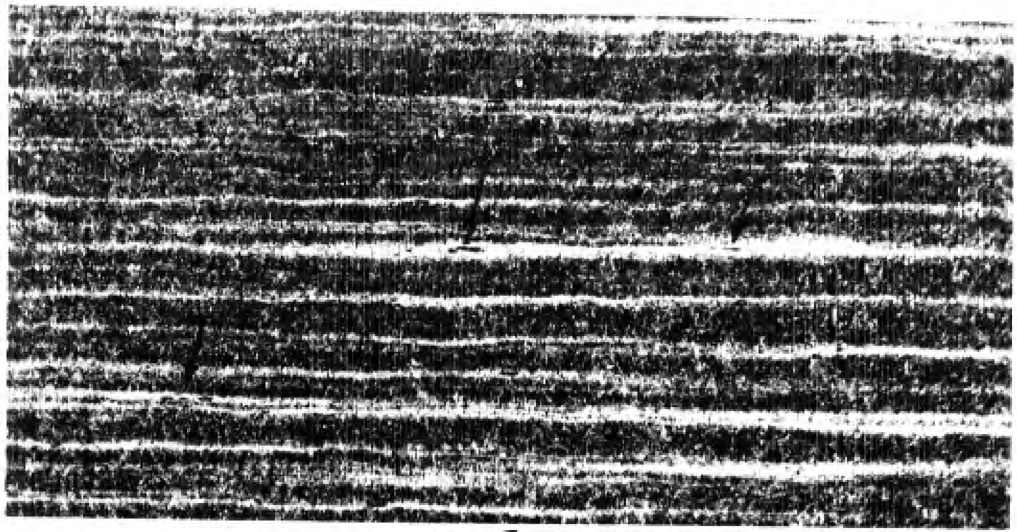
Etched in 1% Nital X100 MA-3795

C. Plate No. 5A

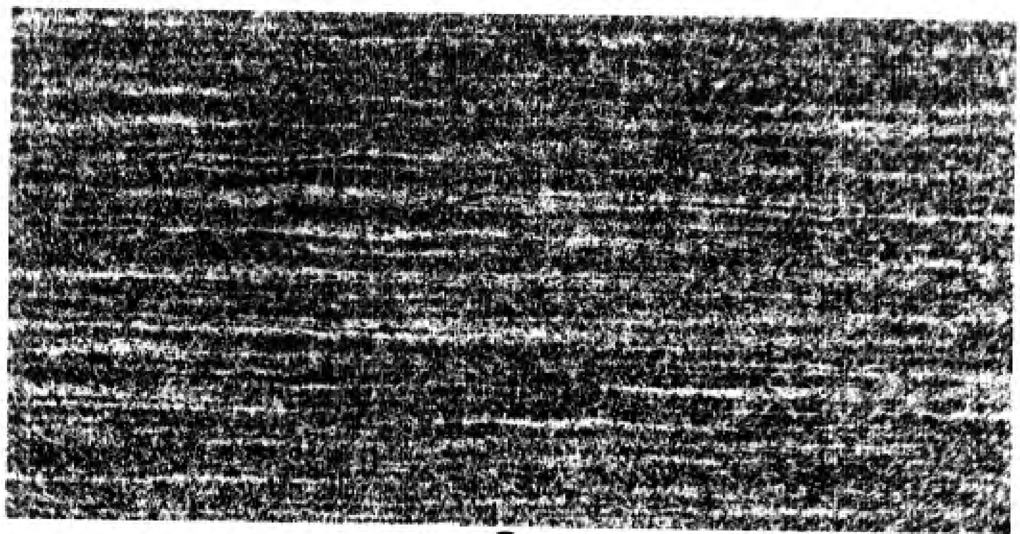
Very little banding in plate No. 5 was revealed by a nital etch. Extremely homogeneous structure at this magnification.

Etched in 1% Nital X100 MA-3794

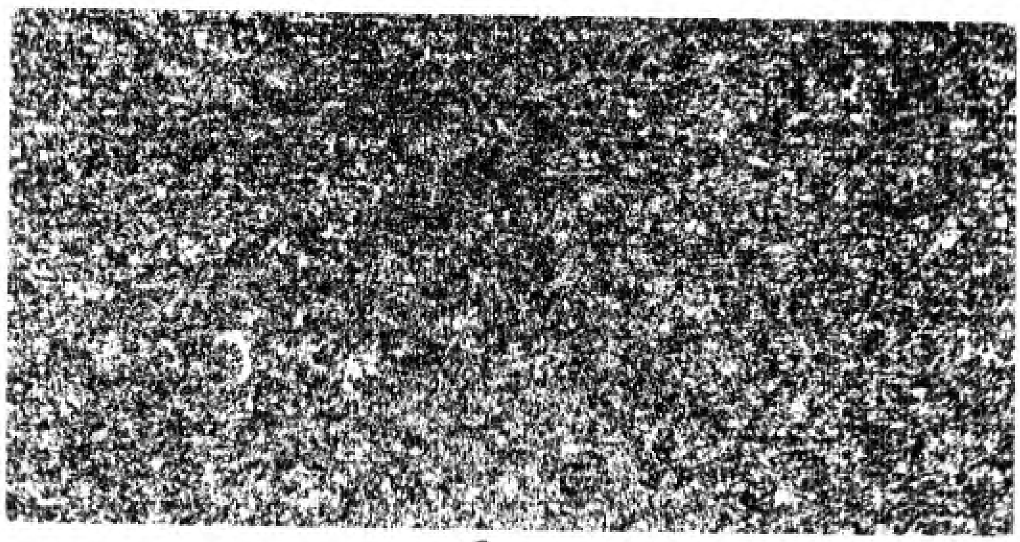
FIGURE 6.



