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U. S. NAVAL PROVING GROUND

DAHLGREN, VA.

REPORT NO. 3-43

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BALLISTIC PERFORMANCE OF LIGHT ARMOR
MANUFACTURED BY THE "PLURAMELT" PROCESS

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March 2, 1943.

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NAVAL PROVING GROUND

REPORT NO. 3 - 43, March 2, 1943.

BALLISTIC PERFORMANCE OF LIGHT ARMOR MANUFACTURED BY THE "PLURAMELT" PROCESS

APPROVED:

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P R E F A C E

AUTHORIZATION

This study was requested in Bureau of Ordnance letter S13-1(4) dated January 11, 1943.

OBJECT

To present a comprehensive survey and analysis of the ballistic performance of light armor manufactured by the "Pluramelt" process.

SUMMARY

A comparison is made of the performance of plates submitted by different manufacturers producing light armor using Pluramelt plates. The performance of Pluramelt plates is also compared with that of carburized and nitrided plates. A summary of experimental heat treatments by the Naval Proving Ground is included together with the ballistic results obtained before and after treatment.

The analysis of light armor performance indicates that:

(a) Plates manufactured by E. C. Atkins and Company and U. S. Spring and Bumper Company from Pluramelt have approximately the same ballistic quality at the present time.

(b) Light armor produced from plates manufactured by the Pluramelt process show a greater variation in ballistic properties than plates case carburized and hardened. Total failures in 1942 of 1/2" acceptance test plates of Pluramelt amounted to 164 out of 928 (17.7%) as compared to 17 carburized plate out of 723 (2.4%). Higher limits were obtained at times with Pluramelt plates and they generally showed excellent shock resistance.

(c) Results of experimental work indicate that Pluramelt plates must have a high surface hardness to pass the ballistic test. Plates having low surface hardness because of incorrect heat treatment or of surface decarburization will have low resistance to penetration. No correlation could be made with other physical or chemical properties.

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I. INTRODUCTION

Face hardened light armor has been made for many years by case carburizing and hardening a low carbon steel. This heat treatment develops a hardness of over 600 Brinell on the face of the plate with a back hardness usually around 400 Brinell. Approximately two years ago, the Allegheny Ludlum Steel Corporation investigated the possibilities of applying their "Pluramelt" process to the manufacture of face hardened light armor. This process consists of building up a metallic layer on a base metal by an electric arc. As applied to light armor, the Allegheny Ludlum Steel Corporation rolls ingots of low carbon-nickel-molybdenum steel into slabs approximately 8" thick. A 2" layer of high carbon steel of similar alloy content is melted onto the slab and this composite slab is then rolled down into the required plate gauge.

Experimental heat treatments of this material by E. C. Atkins and Company early in 1941 enabled this company to qualify as a producer of light armor for the U. S. Navy. As was to be expected, early results were somewhat inconsistent and a considerable number of plate failures occurred. With more experience, E. C. Atkins and Company obtained consistent results and had less than two percent of failures in the first four months of 1942.

In March, 1942, the U. S. Spring and Bumper Company qualified to produce light armor from Pluramelt and submitted their first acceptance test plates in April, 1942. A high percentage of failures occurred which is a common experience for companies starting to manufacture armor plate. However, by September, 1942, the number of failures had been reduced to three percent which usually is considered acceptable.

In November, 1942, failures increased rapidly until more than a third of the acceptance test plates of both companies were failing. Some improvement was obtained in December, but the percentage of plate failures was still too high and, in consequence, the producers of light armor using Pluramelt instituted an investigation in an endeavor to establish the cause of failures and to take corrective steps.

It should be noted that all Pluramelt is made by the Allegheny Ludlum Steel Corporation. The E. C. Atkins Company and U. S. Spring and Bumper Company heat treat and fabricate the Pluramelt as received from Allegheny Ludlum.

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This report compares the performance of light armor produced by the different manufacturers and summarizes the results of experimental heat treating of Pluramelt at the Naval Proving Ground.

II BALLISTIC PERFORMANCE OF ACCEPTANCE TEST PLATES

E. C. Atkins and Company and the U. S. Spring and Bumper Company are the two large producers of light armor for the U. S. Navy using plates made by the Pluramelt process. Diebold Safe and Lock Company and Henry Disston and Sons furnish Bullet Proof Steel (BPS) made of case carburized and hardened plates, while the Reading Hardware Corporation supplied many plates in 1941 which had been hardened by nitriding.

Comparison of ballistic performance has been limited to acceptance test plates of 3/8" and 1/2" plates since these two gauges are most frequently submitted for ballistic test. The overall performance of the different types of plate against .50 cal. AP projectiles is given below in Table I together with the performance of each manufacturer's product.

TABLE I

Performance of 1/2" BPS Acceptance Test Plates.

