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REPORT NO. 710/196

BALLISTIC TESTS OF
EXPERIMENTAL ARMOR PLATE COMPOSITIONS

Progress Report No. II

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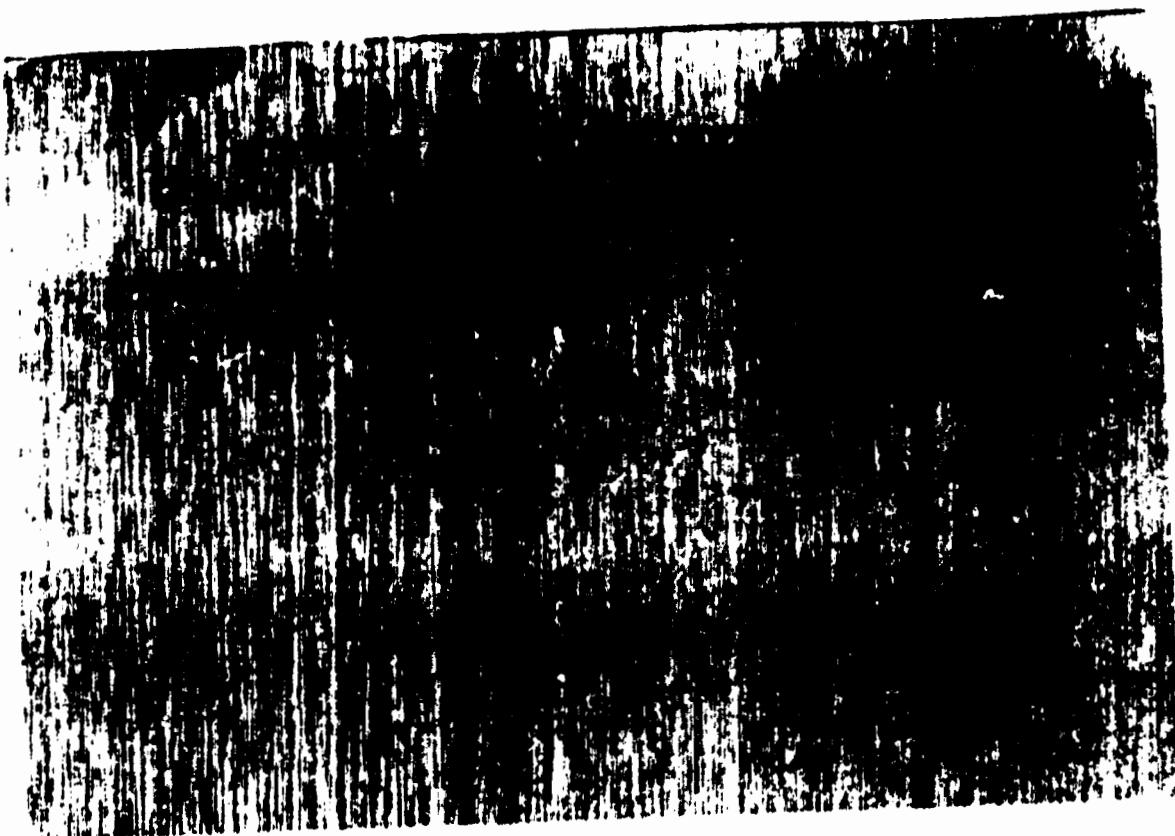
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Research Metallurgist

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BALLISTIC TESTS OF

EXPERIMENTAL ARMOR PLATE COMPOSITIONS

Progress Report No. II

Purpose

The purpose of this investigation was to determine the ballistic properties of a series of 55 experimental armor plate compositions.

Conclusions

1. The following compositions have good ballistic properties with respect to resistance, to penetration and freedom from spalling when heat treated to variable hardness values, and, therefore, are promising steels for further development:

- (a) Standard Chromium-Molybdenum-Vanadium
(C .53, Cr 1.30, Mo .74, V .225)
- (b) Standard Chromium-Molybdenum-Vanadium with
high Molybdenum (C .52, Cr 1.30, Mo 1.54, V .225)
- (c) Standard Chromium-Molybdenum-Vanadium treated
with Titanium (C .53, Cr 1.33, Mo .74, V .23,
Ti .03/.11).
- (d) Chromium-Molybdenum-Vanadium-Tungsten
(C .52, Cr 1.34, Mo .44/.85, V .24, W .62/1.47)
- (e) Nickel-Silicon-Molybdenum
(C .35, Ni 3.23, Si 2.64, Mo .76)
- (f) Manganese-Molybdenum-Tungsten
(C .49, Mn 1.45, Mo 2.66, W .86)
- (g) Manganese-Molybdenum
(C .41, Mn 2.40, Mo .61)
- (h) Nickel-Chromium
(C .56, Ni 2.16, Cr 1.92)

2. High percentages of nickel added to the standard chromium-molybdenum-vanadium composition (about 5 %) does

not increase the ballistic limit appreciably when heat treated to a Brinell hardness of 444. Nickel steels within the 444/477 Brinell hardness range show spalling tendencies.

3. Chromium additions (2-5%) to the standard composition do not noticeably improve its ballistic properties when heat treated to 418-477 Brinell hardness.

4. Laminations promote spalling in armor plate.

5. Armor plate, heat treated to a Brinell hardness range of 360/450, shows only slight tendency to spall (3.4% of plates tested spalled). Spalling occurs in 32% of the plates heat treated to Brinell hardness range of 444/477, while 45% spalled within 477/600 Brinell hardness range.

6. Good quality armor plate must be free from laminations and should have a uniform troostite-sorbitic structure, or a structure composed of acicular troostite.

Experimental Procedure

1. Casting

Sixty-pound induction furnace heats of various chemical compositions, given in Table I, were cast in the form of 4 x 4" ingots. This series of chemical compositions was developed by modifying the basic chromium-molybdenum-vanadium armor plate composition.

2. Sampling of Ingot

(a) Macro Section. A section about 3/4" in thickness was cut 9" from the bottom of the ingot and reserved for macroscopic study.

(b) Chemical Analysis. Millings were taken from the lower face of the macro-section for chemical analysis.

3. Forging

(a) Into Rounds. A lot of ingots consisting of twelve or thirteen ingots were placed in a cold furnace and heated to forging heat, 1150-1185°C (2102-2156°F), in about 3 hours, held within this range for nearly 3-1/2 hours, and forged to bars 2-3/8" in diameter, or to a 3:1 reduction. All forged bars were buried in cinders from forging temperature.

(b) Into Plate. Sections 6" in length were cut from each 2-3/8" round for the purpose of forging into plate. The rounds were heated to an average temperature of 2175°F for approximately 25 minutes and forged into plate according to the following procedure. The section was removed from the furnace, placed vertically on the anvil of the forging hammer and upset, after which it was placed horizontally on the anvil and forged into plate. The average size of the plate was 7 x 7 x 9/16". The forging of all plates was completed after one heating. All plates were buried in cinders after forging.

4. Heat Treatment

A. Normalize and anneal.

The plates were given a normalize and anneal as follows in order to relieve forging strains and also to refine the grain.

(a) Normalizing. All plates were heated at 1750°F for 2 hours and air cooled.

(b) Annealing.

1. The following plates were heated at 1275°F for 3 hours and furnace cooled.

4X, 5X, 6X, 7X, 8, 9X, 10X, 11, 12, 13X, 14, 15, 16, 17X, 18X, 20, 32, 34, 35, 36, 37, 38, 6B, 2B, 5B, 4B, 1B, 3B, 7B, 9B, 10B, 8B, 16B, 15B, 11B, 14B, 18B, 20B, 13B, 19B, 23B, 24B, 25B.

2. The following plates were heated at 1560°F for 3 hours and furnace cooled.

24, 26, 28X, 33, 39, 40, 23, 29, 17B, 21B, 22B, 12B.

Previous to hardening and tempering, all plates were surface ground to 1/2" in thickness.

B. Hardening and Tempering.

The various compositions were heat treated to three different ranges of Brinell hardness, namely, 495/600, 444/477 and 364/430, and in each hardness range ballistic properties were determined. The quenching temperatures were determined for each composition by heating small sections through the critical range from every 100°C from 750-910°C.

5. Ballistic Tests.

All ballistic tests were made with preloaded armor piercing ammunition, the distance from muzzle to plate being 100 yards. The plate which was securely bolted to a wooden frame was normal to fire.

6. Microscopic Examination.

Microscopic examination was made on a few typical high and low ballistic plates.

Results

1. Chemical Analysis.

Chemical analysis of the experimental armor plates is given in Table I.

2. Heat Treatment.

The normalizing, annealing, hardening and drawing temperatures, as determined for each composition, are given in Table II.

3. Ballistic Tests.

Ballistic tests are given on Pages 18-72 inclusive. A summary of all ballistic tests is given in Table III.

4. Microscopic Examination.

Figures 1-3 inclusive show microstructures of typical good and poor plates.

5. Ballistic Hardness Studies.

Figures 16-20 illustrate ballistic hardness relationships.

TABLE I

Chemical Analysis

<u>No.</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>	<u>W</u>	<u>Ti</u>
6B	.53	.71	.006	.016	.310	0	1.30	.74	.225	0	0
4X	.39	.85	.007	.016	.32	0	2.82	.63	.23	0	0
5X	.37	.53	.007	.016	.37	0	5.36	.65	.24	0	0
6X	.41	.73	.007	.015	.23	1.22	1.20	.65	.21	0	0
7X	.41	.67	.007	.015	.20	2.38	1.20	.60	.20	0	0
15B	.355	.69	.008	.016	.175	3.27	1.08	.59	.11	0	0
8	.40	.88	.007	.018	.31	4.60	1.15	.62	.23	0	0
2B	.485	.65	.007	.016	.36	0	1.30	1.13	.21	0	0
5B	.52	.69	.018	.007	.32	0	1.30	1.54	.225	0	0
23B	.455	.85			.23	0	1.47	2.92	.25	0	0
9X	.44	.60	.007	.016	.14	1.26	0	.68	.20	0	0
10X	.43	.66	.007	.014	.24	2.36	0	.61	.21	0	0
11	.42	.60	.007	.014	.21	4.55	0	.60	.23	0	0
12	.42	.69	.007	.018	.28	3.71	0	.27	.23	0	0
13X	.41	.67	.008	.020	.30	4.02	0	.49	.30	0	0

TABLE I (Cont'd)