A.



B.



C.

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Figure 7

A. Plate No. 1A

Typical dark etching banding revealed in plate No. 1. Arrows point to nonmetallics generally found in the bands. These dark etching bands are the same that are lightly etched by nital and etched black by alkaline sodium picrate.

Electrolytic Etch in 10% Chromic Acid.
X100 MA-3801

B. Plate No. 3A

Very slight banding found in plate No. 3.

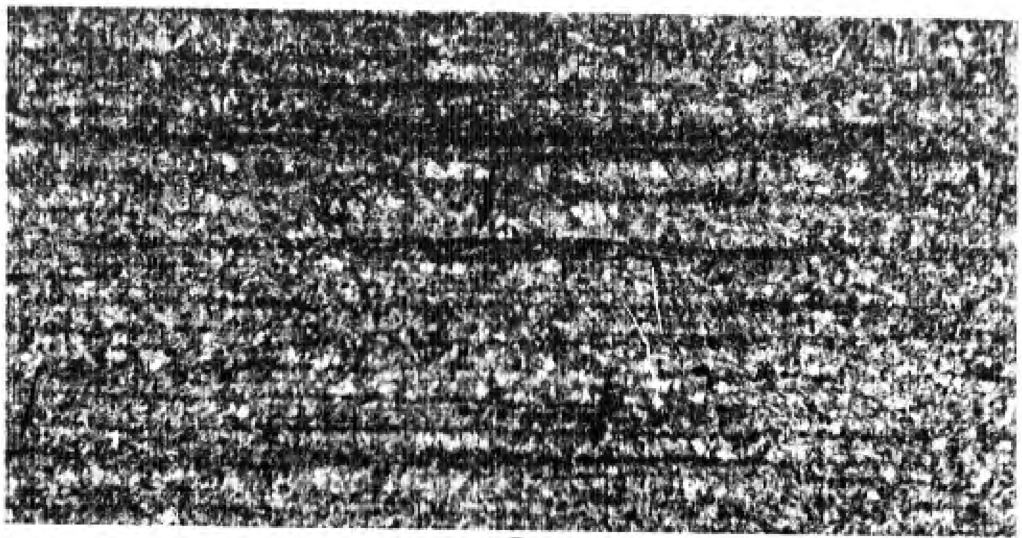
Electrolytic Etch in 10% Chromic Acid.
X100 MA-3800

C. Plate No. 5A

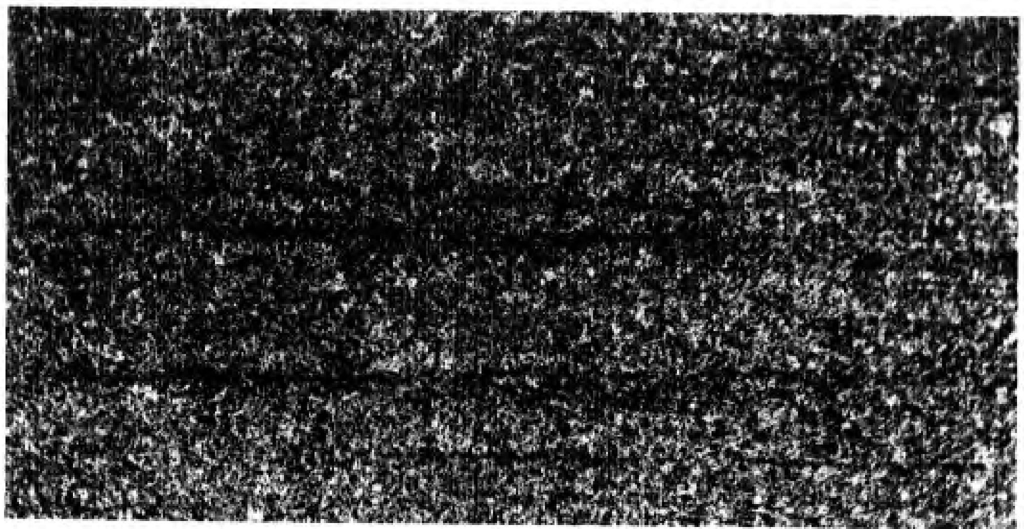
Typical banding in plate No. 5. Less severe than in plate No. 1. These three photomicrographs illustrate the fact that carbon segregation plays a very small part in the intense banding revealed by the alkaline sodium picrate etch. Chromic acid will darken carbides and etch martensitic segregations. A comparison of Figure 7 to Figure 4 shows that segregations other than carbon are responsible for the banding in Figure 4.

Electrolytic Etch in 10% Chromic Acid.
X100 MA-3799

FIGURE 7.



A.