Type of Armor	1941 Total Plates	1941 Plates Failed	1941 % Failures	1942 Total Plates	1942 Plates Failed	1942 % Failures
Pluramelt	54	22	41%	928	164	17.7%
Carburized	71	9	13%	723	17	2.4%
Nitrided	41	11	27%	-	-	-
Company						
Atkins (P)	54	22	41%	553	66	12%
USS&BCo. (P)	-	-	-	375	98	26%
Diebold (C)	33	3	9%	440	1	0.2%
Disston (C)	38	6	16%	283	16	6%
Reading (N)	41	11	27%	-	-	-
3/8" Bullet Proof Steel						
Atkins (P)	50	13	26%	113	5	4%
USS&BCo. (P)	-	-	-	24	3	9%
Diebold (C)	11	0	0%	21	0	0%

(P) = Pluramelt (C) = Carburized (N) = Nitrided

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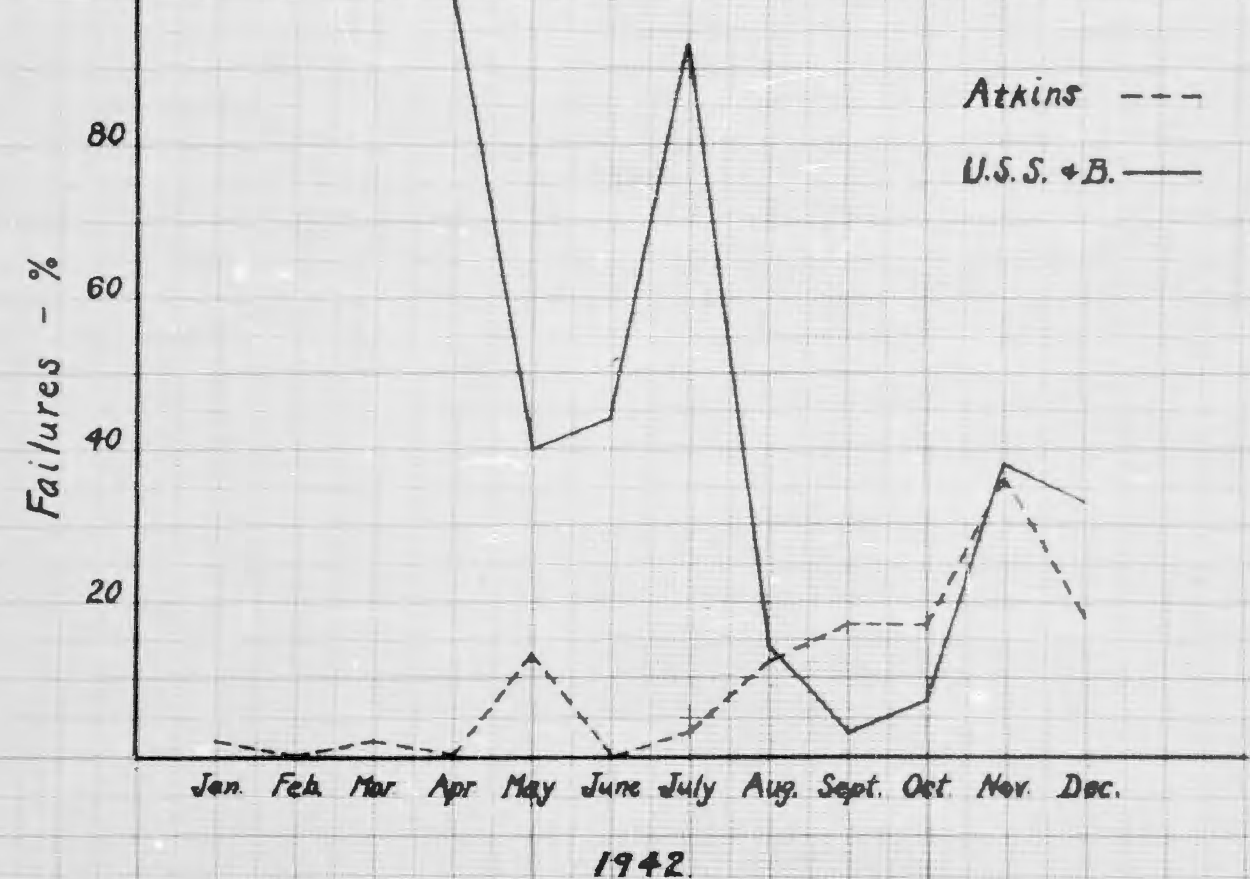
Fig. 1 ½" PLURAMELT

1942

MONTHLY PERFORMANCE
OF
ACCEPTANCE TEST PLATES



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Pluramelt plates had over seven times the percentage of failures of carburized plates in 1942. The facts that Pluramelt is a new type of light armor and that it was treated by manufacturers inexperienced in its production are major factors in the large number of failures. It should be noted that the performance of all manufacturers improved considerably from 1941 to 1942. Thus Atkins reduced the failures of 1/2" BPS from 41% in 1941 to 12% in 1942 and the U. S. Spring and Bumper Company decreased the percentage of failures from 62.5% during the first four months of production to 8% in the second four months period. Table 2 gives the monthly performance of 1/2" BPS during 1942. The percentage of failures is given graphically in Figure 1 for Atkins and for U. S. Spring and Bumper.