No.	C	Mn	P	S	Si	Ni	Cr	Mo	Va	W	Ti
14	.37	.59	.012	.018	.28	3.57	0	.65	.21	0	0
15	.40	.62	.011	.016	.25	3.45	0	.88	.22	0	0
16	.39	.68	.009	.017	.17	3.65	1.15	.31	.20	0	0
17X	.44	.63	.007	.019	.27	3.86	1.26	.47	.27	0	0
16B	.365	.66	.006	.017	.155	4.08	1.22	.62	.255	0	0
18X	.37	.60	.012	.019	.290	5.57	1.15	.78	.225	0	0
20	.38	.68	.012	.014	.22	4.00	1.12	.68	.10	0	0
23	.40	1.68	.012	.017	1.73	0	0	.78	0	0	0
17B	.365	1.38	.009	.016	1.955	0	0	.59	.11	0	0
24	.40	.85	.007	.019	2.20	3.20	0	0	0	0	0
19B	.35	.86	.012	.017	2.635	3.23	0	.76	0	0	0
20B	.37	.80	.011	.016	2.63	3.09	0	1.21	0	0	0
13B	.345	.76	.007	.015	2.48	3.09	0	.64	.27	0	0
26	.44	.68	.011	.016	.39	0	0	2.08	.10	0	0
28X	.44	.56	.009	.019	.34	0	0	4.07	.12	0	0

TABLE I (Cont'd)

No.	C	Mn	P	S	Si	Ni	Cr	Mo	Va	W	Ti
29X	.47	.63	.009	.020	.33	0	0	5.07	.11	0	0
19B	.34	1.38	.011	.016	.415	2.64	0	.82	0	0	0
12B	.49	1.45	.011	.019	.35	0	0	2.66	0	.86	0
32	.37	.57	.009	.017	.19	0	2.18	.60	0	0	0
14B	.435	.69	.011	.018	.200	0	2.12	.66	0	0	0
33	.41	2.40	.011	.018	.37	0	0	.61	0	0	0
11B	.41	.77	.010	.015	.18	2.54	0	1.10	0	0	0
34	.40	.44	.011	.017	.15	3.88	0	.60	0	0	0
35	.56	.26	.010	.022	.23	2.16	1.92	0	0	0	0
36	.61	.18	.009	.018	.28	2.66	2.59	0	0	0	0
37	.36	.38	.009	.020	.21	3.86	2.07	0	0	0	0
38	.28	.45	.009	.020	.19	3.90	1.87	0	0	0	0
4B	.515	.70	.009	.015	.244	0	1.34	.85	.24	.62	0
24B	.47	.91			.198	0	1.51	.34	.285	.68	0
25B	.45	.90			.168	0	1.45	.35	.26	1.35	0

TABLE I (Cont'd)

No.	C	Mn	P	S	Si	Ni	Cr	Mo	Va	W	Ti
1B	.52	.64	.009	.016	.263	0	1.33	.44	.24	1.47	0
3B	.54	.59	.009	.016	.287	0	1.30	.75	.24	1.45	0
7B	.515	.66	.010	.016	.327	0	1.35	.70	.225	2.94	0
39	.36	.65	.007	.015	.30	0	0	1.22	.10	.16	0
40	.43	.55	.007	.015	.33	0	0	2.14	.09	.32	0
21B	.235	.53	.019	.006	.188	0	.62	0	.20	3.36	0
22B	.325	.56	.019	.007	.216	0	.56	.44	.21	2.92	0
10B	.525	.67	.010	.016	.415	0	1.31	.68	.225	0	.03
9B	.585	.63	.006	.017	.41	0	1.32	.68	.24	0	.04
8B	.535	.59	.007	.017	.63	0	1.34	.79	.24	0	.11

TABLE II

Proper Quenching and Drawing Temperatures
Experimental Armor Plate Compositions

Plate No.	Normalize & Anneal	Heat Treat- ment	Quench		Draw
6B	1750°F-2 hrs-air cool	1	1650°F-2	hrs-oil quench	350°F-2 hrs-oil quench
	1560°F-3 hrs-furnace cool	2	" "	" "	850°F-2 hrs-air cool
		3	" "	" "	950°F-2 hrs-air cool
4X	1750°F-2 hrs-air cool	1	1650°F-2	hrs-water quench	350°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	1650°F-2	hrs-oil quench	350°F-2 hrs-air cool
		3	1650°F-2	hrs-oil quench	900°F-2 hrs-air cool
5X	1750°F-2 hrs-air cool	1	1710°F-2	hrs-oil quench	350°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	" "	" "	900°F-2 hrs-air cool
		3	" "	" "	1000°F-2 hrs-air cool
6X	1750°F-2 hrs-air cool	1	1490°F-2	hrs-air cool	350°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	" "	" "	800°F-2 hrs-air cool
		3	" "	" "	900°F-2 hrs-air cool
7X	1750°F-2 hrs-air cool	1	1550°F-2	hrs-oil quench	400°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	1490°F-2	hrs-air cool	350°F-2 hrs-air cool
		3	1550°F-2	hrs-oil quench	925°F-2 hrs-air cool
15B	1750°F-2 hrs-air cool	1	1550°F-2	hrs-water quench	500°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	1550°F-2	hrs-oil quench	400°F-2 hrs-air cool
		3	1450°F-2	hrs-oil quench	650°F-2 hrs-air cool
8	1750°F-2 hrs-air cool	1	1600°F-2	hrs-air cool	350°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	" "	" "	800°F-2 hrs-air cool
		3	" "	" "	900°F-2 hrs-air cool

TABLE II (Cont'd)

Plate No.	Normalize & Anneal	Heat Treatment	Quench		Draw
2B	1750°F-2 hrs-air cool	1	1670°F-2	hrs-oil	quench
	1275°F-3 hrs-furnace cool	2	"	"	"
		3	"	"	"
5B	1750°F-2 hrs-air cool	1	1560°F-2	hrs-oil	quench
	1275°F-3 hrs-furnace cool	2	"	"	"
		3	"	"	"
23B	1750°F-2 hrs-air cool	1	1670°F-2	hrs-oil	quench
	1275°F-3 hrs-furnace cool	2	"	"	"
		3	"	"	"
9X	1750°F-2 hrs-air cool	1	1540°F-2	hrs-water	quench
	1275°F-3 hrs-furnace cool	2	1540°F-2	hrs-oil	quench
		3	"	"	"
10X	1750°F-2 hrs-air cool	1	1490°F-2	hrs-oil	quench
	1275°F-3 hrs-furnace cool	2	"	"	"
		3	"	"	"
11	1750°F-2 hrs-air cool	1	1440°F-2	hrs-oil	quench
	1275°F-3 hrs-furnace cool	2	1450°F-2	hrs-oil	quench
		3	1440°F-2	hrs-oil	quench
12	1750°F-2 hrs-air cool	1	1490°F-2	hrs-oil	quench
	1275°F-3 hrs-furnace cool	2	"	"	"
		3	"	"	"
	650°F-2 hrs-air cool				
	950°F-2 hrs-air cool				
	1050°F-2 hrs-air cool				
	1000°F-2 hrs-furnace cool				
	950°F-2 hrs-air cool				
	1050°F-2 hrs-air cool				
	650°F-2 hrs-air cool				
	1050°F-2 hrs-air cool				
	350°F-3 hrs-air cool				
	350°F-2 hrs-air cool				
	950°F-2 hrs-air cool				
	350°F-2 hrs-air cool				
	950°F-2 hrs-air cool				
	1050°F-2 hrs-air cool				
	350°F-2 hrs-air cool				
	900°F-2 hrs-air cool				
	900°F-2 hrs-air cool				
	350°F-2 hrs-air cool				
	500°F-2 hrs-air cool				
	900°F-2 hrs-air cool				

TABLE II (Cont'd)

Plate No.	Normalize & Anneal		Heat Treat- ment	Quench			Draw
13X	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	"	350°F-3 hrs-air cool
			3	"	"	"	900°F-2 hrs-air cool
14	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1490°F-2	hrs-water	quench	350°F-3 hrs-air cool
			3	1490°F-2	hrs-oil	quench	950°F-2 hrs-air cool
15	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1490°F-2	hrs-water	quench	350°F-2 hrs-air cool
			3	1490°F-2	hrs-oil	quench	1000°F-2 hrs-air cool
16	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1490°F-2	hrs-oil	quench	350°F-3 hrs-air cool
			3	1490°F-2	hrs-oil	quench	900°F-2 hrs-air cool
17X	1750°F-2	hrs-air cool	1	1600°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1600°F-2	hrs-oil	quench	350°F-3 hrs-air cool
			3	1600°F-2	hrs-oil	quench	850°F-2 hrs-air cool
16B	1750°F-2	hrs-air cool	1	1490°F-2	hrs-water	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1510°F-2	hrs-oil	quench	400°F-2 hrs-air cool
			3	1510°F-2	hrs-oil	quench	950°F-2 hrs-air cool
18X	1750°F-2	hrs-air cool	1	1600°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	"	850°F-2 hrs-air cool
			3	"	"	"	950°F-2 hrs-air cool
20	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil	quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	"	500°F-2 hrs-air cool
			3	"	"	"	1000°F-2 hrs-air cool

TABLE II (Cont'd)

Plate No.	Normalize & Anneal		Heat Treat- ment	Quench		Draw
23	1750°F-2	hrs-air cool	1	1650°F-2	hrs-oil quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	350°F-3 hrs-air cool
			3	"	"	900°F-2 hrs-air cool
17B	1750°F-2	hrs-air cool	1	1620°F-2	hrs-oil quench	650°F-2 hrs-air cool
	1560°F-3	hrs-furnace cool	2	"	"	500°F-2 hrs-air cool
			3	"	"	950°F-2 hrs-air cool
24	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil quench	350°F-3 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	350°F-2 hrs-air cool
			3	"	"	900°F-2 hrs-air cool
18B	1750°F-2	hrs-air cool	1	1650°F-2	hrs-oil quench	400°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	600°F-2 hrs-air cool
			3	1620°F-2	hrs-oil quench	925°F-2 hrs-air cool
20B	1750°F-2	hrs-air cool	1	1550°F-2	hrs-water quench	500°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1600°F-2	hrs-oil quench	400°F-2 hrs-air cool
			3	1560°F-2	hrs-oil quench	400°F-2 hrs-air cool
13B	1750°F-2	hrs-air cool	1	1600°F-2	hrs-oil quench	400°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	1560°F-2	hrs-oil quench	400°F-2 hrs-air cool
			3			
26	1750°F-2	hrs-air cool	1	1490°F-2	hrs-oil quench	350°F-2 hrs-air cool
	1275°F-3	hrs-furnace cool	2	"	"	950°F-2 hrs-air cool
			3	"	"	500°F-2 hrs-air cool

TABLE II (Cont'd)