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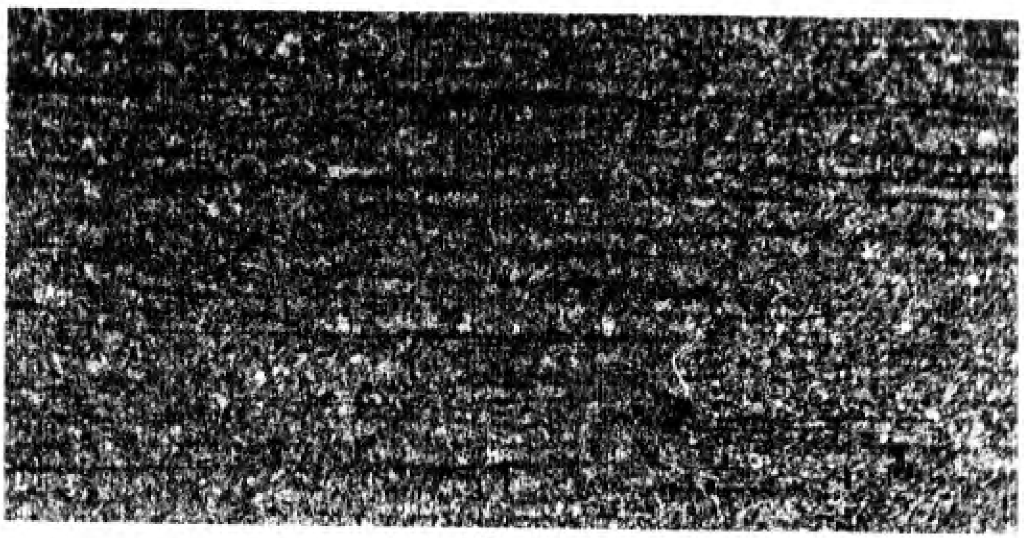

C.

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Figure 8

A. Heat No. 1830 - Reference Disston Letter Dated July 18, 1941

Intense banding found in 1/8" wide band across middle of cross section of this plate. Note that nonmetallics are segregated in the dark etching bands. This photomicrograph checks the results previously obtained with a nital etch.

Etched for 25 minutes in alkaline sodium picrate.
X100

MA-3806

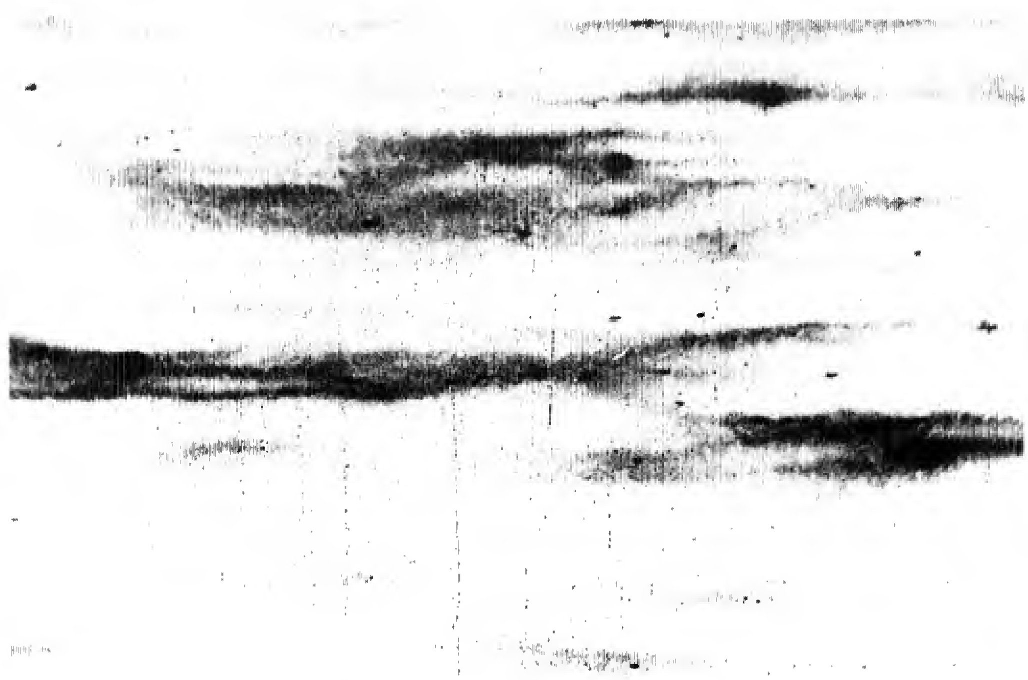
B. Heat No. 1843 - Reference Disston Letter Dated July 18, 1941

Very slight banding occurring throughout the cross section of heat No. 1843. The areas of heat No. 1830 away from the middle of the cross section of the plate are the same as those of heat No. 1843.

Etched for 25 minutes in alkaline sodium picrate.
X100

MA-3807

FIGURE 8.



A.

B.