TABLE 2

Monthly Performance of 1/2" BPS during 1942.

	Atkins (P)			USS&B (P)			Diebold (C)			Disston (C)		
	Total	Failed	%	Total	Failed	%	Total	Failed	%	Total	Failed	%
Jan.	47	1	2	-	-	-	53	0	0	15	0	0
Feb.	15	0	0	-	-	-	47	0	0	6	0	0
Mar.	42	1	2	-	-	-	22	0	0	8	0	0
Apr.	27	0	0	5	5	100	47	0	0	21	0	0
May	31	4	13	15	6	40	39	0	0	10	0	0
June	20	0	0	39	17	44	34	1	3	24	8	33
July	75	2	3	29	27	93	9	0	0	64	0	0
Aug.	68	8	12	28	4	14	32	0	0	9	0	0
Sept.	48	8	17	105	3	3	2	0	0	37	4	11
Oct.	64	11	17	59	4	7	63	0	0	37	1	3
Nov.	59	21	36	16	6	38	59	0	0	31	2	6
Dec.	57	10	18	79	26	33	33	0	0	21	1	5
1942	553	66	12	375	98	26	440	1	0.2	283	16	6

(P) = Pluramelt (C) = Carburized

In an effort to obtain a criterion of comparison other than that of passing or failing ballistic specifications, an attempt has been made in this report to obtain an average velocity limit of light armor plates submitted by the various manufacturers. Since limits were generally not obtained for plates considerably above or below specification quality, an average limit velocity can be obtained from only a few plates. However, by taking the highest partial penetration obtained on high quality plates and the lowest complete penetration on failed plates together with the velocity limit for plates of known quality, it is possible to obtain a median velocity limit for all acceptance test plates which is indicative of plate quality. The median velocity limits for plates produced by the different manufacturers are given below:

1/2" BPS	Number of Plates	Median Velocity Limit
Atkins (P)	611	2117 f.s.
USS&B (P)	412	2116
Diebold (C)	483	2161
Disston (C)	335	2136
Reading (N)	42	2075
Specification limit (O.S.595) Table I		2050
3/8" BPS		
Atkins (PB)	145	1887
USS&B (P)	15	1941
Diebold (C)	32	1890
Specification limit (O.S.595) Table I		1750

(P) = Pluramelt (C) = Carburized (N) = Nitrided

It is interesting to note that these values are consistent with the results of acceptance tests. Diebold plates had the best performance and had a median velocity limit of 2161 ft./sec. while U. S. Spring and Bumper plates with the greatest percentage failures in 1942 had a median velocity limit of 2116. Thus, the average Diebold plate has a margin over specifications of about 100 f.s., while U. S. Spring and Bumper Company plates have a margin of only 50 f.s. The percent failures would be expected to be much greater with the smaller margin.

The nitrided plates produced by the Reading Hardware Company had a comparatively low median velocity limit - 2075 f.s., but this limit probably does not represent the optimum obtainable by nitriding. Reading did not obtain adequate control over their nitriding furnace to begin with and nitrided both faces of their plates. The average limit for their last twenty-five acceptance test plates was 2103 f.s.

III EXPERIMENTAL HEAT TREATMENT OF PLURAMELT PLATES

On June 16, 1942, U. S. Spring and Bumper Company plate NB4R (0.504 actual gauge) failed the ballistic test with a complete penetration at 2060 f.s. The Armor and Projectile Laboratory was requested to heat treat this plate in order to determine whether the plate could pass the specifications when heat treated under controlled conditions. The plate was heated to 1560°F., held 30 minutes at temperature, water quenched and drawn one hour at 300°F. The ballistic limit was raised to 2140 ft./sec., 70 ft./sec. above the specifications for this thickness.

Further failures of 1/2" BPS treated by U. S. Spring and Bumper Company made it seem advisable to start an investigation to determine the cause of failure and means of improving the ballistic quality of light armor made from Pluramelt. The first experiment was to determine the effect of the quenching medium on ballistic properties. Four 1/2" plates were selected at random and treated as before with the only variable being the quench. Results were as follows:

TABLE 3

Effect of Quenching Medium on Ballistic Properties of 1/2" Pluramelt Plates

Plate No.	Case Depth	Brinell Hardness Face	Brinell Hardness Back	Quench	Ballistic Limit, f.s. Before	Ballistic Limit, f.s. After
NB51R	.14"	532	430	Water-spray	1813	1910
NB10R	.17"	555	460	Water-still	2048	2150
NB68	.20"	578	477	Oil	2160(pp)	2220
NB69	.19"	600	286	Air	2190	1970

From the above it can be seen that oil quenching may provide a sufficiently rapid quench to develop full hardness in the plate. Even air cooling resulted in 600 Brinell in the face although the low carbon back failed to harden at this slow rate of cooling.