Plate No.	Normalize & Anneal	Heat Treatment	Quench		Draw
28X	1750°F-2 hrs-air cool	1	1600°F-2 hrs-oil quench	350°F-2 hrs-air cool	
	1560°F-3 hrs-furnace cool	2	1600°F-2 hrs-water quench	350°F-2 hrs-air cool	
		3	1600°F-2 hrs-oil quench	850°F-2 hrs-air cool	
29X	1750°F-2 hrs-air cool	1	1750°F-2 hrs-oil quench	400°F-2 hrs-air cool	
	1560°F-3 hrs-furnace cool	2	1650°F-2 hrs-oil " "	350°F-2 hrs-air cool	
		3	" " " "	800°F-2 hrs-air cool	
19B	1750°F-2 hrs-air cool	1	1550°F-2 hrs-oil quench	400°F-2 hrs-air cool	
	1275°F-3 hrs-furnace cool	2	1450°F-2 hrs-oil " "	925°F-2 hrs-air cool	
		3	" " " "	900°F-2 hrs-air cool	
12B	1750°F-2 hrs-air cool	1	1450°F-2 hrs-oil quench	650°F-2 hrs-air cool	
	1560°F-3 hrs-furnace cool	2	" " " "	800°F-2 hrs-air cool	
		3	" " " "	950°F-2 hrs-air cool	
32	1750°F-2 hrs-air cool	1	1600°F-2 hrs-water quench	350°F-2 hrs-air cool	
	1275°F-3 hrs-furnace cool	2	1750°F-2 hrs-oil quench	500°F-2 hrs-air cool	
		3	1710°F-2 hrs-oil quench	350°F-2 hrs-air cool	
14B	1750°F-2 hrs-air cool	1	1600°F-2 hrs-oil quench	400°F-2 hrs-air cool	
	1275°F-3 hrs-furnace cool	2	" " " "	600°F-2 hrs-air cool	
		3	1560°F-2 hrs-oil quench	1000°F-2 hrs-furnace cool	
33	1750°F-2 hrs-air cool	1	1490°F-2 hrs-oil quench	350°F-2 hrs-air cool	
	1560°F-3 hrs-furnace cool	2	" " " "	500°F-2 hrs-air cool	
		3	" " " "	950°F-2 hrs-air cool	
11B	1750°F-2 hrs-air cool	1	1450°F-2 hrs-oil quench	350°F-2 hrs-air cool	
	1275°F-3 hrs-furnace cool	2	" " " "	500°F-2 hrs-air cool	
		3	1400°F-2 hrs-oil quench	400°F-2 hrs-air cool	

TABLE II (Cont'd)

Plate No.	Normalize & Anneal	Heat Treatment	Quench	Draw
34	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1540°F-2 hrs-oil quench 1540°F-2 hrs-water quench 1540°F-2 hrs-oil quench	350°F-2 hrs-air cool 500°F-2 hrs-air cool 950°F-2 hrs-air cool
35	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1490°F-2 hrs-oil quench " " " " " "	350°F-2 hrs-air cool 800°F-2 hrs-air cool 950°F-2 hrs-air cool
36	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1600°F-2 hrs-oil quench " " " " " "	650°F-2 hrs-air cool 800°F-2 hrs-air cool 900°F-2 hrs-air cool
37	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1490°F-2 hrs-water quench 1490°F-2 hrs-oil quench " " "	350°F-2 hrs-air cool 350°F-2 hrs-air cool 950°F-2 hrs-air cool
38	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1600°F-2 hrs-water quench 1540°F-2 hrs-oil quench " " "	350°F-2 hrs-air cool 350°F-2 hrs-air cool 500°F-2 hrs-air cool
4B	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1560°F-2 hrs-oil quench " " " " " "	925°F-2 hrs-air cool 950°F-2 hrs-air cool 1050°F-2 hrs-air cool
24B	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1550°F-2 hrs-oil quench " " " 1510°F-2 hrs-oil quench	650°F-2 hrs-air cool 600°F-2 hrs-air cool 925°F-2 hrs-air cool
25B-	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1560°F-2 hrs-oil quench " " " " " "	1000°F-2 hrs-air cool 950°F-2 hrs-air cool 1050°F-2 hrs-air cool

TABLE II (Cont'd)

Plate No.	Normalize & Anneal	Heat Treatment	Quench	Draw
1 B	1750°F-2 hrs-air cool 1276°F-3 hrs-furnace cool	1 2 3	1560°F-2 hrs-oil quench " " " " " "	1000°F-2 hrs-furnace cool 950°F-2 hrs-air cool 1050°F-2 hrs-air cool
3 B	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1670°F-2 hrs-oil quench " " " " " "	925°F-2 hrs-air cool 950°F-2 hrs-air cool 1050°F-2 hrs-air cool
7 B	1750°F-2 hrs-air cool 1275°F-3 hrs-furnace cool	1 2 3	1670°F-2 hrs-oil quench " " " " " "	925°F-2 hrs-air cool 950°F-2 hrs-air cool 1050°F-2 hrs-air cool
39	1750°F-2 hrs-air cool 1560°F-3 hrs-air cool	1 2 3	1560°F-2 hrs-oil quench " " " " " "	350°F-2 hrs-air cool 350°F-3 hrs-air cool 950°F-2 hrs-air cool
40	1750°F-2 hrs-air cool 1560°F-2 hrs-air cool	1 2 3	1650°F-2 hrs-water quench 1650°F-2 hrs-oil quench " " "	350°F-3 hrs-air cool 350°F-2 hrs-air cool 950°F-2 hrs-air cool
21B	1750°F-2 hrs-air cool 1560°F-3 hrs-furnace cool	1 2 3	1710°F-2 hrs-water quench " " " " " "	400°F-2 hrs-air cool " " " " " "
22B	1750°F-2 hrs-air cool 1560°F-3 hrs-furnace cool	1 2 3	1650°F-2 hrs-oil quench " " " " " "	400°F-2 hrs-air cool " " " " " "

TABLE II (Cont'd)

Plate No.	Normalize & Anneal	Heat Treatment	Quench	Draw
10B	1750°F-2 hrs-air cool	1	1620°F-2 hrs-oil quench	650°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	" " "	950°F-2 hrs-air cool
		3	" " "	1050°F-2 hrs-air cool
9B	1750°F-2 hrs-air cool	1	1670°F-2 hrs-oil quench	650°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	1670°F-2 hrs-water quench	500°F-2 hrs-air cool
		3	1670°F-2 hrs-oil quench	950°F-2 hrs-air cool
8B	1750°F-2 hrs-air cool	1	1600°F-2 hrs-oil quench	650°F-2 hrs-air cool
	1275°F-3 hrs-furnace cool	2	" " "	925°F-2 hrs-air cool
		3	1560°F-2 hrs-oil quench	925°F-2 hrs-air cool

Composition No. 6B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 600 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.18"	No cracks

Second Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 850°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.46"	No cracks
2	2600	"	.47"	Small cracks

Third Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 460 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.64"	Tiny radial cracks

Composition No. 4X

Dimensions - 7 x 7 x 1/8"

Actual Thickness - .502"

Normalize - Heat to 1750°F - 2 hrs. - air cool.

Anneal - " " 1275°F - 3 " - furnace cool.

First Heat Treatment

Heat to 1650°F - 2 hrs. - water quench.

Draw at 350°F - 2 " - air cool.

Hardness - 532 Brinell

Ballistics

Round	Vel.f/s	Pen.	Depth of Pen.	Remarks
1	2500	partial	.39"	No cracks.
2	2600	complete	---	1" dia. button 2" crack to edge of plate.

Second Heat Treatment

Heat to 1650°F - 2 hrs. - oil quench.

Draw at 350°F - 2 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel.f/s	Pen.	Depth of Pen.	Remarks
1	2600	partial	.47"	Small hair-cracks on back of plate.

Third Heat Treatment

Heat to 1650°F - 2 hrs. - oil quench.

Draw at 300°F - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f/s	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks.
2	2400	partial	.53"	No cracks.

Composition No. 5X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .502"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal - " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1710°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 532 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	Bullet core fused into plate	No cracks.

Second Heat Treatment

Heat to 1710°F. - 2 hrs. - oil quench.
Draw at 900°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Button starting.
2	2400	hit Rd.#1	---	Button.
3	2400	partial	.47"	No cracks.

Third Heat Treatment

Heat to 1710°F. - 2 hrs. - oil quench.
Draw at 1000°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.47"	No cracks.
2	2600	"	.49"	Start of button.

Composition No. 6X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .508"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal - " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - air cool.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete C.I.P.	---	Button
2	2400	partial	.45"	No cracks.
3	2500	"	.50"	Tiny hair-crack.

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - air cool.
Draw at 300°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small cracks.
2	2400	partial	.49"	No cracks.

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - air cool.
Draw at 900°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks.
2	2400	partial	.52"	" " "

Composition No. 7X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .511"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1550°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 435 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.51"	Start of button.
2	2500	"	.49"	" " "
3	2600	"	.37"	No cracks.

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - air cool.
Draw at 330°F. - 2 hrs. - air cool.

Hardness - 460 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.45"	No cracks.
2	2600	"	.49"	Start of button.

Third Heat Treatment

Heat to 1550°F. - 2 hrs. - oil quench.
Draw at 925°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks
2	2400	"	---	" " "
3	2300	partial	.43"	No cracks.

Composition No. 15B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .510"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1550°F. - 2 hrs. - water quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.55"	Button starting.
2	2600	complete C.I.P.	hit near former shot	3/4" button.
3	2600	partial	.57"	Button starting.

Second Heat Treatment

Heat to 1550°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.48"	No cracks.

Third Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 650°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Radial cracks.
2	2500	"	---	Radial cracks.
3	2400	partial	.54"	Start of button.

Composition No. 8

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - air cool.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button
2	2500	partial	.46"	---

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - air cool.
Draw at 800°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks.
2	2400	partial	.56"	" " "

Third Heat Treatment

Heat to 1600°F. - 2 hrs. - air cool.
Draw at 900°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks.
2	2400	partial	.55"	" " "

Composition No. 2B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .497"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench.
Draw at 650°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.33"	No cracks.

Second Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.47"	Small crack.
2	2600	"	.54"	Button starting

Third Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench.
Draw at 1050°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.46"	Button starting.

Composition No. 8B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .505"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 1000°F. - 2 " - furnace cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.45"	No cracks.

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.44"	No cracks.
2	2600	"	.49"	Tiny cracks.

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 1050°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.46"	No cracks.
2	2600	"	.52"	Tiny radial cracks.

Composition No. 23B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench.
Draw at 650°F. - 2 " - air cool.

Hardness - 532 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete		Plate broke into 3 pieces-spalling

A new plate 7 x 7 x 1/2" was forged from Ingot No. 23B

Actual Thickness - .498"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

Second Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench.
Draw at 1050°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete		Button - 3" in diameter was blown out.

Ingot #23B was found to contain piping and cracks extending down the center of the ingot.

Composition No. 9X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1540°F. - 2 hrs. - water quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks.
1	2400	partial	.30"	No cracks.
2	2600	"	.38"	Tiny cracks.

Second Heat Treatment

Heat to 1540°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.43"	No cracks.