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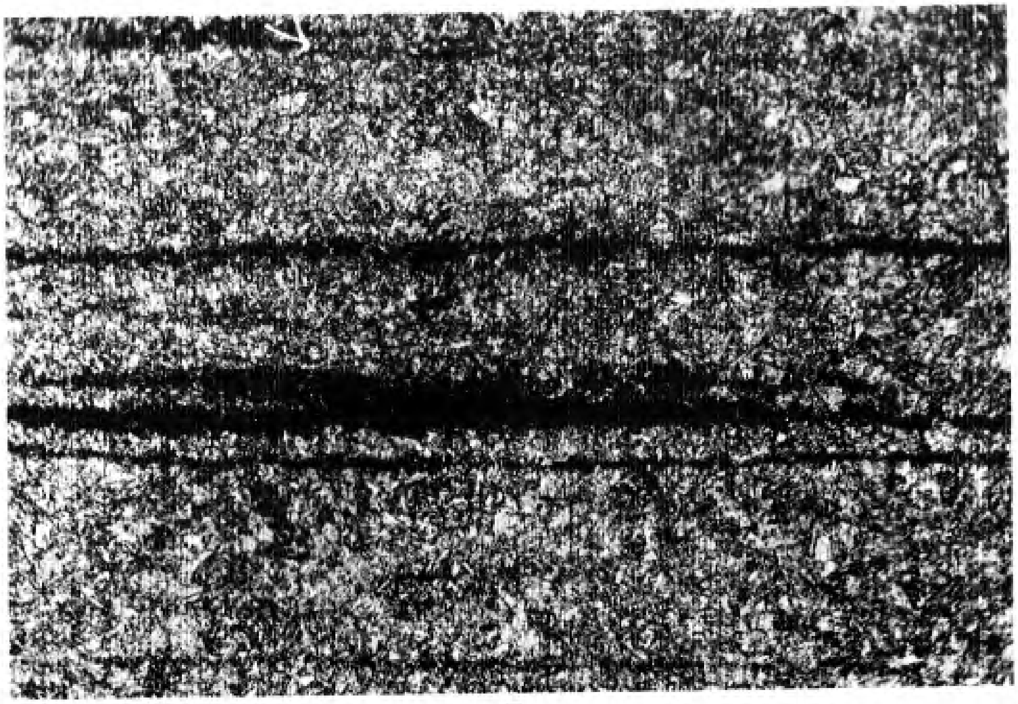
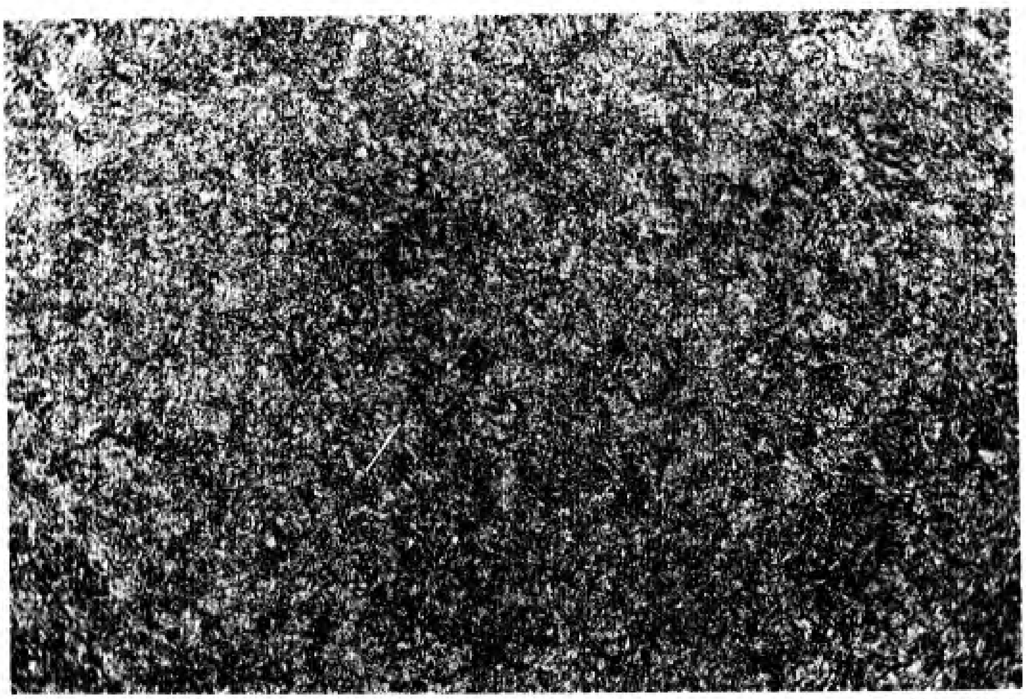
FIGURE 9.



A.



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B.

Figure 10

A. Heat No. 1830

Another area in the 1/8" wide banded zone in the middle of the cross section of the plate.

Etched for 25 minutes in alkaline sodium picrate.
X100 MA-3804

B. Heat No. 1830

View at higher magnification of matrix of plate. Tendency towards grain boundary segregation of carbides. This photomicrograph checks the results previously obtained with both the nital and Murakami etches.