Plate NB51R failed to pass specifications after water quenching. This failure is believed to be caused by the low face hardness. In order to check the effect of low face hardness on ballistic properties, eighteen additional 1/2" plates were selected for investigation. Nine were U. S. Spring and Bumper Company plates which had failed to pass the ballistic test, five were U. S. Spring and Bumper Company plates which had passed, and four were Atkins plates which had also passed specifications. Results of hardness and case depth measurements were as follows:

Plate No.	Ballistic Limit	Brinell Hardness Reported by Mfr.	Brinell Hardness Obtained by NPG	Case Depth
U.S.Spring & Bumper Co.				
NB74	2060 - Failed	601-477	532-444	.15"
NB58R	1570 - Failed	601-477	477-387	.16"
NB76	2030 - Failed	601-444	512-375	.17"
NB29RR	1278 - Failed (LCP)	601-477	477-418	.18"
NB77	2070 - Failed	601-444	532-387	.18"
NB78	1915 - Failed	601-444	532-402	.18"
NB73	1930 - Failed	601-477	512-460	.20"
NB75	2020 - Failed	601-444	532-387	.20"
NB79	1800 - Failed	601-444	532-378	.20"
NB46	2170 - Passed	601-514	555-477	.15"
NB62	2130 - Passed	601-477	555-444	.16"
NB50	2115 - Passed	653-477	600-477	.17"
NB44	2095 - Passed	601-477	555-444	.18"
NB43R	2115 - Passed	601-477	555-444	.19"
E. C. Atkins Co.				
G57H	2160 - Passed (HPP)	627-477	555-460	.16"
G50H	2160 - Passed	653-477	555-444	.18"
G81H	2139 - Passed	627-495	600-477	.20"
G95H	2092 - Passed (HPP)	653-430	600-387	.20"

Hardness values reported by the manufacturer are consistently over 600 Brinell which does not correspond with results of hardness tests made at the Naval Proving Ground. It is thought that the discrepancy is partially due to the difference in amount ground off the surface before making the hardness test. If the surface is ground sufficiently to remove any decarburization, a correctly heat treated plate will have a hardness of 600 Brinell or higher.

However, none of the plates that failed had a face hardness as high as 555 Brinell regardless of the amount of grinding. Microscopic examination of samples from the plates did not show an excessive number of inclusions nor the presence of surface decarburization. Three of these plates were retreated by holding thirty minutes at 1560°F., oil quenching and drawing one hour at 300°F. All three plates passed the specifications by more than 100 ft./sec. after retreating. The ballistic test results before and after retreatment are given below together with hardness measurements and carbon content.

Plate No.	Brinell Hardness (After Retreatment) Face	Back	% Carbon Face	Back	Ballistic Limit f.s. Before	After
NB73	600	430	62	24	1930	2330
NB75	600	418	55	15	2020	2170
NB79	555	375	55	15	1800	2170

It will be noted that NB73 with a 600 Brinell face, 430 Brinell back and a case thickness of 0"20 - 40% case - had a limit of 2330 ft./sec. This limit is considerably above the average and indicates that a hard thick case supported by a fairly hard back will result in excellent resistance to penetration.

The difficulties encountered by the U. S. Spring and Bumper Company appeared to be due to incorrect heat treatment in that maximum hardness was not developed in the face of their BPS plates. When the plates were retreated under controlled conditions, all the oil quenched and tempered plates passed specifications. Results of the experiments conducted at the Naval Proving Ground were made available to the U. S. Spring and Bumper Company at a conference on July 22, 1942. By making suitable changes in the heat treating furnace, the company reduced its percentage of failures from 93% in July to 3% in September.

Near the end of 1942, both U. S. Spring and Bumper and Atkins began to have an excessive number of plate failures. Ohlen-Bishop Company, a subcontractor for Atkins, also had many rejections. In November and December, ten Plurametl plates were retreated at the Naval Proving Ground by water quenching from 1560°F. and drawing at 300°F. All plates passed the specifications on retest. The plates were water quenched because no facilities were available for quenching full size plates in oil and because previous experience in July had shown little difference caused by the method of quenching.

Later, one (1) U. S. Spring and Bumper Company plate and three (3) Ohlen-Bishop plates were oil quenched instead

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of water quenched. Two of the four plates failed the ballistic test after retreatment. The plates that failed were found to have low surface hardness presumably due to the lower hardenability of a decarburized layer on the surface of the plates. Since the plates had been heat treated before the original testing at the Naval Proving Ground, no reliable estimate of the initial amount of decarburization could be made but it appeared to have been over ".010.

A hardness survey of forty-two plates submitted by both Atkins and U. S. Spring and Bumper emphasized the necessity of having a high face hardness since all the plates that failed gave low Brinell hardness readings. No correlation could be made with other physical or chemical properties. Eleven U. S. Spring and Bumper Company plates showing either high or low ballistic limits are listed below together with their main characteristics.