Third Heat Treatment

Heat to 1540°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.56"	Tiny radial cracks.
2	2500	complete	---	" " "

Composition No. 10X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 632 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.50"	Button starting.

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.45"	No cracks.
2	2500	"	.51"	" "
3	2600	"	.53"	Tiny radial cracks.

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 1050°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks.
2	2400	partial	.53"	No cracks.

Composition No. 11

Dimensions - 7 x 7 x 1/8"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 3 hrs. - air cool.
Anneal " " 1175°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1440°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 555 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button
2	2500	partial	---	No cracks
3	2500	"	.27"	" "

Second Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 300°F. - 2 " - air cool.

Hardness - 430 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks.
2	2600	complete	---	Punching started
3	2400	partial	.53"	No cracks

Third Heat Treatment

Heat to 1440°F. - 2 hrs. - oil cool.
Draw at 300°F. - 2 " - air cool.

Hardness - 413 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Small radial cracks
2	2400	partial	.53"	No cracks

Composition No. 12

Dimensions - 7 x 7x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 578 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	Bullet core fused into penetration	No cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.32"	No cracks
2	2600	complete	---	1/4" dia. hole in back of plate.

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 900°F. - 2 " - air cool.

Hardness - 402 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Small radial cracks.
2	2400	"	---	" " "
3	2300	partial	.53"	No cracks.

Composition No. 13X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .803"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1675°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1400°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 532 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete C.I.P.	---	Button
2	2500	partial	.51"	No cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.27"	No cracks
2	2600	complete C.I.P.	---	---
3	2500	partial	.50"	Tiny radial cracks

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 300°F. - 2 " - air cool.

Hardness - 402 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remark
1	2500	complete	---	Small radial cracks.
2	2400	"	---	No cracks
3	2300	partial	.34"	" "

Composition No. 14

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .500"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 435 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.52"	Very small radial cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - water quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.46"	No cracks
2	2600	"	.54"	Button starting

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks
2	2400	"	---	" " "
3	2300	partial	.52"	No cracks

Composition No. 15

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.55"	Button starting
2	2600	"	.54"	" "

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - water quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.50"	No cracks
2	2600	complete	---	Button, 1" x 1 1/2" blown out of back

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 1000°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks
2	2400	"	---	" "
3	2500	partial	.43"	No cracks

Composition No. 16

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .507"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.31"	No cracks
2	2600	"	.53"	Button starting

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete C.I.P.	---	Button
2	2400	partial	.43"	No cracks

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 900°F. - 2 " - air cool.

Hardness - 402 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks
2	2400	partial	.56"	Tiny radial cracks

Composition No. 17X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button
2	2500	"	---	"
3	2400	partial	.50"	No cracks

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.51"	Tiny radial cracks
2	2600	complete C.l.P.	---	Button

Third Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 850°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete C.l.P.	---	Small radial cracks
2	2400	complete	---	" " "
3	2300	partial	.53"	No cracks

Composition No. 16B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .511"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - water quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.48"	Tiny radial cracks
2	2500	"	.40"	No cracks
3	2500	hit for- mer shot	complete	----
4	2600	partial	.50"	Tiny radial cracks

Second Heat Treatment

Heat to 1510°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.54"	Small radial cracks

Third Heat Treatment

Heat to 1510°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks
2	2400	"	---	No cracks
3	2300	partial	.46"	" "

Composition No. 18X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 555 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	Tip of bullet core fused into penetration	No cracks

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 850°F. - 2 " - air cool.

Hardness - 460 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Button starting
2	2400	"	---	Small radial cracks
3	2300	partial	.47"	No cracks

Third Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks
2	2400	partial	.53"	" " "

Composition No. 20

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .502"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 532 Brinell

Ballistics

Round	Vel. f./s.	n.	Depth of Pen.	Remarks
1	2600	partial	.44"	No cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.52"	No cracks
2	2600	complete	---	Small radial cracks

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 1000°F. - 2 " - air cool.

Hardness - 430 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Small radial cracks
2	2400	partial	.52"	" " "

Composition No. 23

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.42"	Tiny hair-crack

Second Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.54"	Tiny radial cracks
2	2600	complete	---	" " "

Third Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 900°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks
2	2400	partial	.50"	No cracks

Composition No. 17B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 hrs. - furnace cool.

First Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench.
Draw at 650°F. - 2 " - air cool.

Hardness - 495

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	3/4" dia. Button
2	2500	partial	.53"	No cracks

Second Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	complete	---	No cracks
2	2300	partial	.46"	" "

Third Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 387 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.52"	Tiny cracks
2	2500	complete	---	Small radial cracks
3	2400	"	---	Small cracks
4	2300	partial	.50"	No cracks

Composition No. 24

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 3 " - air cool.

Hardness - 555 Brinell

<u>Ballistics</u>		Depth of		Remarks
Round	Vel.f./s.	Pen.	Pen.	
1	2500	partial	.26"	No cracks
2	2600	complete	---	Tiny radial cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 495 Brinell

<u>Ballistics</u>		Depth of		Remarks
Round	Vel.f./s.	Pen.	Pen.	
1	2600	complete	---	Button
2	2500	partial	.55"	Button starting

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 900°F. - 2 " - air cool.

Hardness - 387 Brinell

<u>Ballistics</u>		Depth of		Remarks
Round	Vel.f./s.	Pen.	Pen.	
1	2500	complete	---	No cracks
		C.I.P.		
2	2400	complete	---	Small radial cracks
3	2300	partial	.53"	No cracks

Composition No. 18B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .505"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.41"	No cracks

Second Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 600°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.50"	Tiny radial cracks
2	2600	"	.41"	No cracks

Third Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench.
Draw at 925°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.55"	Small radial cracks

Composition 20B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1550°F. - 2 hrs. - water quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.47"	No cracks
2	2600	complete C.I.P.	---	3/4" dia. Button blown out

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.38"	No cracks

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.48"	No cracks

Composition No. 13B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete C.I.P.	---	Button
2	2400	partial	.47"	No cracks

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 430 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button
2	2600	hit Rd.#1 complete	---	Button
3	2600	partial	.47"	No cracks

Plate could not be heat treated to a greater hardness than 477 Brinell, therefore, only two heat treatments are listed.

Composition No. 26

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.
Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	complete	---	No cracks
2	2300	hit Rd.#1	---	Button
3	2300	complete partial	.42"	No cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.
Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.55"	No cracks
2	2500	complete	---	Small radial cracks

Third Heat Treatment

*Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.
Hardness - 364 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks
2	2400	complete	---	" " "
3	2300	complete	---	" " "
4	2200	partial	.47"	No cracks

*Doubtful

Composition No. 28X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .503"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.32"	No cracks

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - water quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.32"	No cracks
2	2600	"	.32"	" "

Third Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 850°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial Cracks
2	2400	"	---	" " "
3	2300	partial	.51"	No cracks

Composition No. 29X

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F.- 2 hrs. - air cool.
Anneal " " 1560°F.- 3 " - furnace cool.

First Heat Treatment

Heat to 1750°F.- 2 hrs.- oil quench.
Draw at 400°F.- 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete C.I.P.	---	Crack between rounds #1 and #2 about 2 3/4" long.
2	2500	complete	---	
3	2400	"	---	
4	2300	partial	.50"	Crack from pen- etration to former shot

Second Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete C.I.P.	---	Small radial cracks
2	2500	complete	---	" " "
3	2400	"	---	" " "
4	2300	partial	.50"	No cracks

Third Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench.
Draw at 800°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Plate broke into pieces after Rd.#3
2	2400	"	---	
3	2300	"	---	

Composition No. 19B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1550°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 hrs. - air cool.
Hardness - 495 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button
2	2500	partial	.49"	Start of button

Second Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 925°F. - 2 " - air cool.
Hardness - 337 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Small radial cracks
2	2600	"	---	" " "
3	2400	"	---	" " "
4	2300	partial	.53"	" " "
5	2300	"	.51"	" " "

Third Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 900°F. - 2 " - air cool.
Hardness - 387 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Small radial cracks
2	2400	"	---	" " "
3	2300	Partial	.55"	" " "

Composition No. 12B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .507"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 650°F. - 2 " - air cool.

Hardness - 555 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.36"	No cracks

Second Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 800°F. - 2 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.42"	No cracks
2	2600	"	.36"	"

Third Heat Treatment

Heat to 1450°F. - 2 hrs.-oil quench.
Draw at 950°F. - 2 " -air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.46"	No cracks
2	2500	"	.51"	"
3	2600	complete	---	Small radial cracks

Composition No. 32

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .502"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - water quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.54"	Radial cracks
2	2600	complete C.I.P.	---	1" - Button - plate cracked along penetra- tion - 7" long crack.

Second Heat Treatment

Heat to 1750°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	---	---
2	2600	---	---	Plate broke into several pieces after second shot.

Third Heat Treatment

Heat to 1710°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button starting
2	2500	partial	.52"	Tiny radial cracks

Composition No. 14B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. -air cool.
Anneal " " 1275°F. - 3 " -furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.38"	No cracks

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.
Draw at 600°F. - 2 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	1" dia. Button blown out.
2	2600	partial	.34"	Crack 1" long to edge of plate.

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 1000°F. - 2 " - furnace cool.

Hardness - 418 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Small radial cracks.
2	2500	"	---	" " "
3	2400	partial	.51"	" " "

Composition No. 33

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .512"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1560°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.28"	No cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.54"	Tiny radial cracks
2	2600	complete	---	" " "

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.54"	Tiny radial cracks
2	2500	complete	---	Small cracks

Composition No. 11B

Dimensions - 7 x 7 x 1/2"
Actual Thickness -.510"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	Bullet core fused into plate	No cracks
2	2600	"	.38"	" "

Second Heat Treatment

Heat to 1450°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete C.I.P.	---	3/4" Button
2	2400	partial	.50"	No cracks

Third Heat Treatment

Heat to 1400°F. - 2 hrs. - oil quench.
Draw at 400°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.51"	Small crack on back

Composition No. 34

Dimensions - 5 x 5 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1540°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete C.I.P.	---	Button
2	2500	"	---	"
3	2400	partial	.53"	Tiny radial cracks

Second Heat Treatment

Heat to 1540°F. - 2 hrs. - water quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete C.I.P.	---	3/16" dia. Hole in back of plate.
2	2400	complete	---	" " "
3	2300	partial	.45"	No cracks

Third Heat Treatment

Heat to 1540°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 364 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	complete	---	Small radial cracks
2	2300	"	---	" " "
3	2200	partial	.50"	No cracks

Composition No. 35

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 600 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.23"	No cracks

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 800°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.63"	Tiny radial cracks
2	2600	complete	---	" " "

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 850°F. - 2 " - air cool.

Hardness - 375 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	---	Tiny radial cracks
2	2300	partial	.54"	No cracks
3	2400	"	.54"	" "

Composition No. 36

Dimensions - 7 x 7 x 1/2"

Actual Thickness - .508"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.

Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.

Draw at 650°F. - 2 " - air cool.

Hardness - 532 Brinell

<u>Ballistics</u>		Depth of		<u>Remarks</u>
<u>Round</u>	<u>Vel.f./s.</u>	<u>Pen.</u>	<u>Pen.</u>	
1	2600	complete	---	Button-crack 1" long
2	2500	partial	.42"	Crack from Rd. #1 to Rd.#2, 2 1/2" long crack to edge of plate - 1" long

A new plate 7 x 7 x 1/2" was forged from the ingot

Actual Thickness - .485"- .492"

Heat Treatments

Normalize - Heat to 1750°F. - 2 hrs. - air cool.

Anneal " " 1275°F. - 3 " - furnace cool.

Second Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.

Draw at 800°F. - 2 " - air cool.

Hardness - 477 Brinell

<u>Ballistics</u>		Depth of		<u>Remarks</u>
<u>Round</u>	<u>Vel.f./s.</u>	<u>Pen.</u>	<u>Pen.</u>	
1	2500	complete	---	Button
2	2400	partial	.53"	Tiny cracks

Third Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench.

Draw at 900°F. - 2 " - air cool.

Hardness - 387 Brinell

<u>Ballistics</u>		Depth of		<u>Remarks</u>
<u>Round</u>	<u>Vel.f./s.</u>	<u>Pen.</u>	<u>Pen.</u>	
1	2400	complete	---	Tiny radial cracks
2	2300	"	---	No cracks
3	2200	partial	.50"	" "

Composition No. 37

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .509"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1490°F. - 2 hrs. - quench in water.
Draw at 350°F. - 3 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.53"	Tiny cracks
2	2500	"	.52	" "
3	2600	partial C.I.P.	---	Button starting

Second Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Button
2	2400	partial	.51"	Button starting
3	2500	"	.55"	Tiny radial cracks.

Third Heat Treatment

Heat to 1490°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 340 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	complete C.I.P.	---	Tiny radial cracks
2	2300	complete	---	" " "
3	2200	partial	.52"	No cracks

Composition No. 38

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1600°F. - 2 hrs. - quench in water.
Draw at 350°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial C.l.P.	---	Radial cracks - start of spall.
2	2400	partial C.l.P.	---	" " " "
3	2600	complete C.l.P.	---	Radial cracks - spalling.

Second Heat Treatment

Heat to 1540°F. - 2 hrs. - oil quench.
Draw at 350°F. - 2 " - air cool.

Hardness - 460 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Radial cracks
2	2500	complete C.l.P.	---	" "
3	2400	complete	---	Button starting
4	2300	partial	.49"	No cracks

Third Heat Treatment

Heat to 1540°F. - 2 hrs. - oil quench.
Draw at 500°F. - 2 " - air cool.

Hardness - 418 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2400	complete	---	Tiny radial cracks
2	2300	partial	.48"	No cracks

Composition No. 4B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 925°F. - 2 " - air cool.

Hardness - 495 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.42"	No cracks

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.46"	No cracks
2	2600	"	.51"	Small radial cracks

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 1050°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.50"	No cracks
2	2600	"	.53"	Tiny radial cracks

Composition No. 24B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1550°F. - 2 hrs. - oil quench.
Draw at 650°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.50"	Button starting

Second Heat Treatment

Heat to 1550°F. - 2 hrs. - oil quench.
Draw at 600°F. - 2 " - air cool.

Hardness - 512 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.45"	1" crack to edge of plate
2	2600	"	.55"	Button starting

Third Heat Treatment

Heat to 1510°F. - 2 hrs. - oil quench.
Draw at 325°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f./s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	---	Very small crack
2	2600	partial	.53"	" "

Composition No. 25B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .506"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal " " 1275°F. - 3 " - furnace cool.

First Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 1000°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.51"	Start of button

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 950°F. - 2 " - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.44"	Tiny cracks
2	2600	"	.51"	" "

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw at 1050°F. - 2 " - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel.f./s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.53"	Tiny radial cracks

Composition No. 1B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .505"

Normalize - Heat to 1750°F. - 2 hrs. - air cool.
Anneal - Heat to 1275°F. - 3 hrs. - furnace cool.

First Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench
Draw at 1000°F. - 2 hrs. - furnace cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.49"	Small radial cracks.

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw to 950°F. - 2 hrs. - air cool.

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.45"	No cracks.
2	2500	partial	.45"	No cracks.
3	2600	partial	.50"	No cracks.

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench.
Draw to 1050°F. - 2 hrs. - air cool.

Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.50"	No cracks.
2	2600	partial	.50"	No cracks.

Composition No. 3B

Dimensions - 7 x 7 x 1/2"

Actual Thickness - .504"

Normalize - Heat to 1750°F. - 2 hrs. - air cool

Anneal - Heat to 1275°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench

Draw at 925°F. - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.49"	Button starting.

Second Heat Treatment

Heat to 1670°F., - 2 hrs. - oil quench

Draw at 950°F., - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.39"	No cracks.
2	2600	partial	.35"	No cracks.

Third Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench

Draw at 1050°F. - 2 hrs. - air cool

Hardness - 460 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.51"	Bullet hit previous crack and caused a 1" dia. button to be started.
2	2400	partial	.42"	
3	2600	complete	-	

Composition No. 7B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .495"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1275°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench
Draw at 925°F. - 2 hrs. - air cool
Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	Complete C.I.P.	-	Button - 1" diam.
2	2500	partial	.42"	No cracks.

Second Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench
Draw at 950°F. - 2 hrs. - air cool
Hardness - 460 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.45"	No cracks.
2	2400	partial	.42"	No cracks.
3	2600	complete	-	Button - 7/8" diam.
4	2500	partial	.45"	Crack between rounds #3, 4. - 1" long.

Third Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench
Draw at 1050°F. - 2 hrs. - air cool
Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2300	partial	.40"	No cracks.
2	2200	partial	.45"	" "
3	2400	partial	.45"	" "
4	2600	complete-but former shot spalls - radial cracks.		
5	2600	partial	.48"	No cracks.

Composition No. 39

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .495"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1560°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench
Draw at 350°F. - 2 hrs. - air cool

Hardness - 512 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	-	Button
2	2500	partial	.55"	Button starting

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench
Draw at 350°F. - 3 hrs. - air cool

Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2400	complete	-	Tiny radial cracks
2	2300	partial	.54"	" " "

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench
Draw at 950°F. - 2 hrs. - air cool

Hardness - 402 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2400	complete	-	Tiny radial cracks
2	2300	partial	.52"	No cracks

Composition No. 40

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .505"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1560°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1650°F. - 2 hrs. - water quench
Draw at 350°F. - 3 hrs. - air cool

Hardness - 532 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.39"	No cracks
2	2500	partial	.47"	No cracks
3	2600	partial	.48"	Tiny cracks

Second Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench
Draw at 350°F. - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	complete	-	Tiny radial cracks.
2	2500	partial	.48"	" " "

Third Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench
Draw at 950°F. - 2 hrs. - air cool

Hardness - 418 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2400	partial	.53"	No cracks
2	2500	complete	-	Tiny cracks
3	2300	partial	.45"	No cracks

Composition No. 21B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .503"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1560°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1710°F. - 2 hrs. - water quench
Draw at 400°F. - 2 hrs. - air cool

Hardness - 430 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	-	Small radial cracks
2	2400	complete	-	" " "
3	2300	partial	.50"	No cracks

Composition No. 22B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .501"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1560°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1650°F. - 2 hrs. - oil quench
Draw at 400°F. - 2 hrs. - air cool

Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2300	partial	.47"	No cracks.
2	2400	partial	.50"	" "
3	2500	partial	.54"	" "
4	2600	complete	-	Small radial cracks.

Composition No. 10B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .505"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1275°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench
Draw at 650°F. - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.40"	No cracks

Second Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench
Draw at 950°F. - 2 hrs. - air cool

Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.50"	No cracks
2	2600	partial	.54"	Tiny radial cracks

Third Heat Treatment

Heat to 1620°F. - 2 hrs. - oil quench
Draw at 1050°F. - 2 hrs. - air cool

Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.48"	No cracks
2	2600	partial	.50"	No cracks

Composition No. 9B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .498"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1275°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench
Draw at 650°F. - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.54"	Button starting

Second Heat Treatment

Heat to 1650°F. - 2 hrs. - quench in water
Draw at 500°F. - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.55"	Button starting
2	2600	complete	-	Button

Third Heat Treatment

Heat to 1670°F. - 2 hrs. - oil quench
Draw at 950°F. - 2 hrs. - air cool

Hardness - 444 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	complete	-	Small radial cracks
2	2400	partial	.55"	No cracks

Composition No. 8B

Dimensions - 7 x 7 x 1/2"
Actual Thickness - .510"

Normalize - Heat to 1750°F. - 2 hrs. - air cool
Anneal - Heat to 1275°F. - 3 hrs. - furnace cool

First Heat Treatment

Heat to 1600°F. - 2 hrs. - oil quench
Draw at 650°F. - 2 hrs. - air cool

Hardness - 555 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.27"	No cracks

Second Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench
Draw at 925°F. - 2 hrs. - air cool

Hardness - 477 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2500	partial	.47"	No cracks
2	2600	partial	.50"	" "

Third Heat Treatment

Heat to 1560°F. - 2 hrs. - oil quench
Draw at 925°F. - 2 hrs. - air cool

Hardness - 460 Brinell

Ballistics

Round	Vel. f/s.	Pen.	Depth of Pen.	Remarks
1	2600	partial	.50"	Tiny radial cracks

Discussion

This investigation covers a study of ballistic properties of experimental armor plate compositions which were heat treated to three different Brinell hardness ranges, namely, 495/600; 444/477; 364/430.

Unfortunately, many of this series of plates were not drawn to the lower hardness range, due to difficulties encountered in the determination of proper drawing temperatures.

The ballistic properties of the relative high hardness ranges of these compositions were investigated, since in the recent survey of ballistic properties of armor plate, some special steels such as nickel-silicon steels showed excellent ballistic resistance at a Brinell Hardness of 555.

With the exception of only a few cases, conclusions are based solely on the ballistic properties of the plates without consideration of the relation of the microstructure to ballistics. This phase of the investigation will be continued in a subsequent report.

The relation of microstructure is very important, as already published in Report No. 710/79. A study of the microstructure of a few of the plates showing excellent ballistic resistance, and other plates which spalled badly in various hardness ranges, revealed a close relationship

between spalling and the presence of elongated nonmetallic inclusions or laminations.

It was determined in the plates examined, that in all cases, spalled plates contained elongated nonmetallics. This was true in plates having a high and medium high hardness (Figs. 14(a), 15(a)). Moreover, in addition to the presence of laminations, spalled plates had a relatively large grain size. The microstructure was typical of martensite with some acicular troostite or troostite-sorbite, depending on the heat treatment (Figs. 14(b), 15(b)).