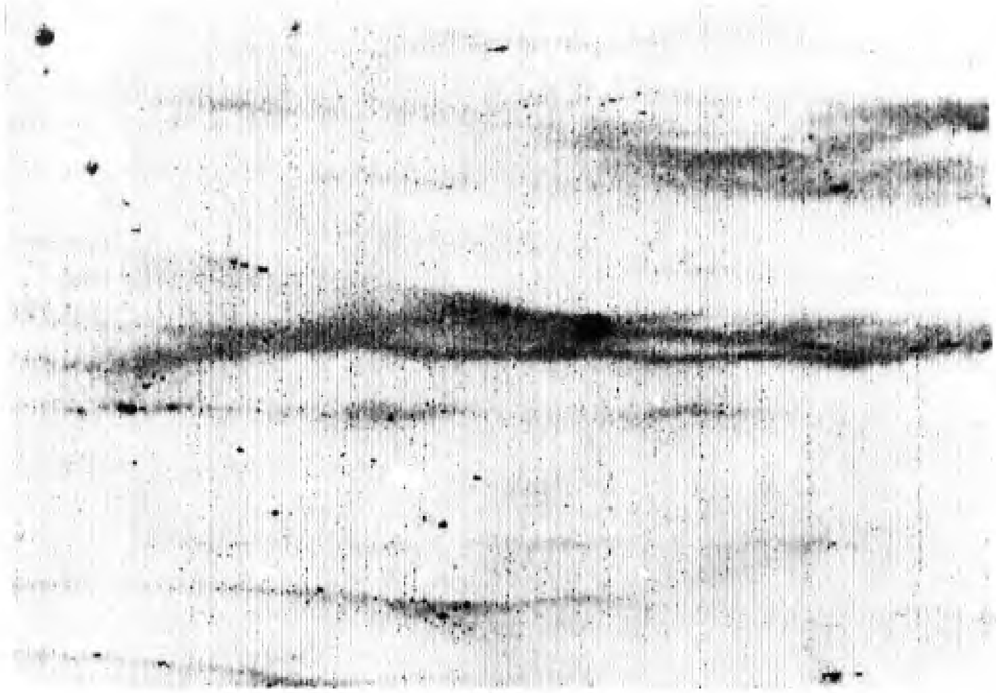
Etched for 25 minutes in alkaline sodium picrate.
X1000 MA-3803

C. Heat No. 1830

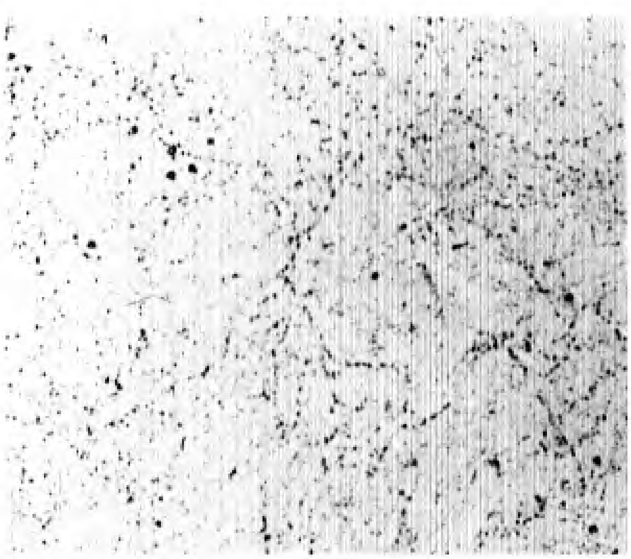
View at higher magnification of band in middle of cross section of plate. Partially spheroidized lamellar structure revealed by this reagent checks the results previously obtained with a nital etch.

Etched for 25 minutes in alkaline sodium picrate.
X1000 MA-3802

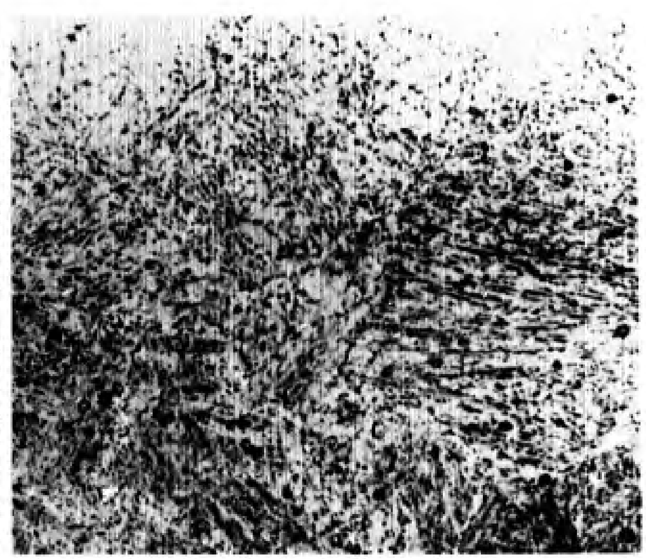
FIGURE 10.



A.



B.



C.

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Figure 11.