TABLE 4

Plate	Margin ft./sec.	Brinell Face	Brinell Back	%Case	Decarburization P = Pronounced S = Slight	%Carbon Face	%Carbon Back
Passed							
357	+ 125	555	401	26	P	59	17
361	+ 139	601	401	33	S	53	20
366	+ 135	555	363	22	P	58	17
374	+ 244	555	415	24	P	54	19
375	+ 145	601	401	33	S	59	15
387	+ 213	578	415	33	P	57	17
Average	+ 167	574	400	28	66% P	57	18
Failed							
348	- 522	477	415	33	P	50	20
349	- 452	514	477	33	P	51	20
356	- 537	495	415	24	VP	58	19
360	- 109	534	375	26	P	51	17
380	- 183	514	429	20	P	43	17
Average	- 360	507	422	27	100% P	51	19

In order to make a thorough study of the cause of plate failures, the Bureau of Ordnance requested Allegheny-Ludlum and Atkins to furnish the Naval Proving Ground with six 1/2" Pluramelt plates in the hot rolled and annealed condition. An examination of samples cut from the plates as received indicated the following:

Plate	Heat	Case Depth	Brinell Case	Brinell Back	Surface Case
A	11988-5	0.10"	267	229	.007" Decarburization.
AN	11988-5	0.10"	267	229	.007" Decarburization.
B	21017-5	0.11"	248	262	Ferrite Bands to Depth of .025".
BN	21017-5	0.10"	248	262	Ferrite Bands to Depth of .025".
G18J	11936-5	0.14"	269	288	Partial decarb to Depth of .005".
G26FA	11965-10	0.11"	262	253	Partial decarb to Depth of .005".

Plates G18J and G26FA were cut in half to permit both oil and water quenching. The plates were hardened by holding thirty minutes at 1560°F. and drawing one hour at 300°F. Plates AN and BN were given a preliminary normalize at 1650°F. for thirty minutes and air cooled. Samples cut from the plates after hardening were found to have the following characteristics:

Plate	Quench	Brinell Face	Brinell Back	Surface
A	Oil	637	415	Thin layer free ferrite at surface.
AN	Oil	627	410	
B	Oil	611	421	Banding not noticeable except for occasional pearlite layer.
BN	Oil	601	415	
G18-O	Oil	601	388	Fully martensitic.
G18-W	Water	653	415	Fully martensitic.
G26-O	Oil	601	388	Some free ferrite in case.
G26-W	Water	627	415	Fully martensitic.

Results of ballistic tests are given below:

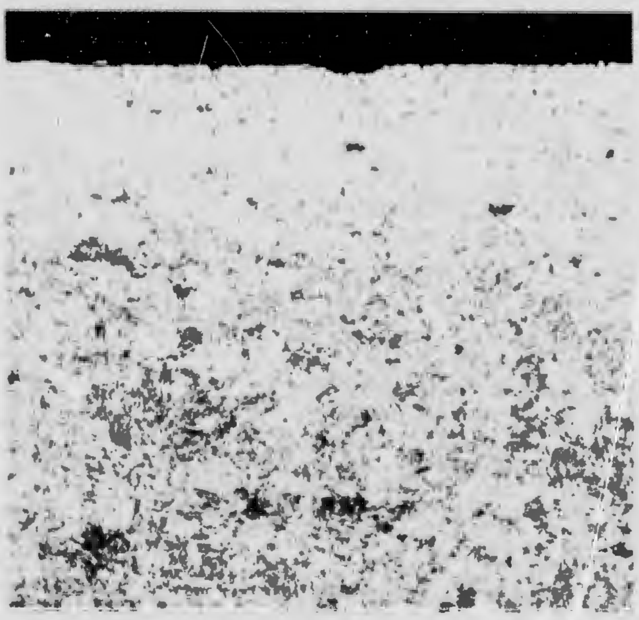
Plate	Quench	Gauge	50 cal. AP M2 Striking Velocity Required	50 cal. AP M2 Striking Velocity Limit
A	Oil	0.486	2030	2140
AN	Oil	0.488	2035	2164
B	Oil	0.500	2065	2262
BN	Oil	0.501	2066	2220
G18-O	Oil	0.495	2053	2226
G18-W	Water	0.492	2045	2262
G26-O	Oil	0.500	2065	2155
G26-W	Water	0.497	2058	2272

From these results, it is possible to make some general observations.

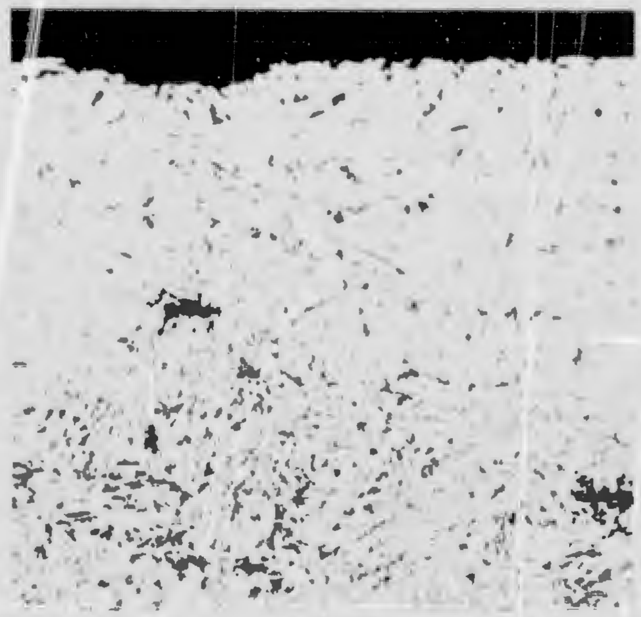
Figure 2

Plate A - Annealed

Partial decarburization of about .007"