High ballistic plates having a high hardness were free from laminations. A uniform distribution of fine rounded nonmetallics was present in these steels (Figs. 13(a), 14(c)). These plates had, in most cases, a fine martensitic structure with some acicular troostite, or troostite-sorbite, (Figs. 13(b), 15(c) & (d)). In one case, however, (Fig. 14(d)) a high ballistic plate had a relatively coarse martensitic structure but no laminations were present.

High ballistic plate of the medium high hardness range had a troostite-sorbite structure (Figs. 13(c), 13(d), 15(c), 15(d), 15(e), 15(f)).

Apparently the presence of laminations in armor plate promotes spalling.

Figures 1 to 12, inclusive, illustrate a few typical

high and low ballistic plates which have been heat treated to various hardness ranges.

The true ballistic limit was not obtained in many of the plates heat treated to a high hardness since the highest velocity ammunition used was Cal .30 A.P. M1922, striking velocity, 2600 f.s.

A brief summary of the effect of adding one or more special elements to the standard chromium-molybdenum-vanadium composition is given below:

1. Standard Chromium-Molybdenum-Vanadium Composition

C .45/.55; Cr 1.10/1.30; Mo .60/.80; Va .20/.30;

defeated Cal .30 A.P. M1922, 2600 f.s. striking velocity;

Brinell hardness 460/600;

2. Standard plus 5% Chromium

Tendency to spall 477 Brinell hardness; B.L. 2450/2600 f.s.

With 2.82% Cr, B.L. 2450 f.s. at 418 Brinell.

3. Standard plus 1.2 - 5.57% Nickel

Increase of nickel causes tendency toward spalling and buttoning, especially at higher ranges of hardness.

High nickel - 5.57% - shows no exceptional ballistic properties at 444/460 Brinell hardness. Good ballistic resistance at 512/555 Brinell hardness. Plates Nos. 16B and 18X, slight tendency to spall at 444/477 Brinell.

Plate No. 16 has good ballistic resistance and ductility at 402 Brinell. Plate No. 20 has good ballistic properties at 430/532 Brinell.

4. Standard plus 1.13 - 1.54% Molybdenum

At 477 Brinell, four out of six plates had ballistic limit of 2600 f.s. (partial). Slight tendency to spall at 477 Brinell.

5. Standard plus Nickel with no Chromium. 1.26 - 4.55% Ni

No spalling at 402/444 Brinell. Spalling at 477/555 Brinell. Plate No. 9X has very good ballistic properties. Plate No. 11 has good ballistic properties at 418/430 Brinell.

6. Silicon-Manganese-Molybdenum, Plate No. 23

Mn 1.38%; Si 1.73%; Mo .78%; - Good ballistic properties at all hardness values. The ballistic properties of these compositions containing .11% vanadium were relatively lower. Spalling occurred at 430/477 Brinell.

7. Nickel-Silicon-Molybdenum

Ni 3.23%; Si 2.635%; Mo .76%. Excellent ballistic properties. Increasing molybdenum to 1.2% causes spalling at 512 Brinell, although defeats Cal .30 A.P. M1922 bullet, 2600 f.s. at 444/477 Brinell.

8. Molybdenum-Vanadium; 2.08 - 5.07% Mo; .12% Va

No spalling at 364/512 Brinell. Plate No. 28X
partial 2600 f.s. at 477/495 Brinell.

9. Manganese-Nickel-Molybdenum

Mn 1.38%; Ni 2.64%; Mo .82%; Low ballistic limit
at 387 Brinell. Spalling at 495 Brinell.

10. Manganese-Molybdenum-Tungsten

Mn 1.45%; Mo 2.66%; W 0.86%; Excellent ballistics
at various hardness values, no spalling.

11. Chromium-Molybdenum

Cr 2.18%; Mo .60%; Tendency to spall at 444/512 Brinell.
Ballistic Limit 2450 f.s. at 418 Brinell.

12. Manganese-Molybdenum

Mn 2.40%; Mo .61%; Good ballistics at 444/512 Brinell.
Ballistic limit 2450 f.s. at 418 Brinell.

13. Nickel-Molybdenum

Ni 2.54%; Mo 1.10%; Very good ballistic properties at
various hardness values. Partial 2600 f.s. at 444 Brinell.
Increasing nickel to 3.88% and lowering molybdenum to .60%
does not improve ballistic properties.

14. Nickel-Chromium

Ni 2.16/3.90%; Cr 1.87/2.59%. These steels have good ballistic properties at various hardness values.

15. Standard Plus Tungsten

W 0.62%; Plate No. 4B. Excellent ballistic properties. Mo .35/.70%; 1.35/2.92% W; have good ballistic properties at 444 Brinell. Spalling occurs at higher hardness.

16. Molybdenum-Tungsten-Vanadium

Mo 1.22/2.14%; W .16/.32%; Va .10% - low ballistic limits with exception of Plate No. 40 which had good ballistic properties at various hardness values.

17. Chromium-Vanadium-Tungsten

Cr .62%; W 3.36%; Va .20%; This plate did not have high ballistic properties.

18. Chromium-Molybdenum-Vanadium-Tungsten

Cr .56%; Mo .44%; Va .21%; W 2.92%. Good ballistic properties at 444 Brinell.

19. Standard Composition Treated with Titanium

Ti .03/.11% ; Plates Nos. 8B and 10B containing .03 and .11% Ti, respectively, have very good ballistic properties.

Curves showing the relationship between Brinell hardness and ballistic limit are shown in Figures 16 - 20.

Although in many cases the ballistic resistance is noticeably high in plates having ranges of hardness, 444/477 and 495/600, the percentage of spalling increases in many of the hard plates (Tables VI and VII) due to the brittleness of the martensitic constituent present and also possibly due to the presence of laminations.

Results of Investigation

1. Compositions having a ballistic limit of 2450 f.s. to 2550 f.s. with no spalling, and with Brinell hardness of 364/430, are given below in Table IV.

TABLE IV
Chemical Composition

<u>Plate</u> <u>No.</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>	<u>W</u>	<u>Ti</u>
4X	.39	.85	.007	.016	.32	0	2.82	.63	.23	0	0
9X	.44	.60	.007	.016	.14	1.26	0	.68	.20	0	0
11	.42	.60	.007	.014	.21	4.55	0	.60	.23	0	0
16	.39	.68	.009	.017	.17	3.65	1.15	.31	.20	0	0
20	.38	.68	.012	.014	.22	4.00	1.12	.68	.10	0	0
23	.40	1.68	.012	.017	1.73	0	0	.78	0	0	0
12B	.49	1.45	.011	.019	.35	0	0	2.66	0	.86	0
14B	.435	.69	.011	.018	.200	0	2.12	.66	0	0	0
33	.41	2.40	.011	.018	.37	0	0	.61	0	0	0
35	.56	.26	.010	.022	.23	2.16	1.92	0	0	0	0
40	.43	.55	.007	.015	.33	0	0	2.14	.09	.32	0

2. Compositions which resist penetration with Cal .30 A.P. M1922, 2600 f.s. with no spalling and having a

hardness range of 444/470 are given below in Table V.

TABLE V
Chemical Composition

<u>Plate</u> <u>No.</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>	<u>W</u>	<u>Ti</u>
6B	.53	.71	.006	.016	.310	0	1.30	.74	.225	0	0
15B	.355	.69	.008	.016	.175	3.27	1.08	.59	.11	0	0
5B	.52	.69	.018	.007	.32	0	1.30	1.54	.225	0	0
9X	.44	.60	.007	.016	.14	1.26	0	.68	.20	0	0
10X	.43	.66	.007	.014	.24	2.36	0	.61	.21	0	0
16B	.365	.66	.006	.017	.155	4.08	1.22	.62	.255	0	0
18B	.35	.86	.012	.017	2.635	3.23	0	.76	0	0	0
20B	.37	.80	.011	.016	2.63	3.09	0	1.21	0	0	0
28X	.44	.56	.009	.019	.34	0	0	4.07	.12	0	0
11B	.41	.77	.010	.015	.18	2.54	0	1.10	0	0	0
4B	.515	.70	.009	.015	.244	0	1.34	.85	.24	.62	0
25B	.45	.90	0	0	.168	0	1.45	.35	.26	1.35	0
1B	.52	.64	.009	.016	.263	0	1.33	.44	.24	1.47	0
10B	.525	.67	.010	.016	.415	0	1.31	.68	.225	0	.03
8B	.535	.59	.007	.017	.63	0	1.34	.79	.24	0	.11

3. Compositions which resist penetration with
calibre .30 A.P. M1922, 2600 f.s. with no spalling and having

a hardness range of 495/600 are given below in Table VI.

TABLE VI
Chemical Composition

<u>Plate</u> <u>No.</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>	<u>W</u>	<u>Ti</u>
6B	.53	.71	.006	.016	.310	0	1.30	.74	.225	0	0
4X	.39	.85	.007	.016	.32	0	2.82	.63	.23	0	0
5X	.37	.53	.007	.016	.37	0	5.36	.65	.24	0	0
9X	.44	.60	.007	.016	.14	1.26	0	.68	.20	0	0
12	.42	.69	.007	.018	.28	3.71	0	.27	.23	0	0
14	.37	.59	.012	.018	.28	3.57	0	.65	.21	0	0
16B	.365	.66	.006	.017	.155	4.08	1.22	.62	.255	0	0
18X	.37	.60	.012	.019	.290	5.57	1.15	.78	.225	0	0
20	.38	.68	.012	.014	.22	4.00	1.12	.68	.10	0	0
23	.40	1.68	.012	.017	1.73	0	0	.78	0	0	0
18B	.35	.86	.012	.017	2.635	3.23	0	.76	0	0	0
28X	.44	.56	.009	.019	.34	0	0	4.07	.12	0	0
12B	.49	1.45	.011	.019	.35	0	0	2.66	0	.86	0
14B	.435	.69	.011	.018	.200	0	2.12	.66	0	0	0
33	.41	2.40	.011	.018	.37	0	0	.61	0	0	0
11B	.41	.77	.010	.015	.18	2.54	0	1.10	0	0	0
35	.56	.26	.010	.022	.23	2.16	1.92	0	0	0	0
4B	.515	.70	.009	.015	.244	0	1.34	.85	.24	.62	0
40	.43	.55	.007	.015	.33	0	0	2.14	.09	.32	0
10B	.525	.67	.010	.016	.415	0	1.31	.68	.225	0	0.03
8B	.535	.59	.007	.017	.63	0	1.34	.79	.24	0	0.11