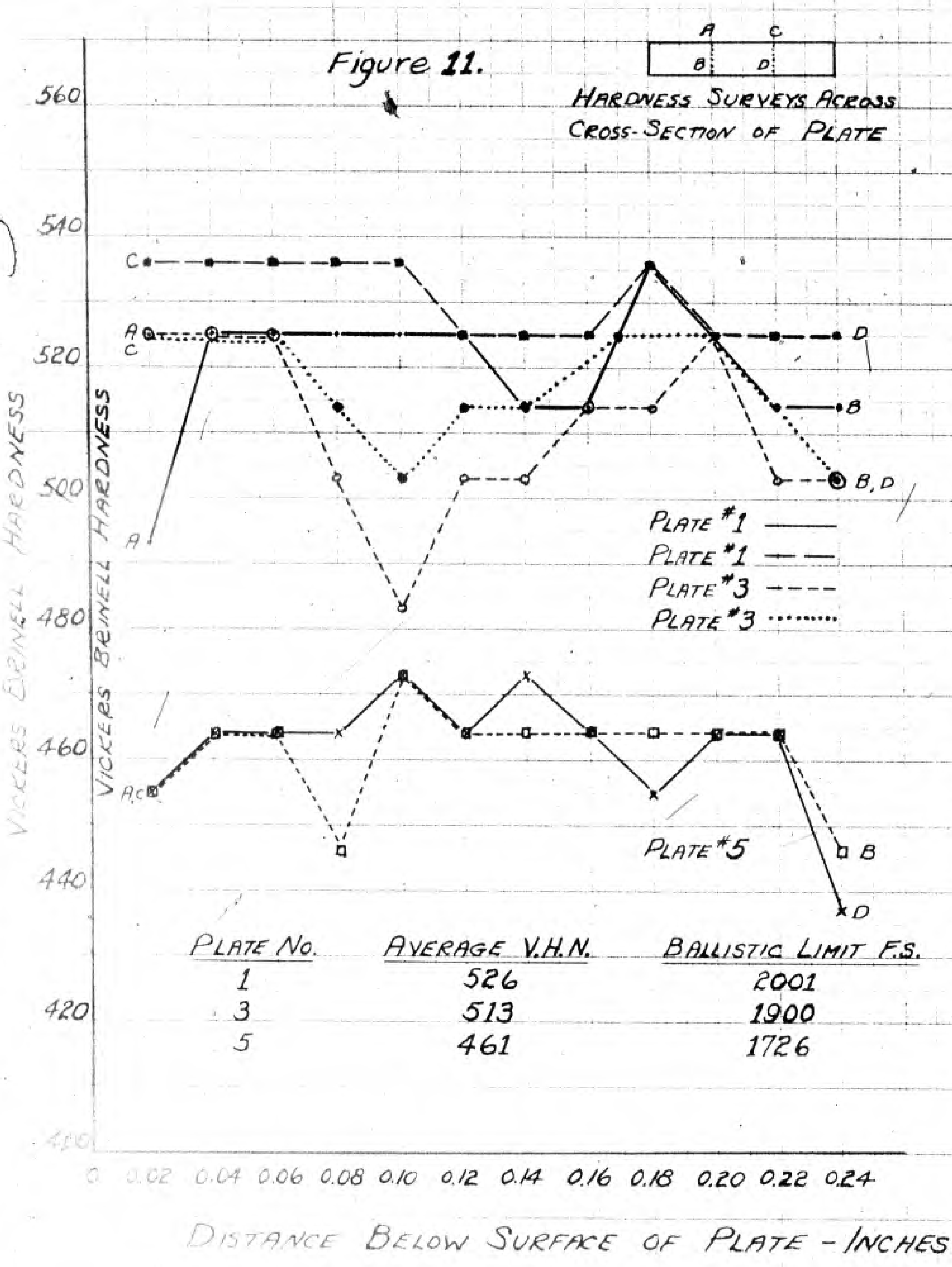

PLATE NO.	AVERAGE V.H.N.	BALLISTIC LIMIT F.S.
1	526	2001
3	513	1900
5	461	1726

APPENDIX A

COPY

HENRY DISSTON & SONS, INC.

PHILADELPHIA, U.S.A.

September 15, 1941

Lt. Col. S. B. Ritchie
Watertown Arsenal
Watertown, Mass.

My dear Col. Ritchie:

I am attaching hereto a report of September 11 on 1/4" Armor Plate.

I would appreciate it if you or some of your staff went over it and gave me your reactions as to such data as is in the report.

The metallographic data here appears to be in line with some findings which I have observed on reading some of the reports emanating from your organization.

There is a bare possibility that the greater exactitude of the identity of the plate and its early history is something on which you are not too well aware on plate examined by yourself.

Any comments you make will be welcome.

Thanking you for your trouble, I remain

Yours very truly,

E. K. SPRING
METALLURGIST

b

COPY

COPY

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WAR DEPARTMENT

WATERTOWN ARSENAL

WATERTOWN, MASS.

September 18, 1941

Mr. E. K. Spring
Metallurgist
Henry Disston & Sons, Inc.
Philadelphia, Pennsylvania

Dear Mr. Spring:

This will acknowledge your letter of September 15 with which you furnished a copy of a report dated September 11 on 1/4" armor plate.

Please be assured that we shall be happy to examine this report and furnish any comments we may have to offer. It will be studied with interest.

For the Commanding General:

Yours very truly,

S. B. Ritchie,
Lt. Col., Ordnance Dept.,
Director of Laboratory.

COPY

COPY

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WAR DEPARTMENT

WATERTOWN ARSENAL

WATERTOWN, MASS.

September 19, 1941

Mr. E. K. Spring
Metallurgist
Henry Disston & Sons, Inc.
Philadelphia, Pennsylvania

Dear Mr. Spring:

We have received your interesting report dated September 11, 1941, on "Metallographic Examination of 1/4" Navy Test Plates".

The carbide segregation in these plates is clearly revealed by the sodium picrate etch. We have noted in some types of steels that this reagent reveals dendritic segregation especially in cast high manganese steels and cast steels containing copper. It is possible that the sodium picrate has revealed segregations other than carbides in the bands, therefore, this reagent has shown more clearly the banded areas than the other reagents, reference being made more especially to the Murakami reagent. The Murakami reagent reveals only the individual carbides.

It is suggested that you heat your Murakami reagent containing the samples to be etched in a water bath for some 15 - 20 minutes. This period of time should be sufficient to etch carbide segregations in armor plate. Do not use this reagent more than once as it oxidizes rapidly.