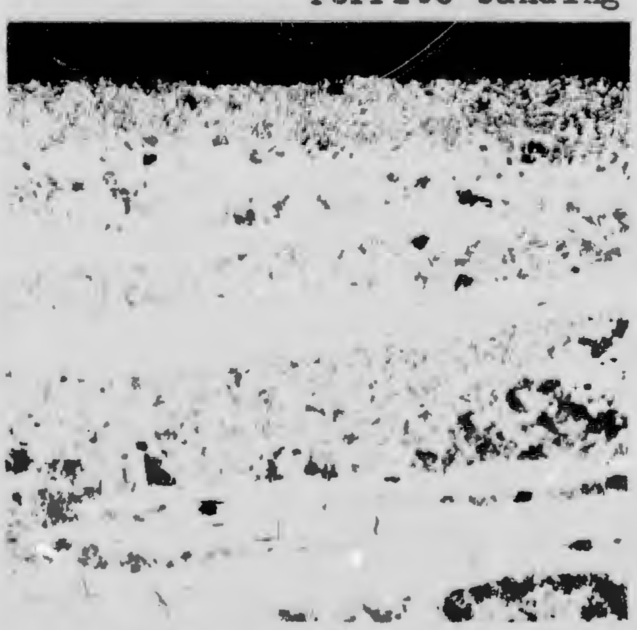
100X 2% Nital Etch



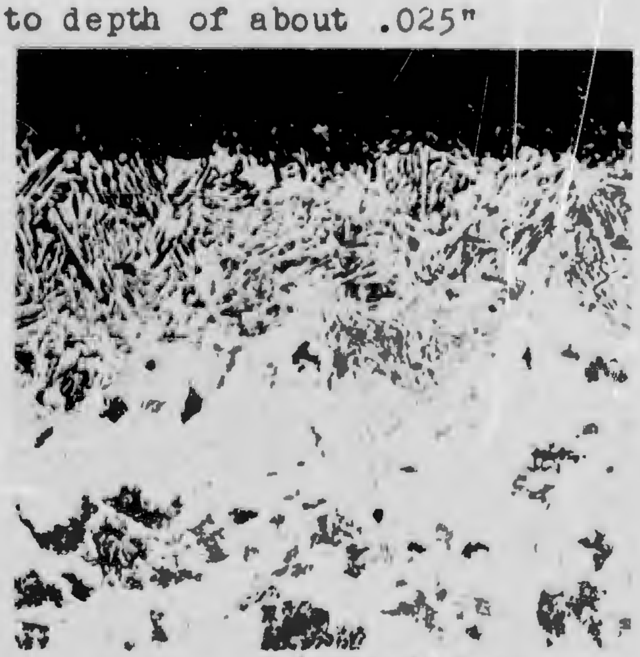
300X 2% Nital Etch

Plate B - Annealed

Ferrite banding to depth of about .025"