4. A summary of ballistic data showing the percentage of spalling vs. the hardness of the plates is given in Table VII.

TABLE VII

<u>Hardness</u> <u>Range</u>	<u>No. of</u> <u>Plates</u>	<u>No. of</u> <u>Spalled</u> <u>Plates</u>	<u>%</u> <u>Spalled</u> <u>Plates</u>	<u>No. of Plates</u> <u>Partial Pen.</u> <u>at 2600 f. s.</u> <u>No Spalls</u>	<u>% Plates</u> <u>Partial Pen.</u> <u>at 2600 f.s.</u> <u>No Spalls</u>
364/430	29	1	3.4%	0	0%
444/477	78	25	32.1%	30	38.7%
495/600	49	22	44.9%	21	42.9%

Respectfully submitted,

E. L. Reed

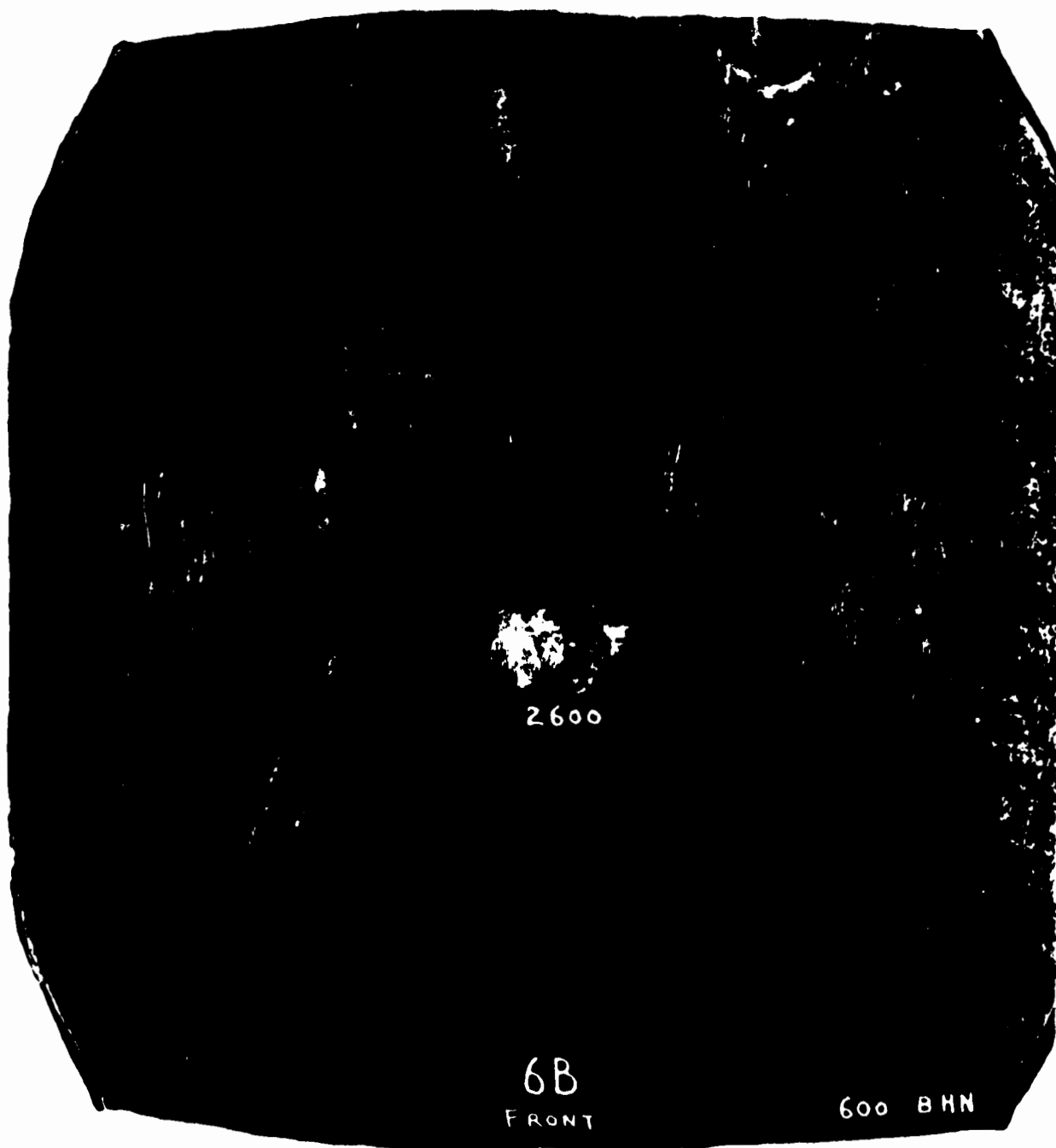
E. L. Reed,
Research Metallurgist.

Figure 1 - Front

Plate No. 6B

Defeated Cal .30 A.P. M1922 bullet, striking
velocity 2600 f.s., 600 Brinell hardness with
no buttons or spalls.

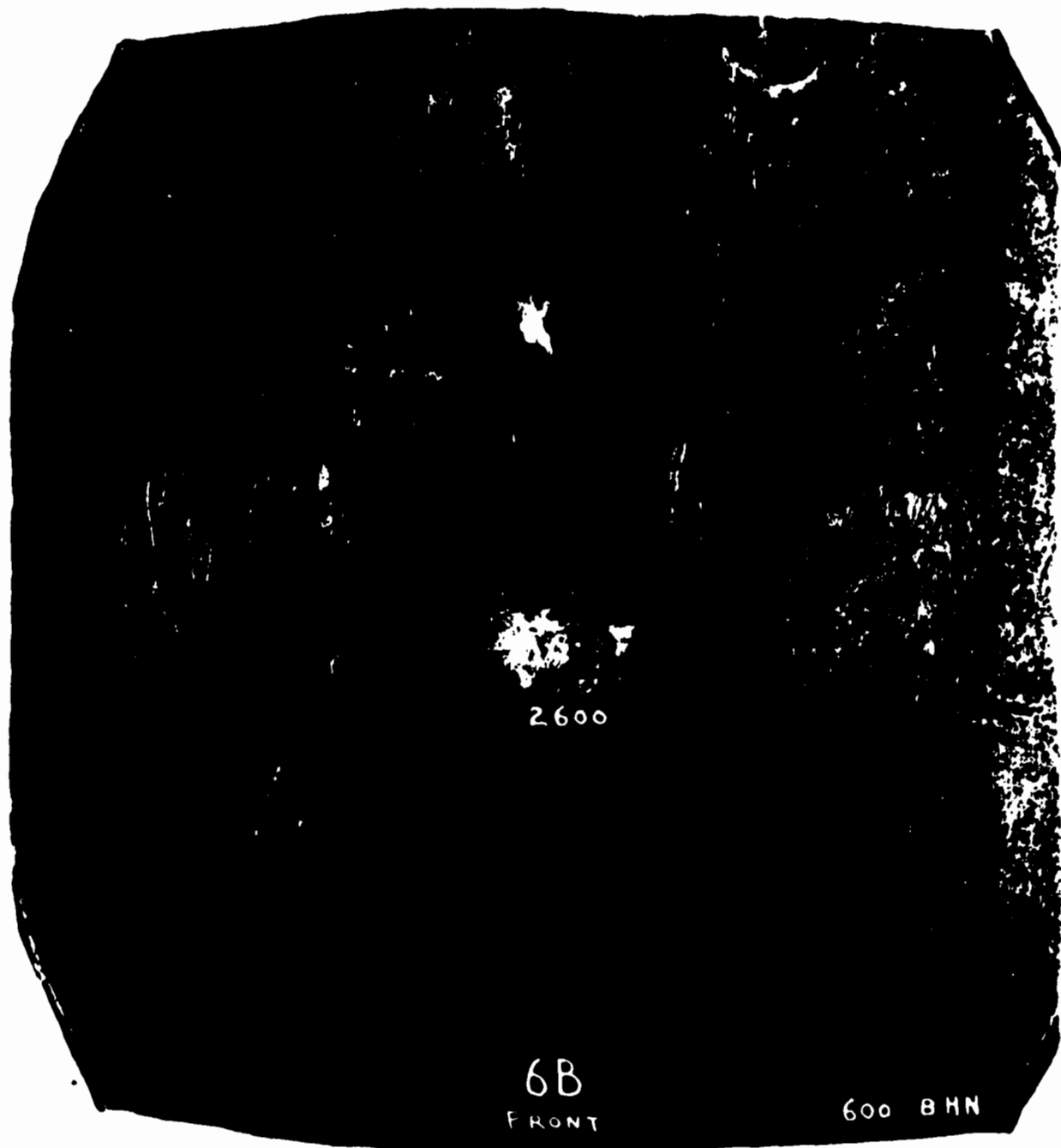
C	Mn	P	S	Si	Cr	Mo	Va
.53	.71	.006	.016	.310	1.30	.74	.225



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WATERTOWN ARSENAL
Front 3-22-37 710-277