Another reagent we successfully use considerably for revealing banding in steels is the Oberhoffer's reagent consisting of the following constituents:

Ethyl alcohol	-	500 cc
Water	-	500 cc
$SnCl_2$	-	0.5 gram
$CuCl_2$	-	1.0 gram
$FeCl_3$	-	30 grams
Hcl(conc)	-	50 cc

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Mr. E. K. Spring, 9/19/41, page 2.

It would be interesting to compare the microstructure revealed by etching in 1% nital since you infer that the microstructure of plate No. 3 has a coarser acicular structure than the other plates. In this connection, if you would be willing we would like to study these samples at this Laboratory. We would like to try the sodium picrate etch on these three interesting samples.

We agree with you that a history of the plates is very helpful in the metallurgical study.

Your cooperation in this matter is appreciated.

For the Commanding General:

Very truly yours,

G. L. Cox,
Major, Ordnance Dept.,
Asst. to the Director
of Laboratory.

COPY

HENRY DISSTON & SONS, INC.

PHILADELPHIA, U.S.A.

September 22, 1941

Watertown Arsenal
Watertown, Mass.

Attention Major G. L. Cox

1/4" ARMOR

Gentlemen:

We are sending you under separate cover, a holder containing three micro samples referred to in our report dated September 11, 1941 with title "Metallographic Examination of 1/4" Navy Test Plates."

You have offered to examine these samples in your letter of September 19.

These samples are stamped 1, 3, and 5. Numbers 1 and 5 show, number 3, being in the middle, does not show. Sample number 1 from heat 768-1 gave microphoto Figure 1. Sample number 3 from heat 1065-2 gave microphoto Figure 2. Sample number 5 from heat 1618-2 gave microphoto Figure 3. Reference to our report of September 11 I believe will give you all the information you need.

We would much appreciate having your findings.

Yours very truly,

E. K. SPRING
METALLURGIST

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September 11, 1942

E. K. SPRING

MR. R. T. NALLE

METALLOGRAPHIC EXAMINATION OF 1/4" NAVY TEST PLATES

Three samples of 1/4" thick, 845 Homo Navy Plate, differing from each other ballistically, were examined metallographically in an attempt to establish a connection between variations in microstructure and the variations observed in ballistics.

The samples examined are as follows:-

No.	Heat No.	B/L F.S.	Rockwell	Analysis C	Mn	Si	Ni	Cr	W	V	Mo	Cu
1	768-1	2001	53-55	.45	.71	.29	.05	1.16	none	.20	.70	.10
3	1065-2	1900	52½	.47	.76	.25	.04	1.24	none	.27	.66	.10
5	1618-2	1726	50-53	.48	.69	.33	.06	1.10	none	.23	.69	.08

Microsamples from each heat were examined with various appropriate etching reagents with the following results:

Etchant	Remarks
Nital (1%)	Slight structural differences. 1 and 3 nearly the same being generally vermiform martensite. 5 tends more toward the acicular and etches darker.
Picral (2%)	Results similar to those obtained with nital with possibly better definition of structure.
A S M #3	Slight structural differences in all three samples. Grain size imperfectly indicated only in 1.
Murakami's Reagent A & B	Both etchants have only a slight affect in marking the steel. Very little difference between samples.

COPY

Remarks

This etchant colors carbides dark. Results obtained with it were more informative than with any other tried. Photomicrographs of structures revealed by this etchant follows: Figs. 1, 2, and 3 whose captions are self explanatory.

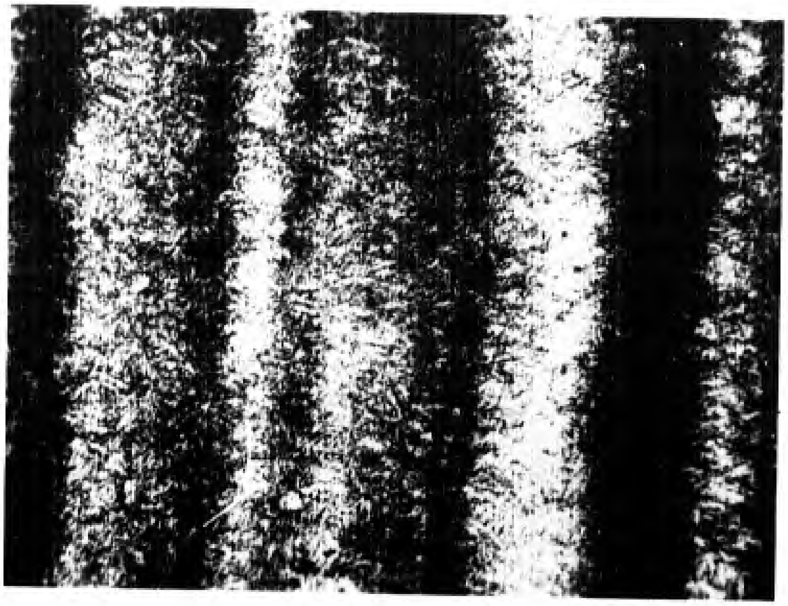

Fig. 1 - 1/4" Navy Armor, Heat #768-1, B/L 2001 f.s. Etchant A S M #22 (15 min.) Magnification 1000 X (Photo #1030)