100X 2% Nital Etch



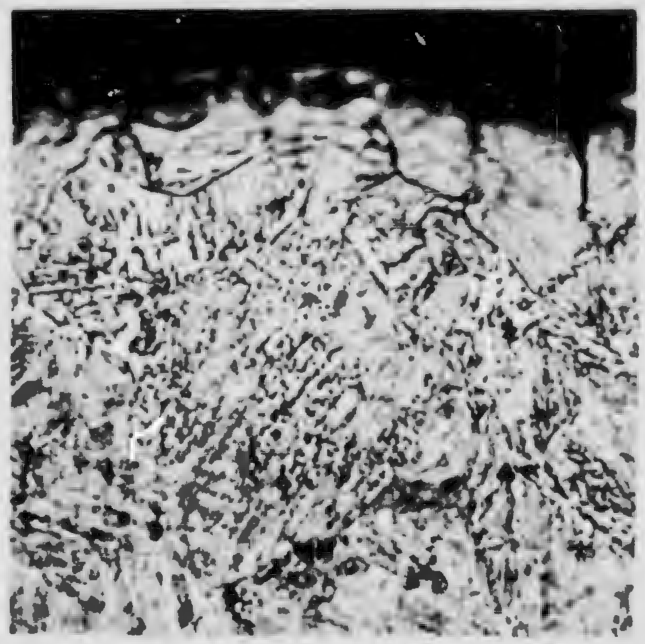
300X 2% Nital Etch

Figure 3

Plate A - hardened
Ferrite layer at the surface

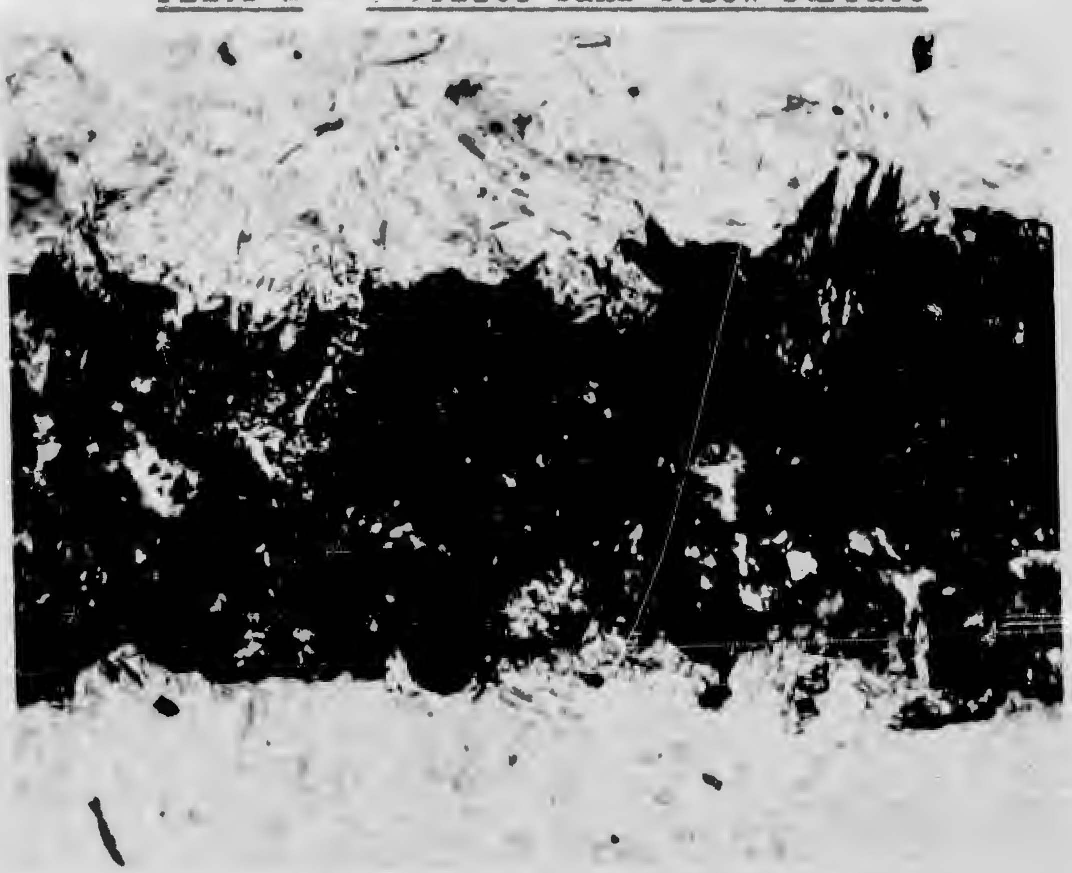
1000X Picral-Nital Etch

Plate B - hardened
No banding evident at surface



1000X Picral-Nital Etch

Plate B - Pearlite band below surface



1000X Picral-Nital Etch

Figure 4

Plate G-26 - Oil Quenched
Acicular ferrite in the case

1000X Picral Etch

Plate G-26 - Water Quenched
Fully martensitic surface

1000X Picral Etch

(a) Effect of Decarburization.

Surface defects appear to be more detrimental than defects in the body of BPS plates. In Figure 2, photomicrographs of the edge of plates A and B as annealed show decarburization to a depth of .007" in A and ferrite banding to a depth of .025" in B. When hardened, Plate A had a layer of ferrite at the surface while B had little ferrite at the surface but had long pearlite bands below the surface (Figure 3). These pearlite bands are formed in low alloy regions in oil quenching the plate. The presence of these low alloy regions were shown in the annealed state by the ferrite bands. On ballistic testing, Plate B was found to have 120 ft./sec. higher limit than A. It is thought that this difference is due to the presence of the ferrite layer. The Brinell test does not indicate this surface defect because the ferrite layer is removed by grinding when preparing the sample for hardness testing.

(b) Effect of Normalizing.

The normalizing of annealed Pluramelt plates before hardening had little or no effect on the ballistic limit. The additional heat treatment provides further opportunity for surface decarburization and is, therefore, not considered advisable.

(c) Effect of Quenching Medium.

Plate G-18 had approximately the same limit on either oil or water quenching, while Plate G-26 had a 120 ft./sec. lower limit when oil quenched than when water quenched. The microstructure of the face of the oil and water quenched plates furnishes a possible explanation for these results. Plate G-18 was fully martensitic at the surface in either quenching medium, but Plate G-26 developed some acicular ferrite when oil quenched while it was fully martensitic on water quenching (Figure 4).

From previous work on Pluramelt and from the above data, it is thought that in the absence of surface decarburization, oil and water quenching will give similar ballistic results. With partial decarburization, the water quenching will give higher ballistic limits; while heavy decarburization will result in plate failures on either water or oil quenching.