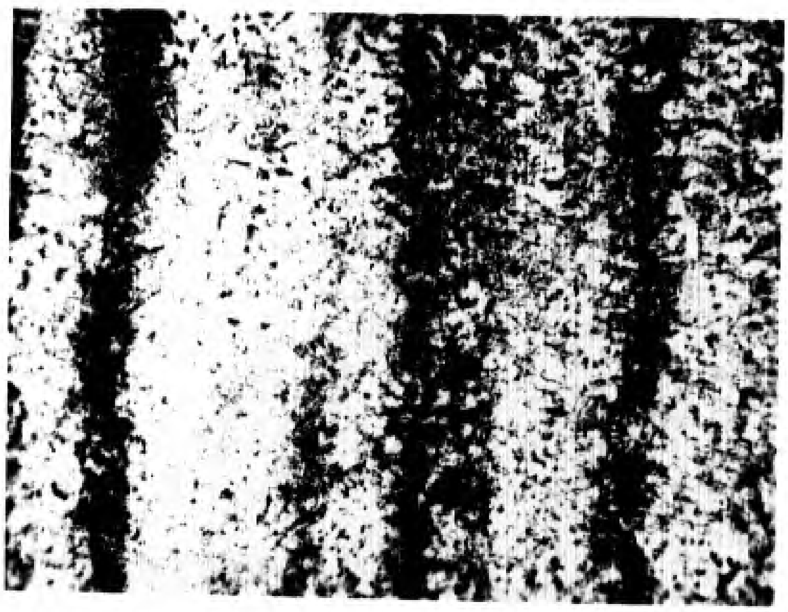

Fig. 2 - 1/4" Navy Armor, Heat #1065-2, B/L 1900 f.s. Etchant A S M #22 (15 min). Magnification 1000 X (Photo #1031).

Etchant - Alkaline sodium picrate (A.S.M. #22.)

W.A.639-3726

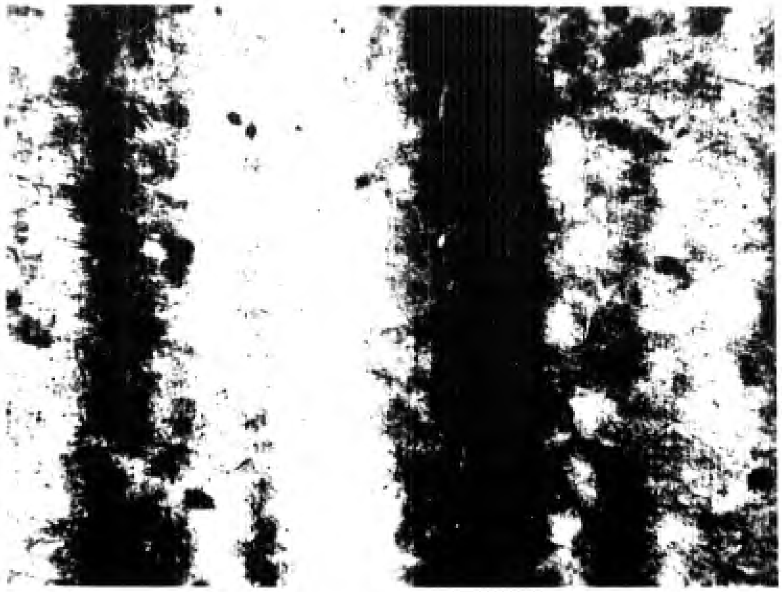

Fig. 3 - 1/4" Navy Armor, heat #1618-2, B/L 1726 f.s.
Etchant A S M #22 (15 min). Magnification 1000 X
(Photo #1032)

From an examination of the samples and photographs the following conclusions were reached.

1 - As the B/L becomes progressively lower the structure becomes progressively coarser.

2 - As the B/L becomes progressively lower the carbide banding becomes more prominent and the light and dark bands become larger and move further apart.

3 - As the B/L becomes progressively lower, carbon diffusion becomes less pronounced. This is evidenced by the light bands in Fig. 1 being generally darker than in the other two and those in Fig. 3 being lighter.

4 - There were non-metallics present in all samples but only in #3 were these stringers arranged in the bands of higher carbon. This condition is illustrated in Fig. 3.

Inquiry revealed that these heats were melted in the following sizes of ingots:

768 - 1	7 x 12 Short
1065 - 2	(9 x 16 Long
	(9 x 16 Short
1618 - 2	9 x 16 Long

This work indicates that the ballistics of this material will be aided by increased carbon diffusion and reduced banding. The use of small moulds is indicated.

b

c.c. J. M. Goodpasture
R. Sibley
Dr. H. B. Allen

METALLURGIST

By P. Lansdale

References to the Sodium Alkaline Picrate Etch in Literature

"Metallographers' Handbook of Etching" - Berglund

Alkaline picrate does not always blacken the cementite of high chromium content.

In manganese steels, many reagents often bring out the distinctive banded appearance of manganese segregations.

In silicon steels an alkaline solution of sodium picrate blackens ferrite containing silicon, and, therefore, is useless for indicating carbides in silicon iron and steels.

"Use of Sodium Picrate in Revealing Dendritic Segregation in Iron Alloys" - Sauveur, Krivobok. A.I.M.M.E. Transactions. Vol. LXX, 1924. Pages 239-253.

Boiling sodium picrate imparts dark coloration to manganese sulfide inclusions and will darken regions around inclusions and regions higher in manganese.