Little data is available on the permissable depth of decarburization of the face. Plate A above passed the specifications by a margin of 100 ft./sec. and had .007" decarburization. Plate HP356 tested in January (see

Appendix) failed when oil quenched and barely passed when water quenched. This plate had over 0.020" decarburization which thus must be considered an excessive amount.

IV DISCUSSION

Light armor produced from plates made by the Pluramelt process has had an excessive percentage of failures in 1942 - 17.7% of 1/2" acceptance test plates. The failures can be attributed to a large extent to the fact that Pluramelt has only recently been used for armor plate and that it is treated by manufacturers inexperienced in its production. The performance of BPS plates treated by Atkins and by U. S. Spring and Bumper Company has been similar during the past six months.

At present, the main weakness of Pluramelt plates is the wide variation in penetration resistance shown by test plates. Several 1/2" acceptance test plates of Pluramelt have had high limits (above 2300 ft./sec.) when tested with .50 cal. AP M2 bullets. 2300 ft./sec. is higher than any limits determined for carburized or nitrided plates at the Naval Proving Ground. Pluramelt has also shown excellent shock resistance. Under the new specifications, Buord Spec. O.S. 2775, several 1/2" carburized plates have failed the shock test with 20mm HE projectiles while all Pluramelt plates have successfully passed this test.

Recent failures of plates manufactured by E. C. Atkins and Company and by the U. S. Spring and Bumper Company can be partly accounted for by surface decarburization which is introduced during heat treating, and during rolling and annealing operations by the Allegheny Ludlum Steel Corporation. All possible means should be used to minimize this defect on BPS plates.

Results of experimental work at the Naval Proving Ground indicate that Pluramelt plates having high surface hardness may have satisfactory ballistic properties. On the other hand, plates having low surface hardness due to incorrect heat treatment or to excessive surface decarburization will, in general, have low resistance to penetration.

For the past two years, tensile strength data furnished by a manufacturer on the low carbon back of Pluramelt plates have been as follows:

Yield Point	Tensile Strength	% Elong.	% Red. Area
171,230	211,660	11	42

These physical properties are of little value for purposes of correlation since they have not varied with changes in chemical analysis, gauge or heat treatment. It is questionable whether it is necessary to obtain tensile test results on BPS plates but is is essential that the low carbon back have sufficient hardenability to harden throughout on oil quenching. Brinell hardness readings on the back of Pluramelt plates should be taken by grinding down below any surface decarburization before making the impression in order to obtain a representative value.

V APPENDIX

Experimental Reheat Treatment of 1/2" Plurament at the Naval Proving Ground

U. S. Spring and Bumper Company

Date	Plate	Quenching Medium	Ballistic Limit, f.s. As Submitted	Ballistic Limit, f.s. After Reheat Treatment by NPG
June 16,1942	NB4R	Water	2060 (LCP)	2140
July 3	NB51R	Water-spray	1813	1910
July 3	NB10R	Water-still	2048	2150
July 3	NB68	Oil	2160 (PP)	2220
July 3	NB69	Air	2190	1970
July 17	NB51R	Oil	1813	2005
July 20	NB73	Oil	1925	2330
July 20	NB75	Oil	2020	2170
July 20	NB79	Oil	1800	2170
July 22	NB29RR	Oil	1278	2100(PP)
Sept. 22	NB14	Water	1925	1954(LCP)
Dec. 26	NB315	Water	1940	2209
Jan. 2, 1943	NB356	Oil	1510	1900
Jan. 2	NB356	Water	1510	2067

Atkins

Date	Plate	Quenching Medium	As Submitted	After Reheat Treatment by NPG
Oct. 29,1942	G4E	Water	1977	2325
Nov. 3	G46D	Water	2030	2150
Nov. 3	G1F	Water	2055	2130
Nov. 3	G16C	Water	2065	2180
Dec. 26	G46DR	Water	2025	2220

Ohlen-Bishop

Date	Plate	Quenching Medium	Ballistic Limit As Submitted	Ballistic Limit After Reheat Treatment by NPC
Dec. 26,1942	18	Water	1712	2401
Dec. 26	29	Water	1955	2238
Dec. 26	40	Water	2201	2444
Dec. 26	50	Water	1883	2367
Dec. 30	43	Water	2130	2280
Jan. 5, 1943	18	Oil	1712	2058
Jan. 5	29	Oil	1955	2129
Jan. 5	50	Oil	1883	2188

Allegheny-Ludlum
(Green Plates)

Date	Plate	Quenching Medium	Ballistic Limit As Submitted	Ballistic Limit After Reheat Treatment by NPC
Jan. 23,1943	A	Oil		2140
Jan. 23	AN	Oil		2164
Jan. 23	B	Oil		2262
Jan. 23	BN	Oil		2220
Jan. 25	G18-O	Oil		2226
Jan. 25	G18-W	Water		2262
Jan. 25	G26-O	Oil		2155
Jan. 25	G26-W	Water		2272

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