Figure 2 - Back

Plate No. 6B



ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

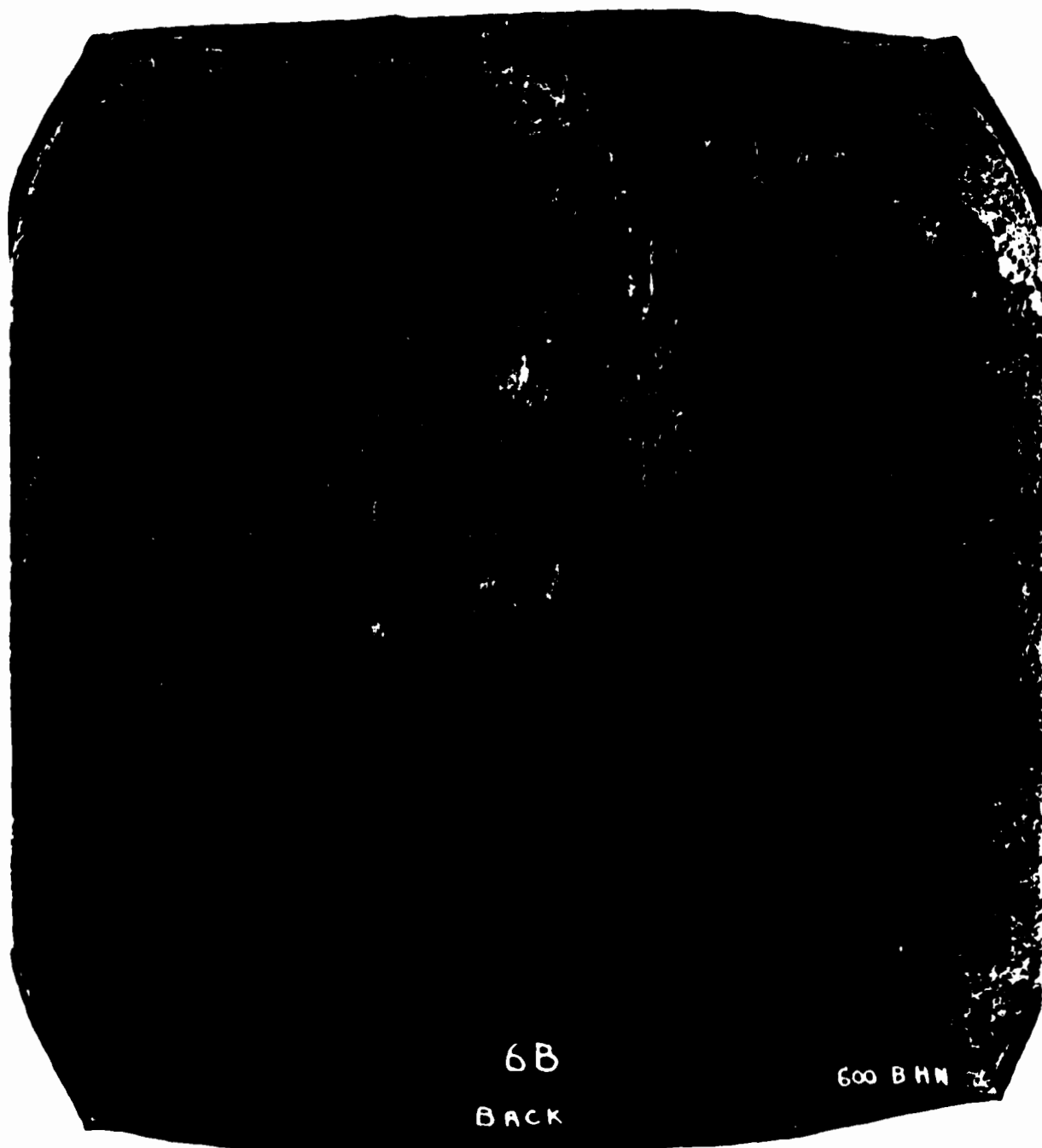
Front 3-22-37 710-277

Figure 3 - Front

Plate No. 17X

Buttons thrown off plate using Cal .30 A.P.
M1922 bullet, striking velocities 2500 and 2600 f.s.
Brinell Hardness 512.

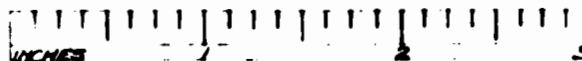
C	Mn	P	S	Si	Ni	Cr	Mo	Va
.44	.63	.007	.019	.27	3.86	1.26	.47	.27



6B

600 BHM

BACK

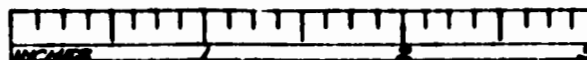
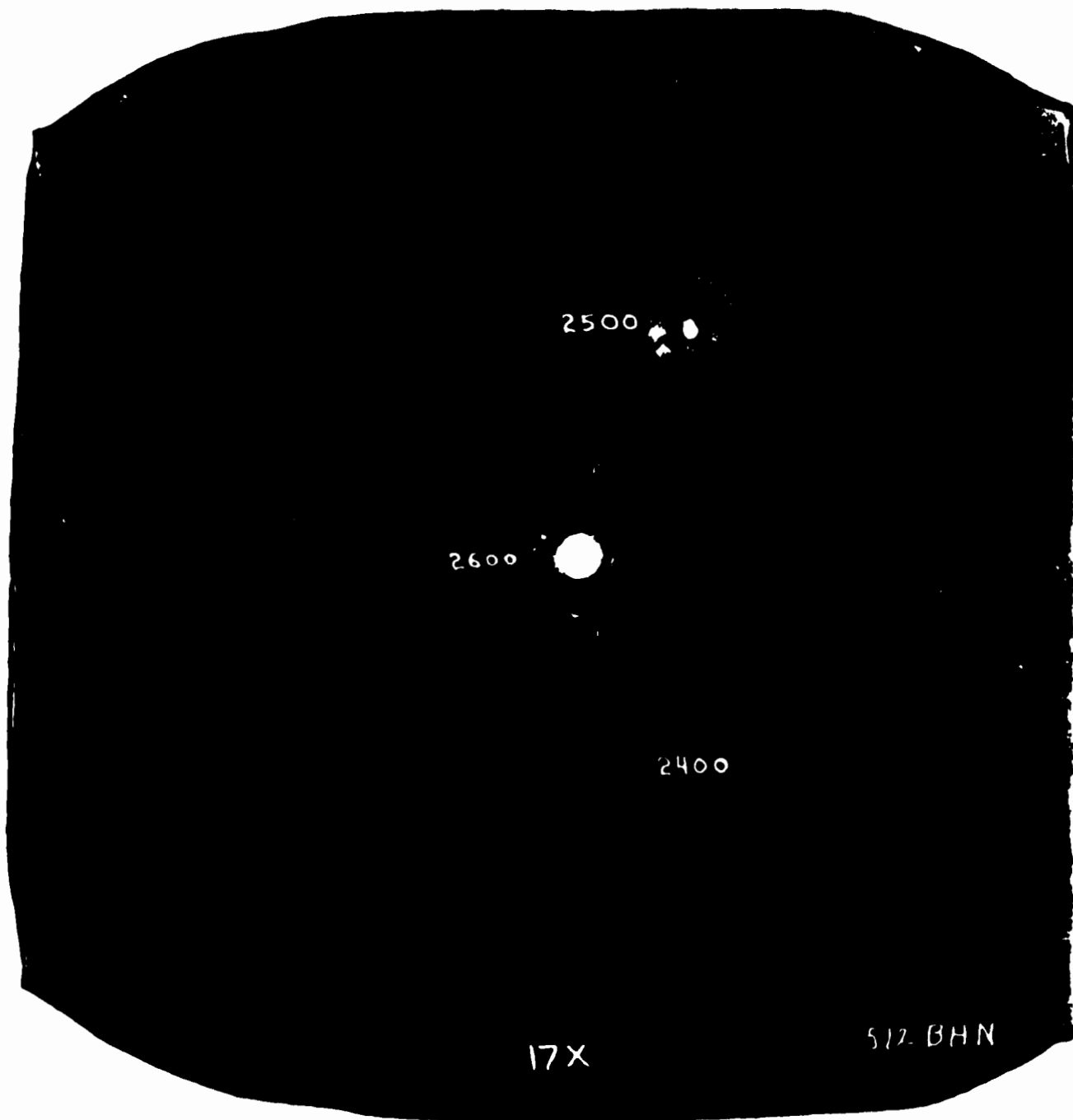


ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

Back 3-22-77 710-278

Figure 4 - Back

Plate No. 17X



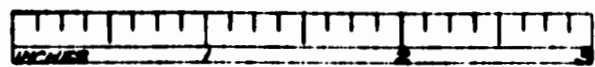
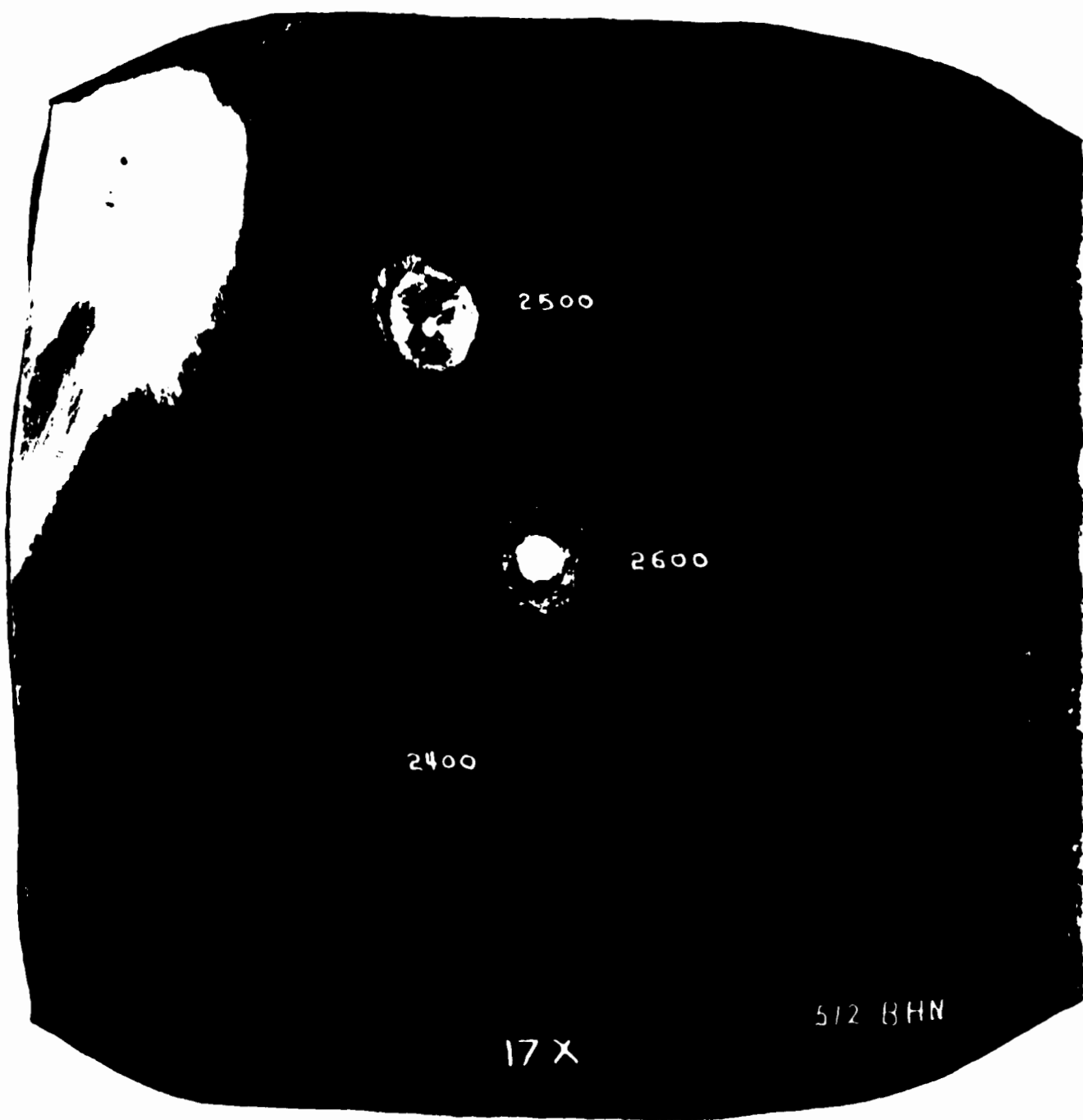
ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL
17X Front 3-22-37 710-271

Figure 5 - Front

Plate No. 20

Defeated Cal .30 A.P. M1922 bullet, striking
velocity 2600 f.s., at 532 Brinell hardness
no buttons or spalls.

C	Mn	P	S	Si	Ni	Cr	Mo	Va
.38	.68	.012	.014	.22	4.00	1.12	.68	.10

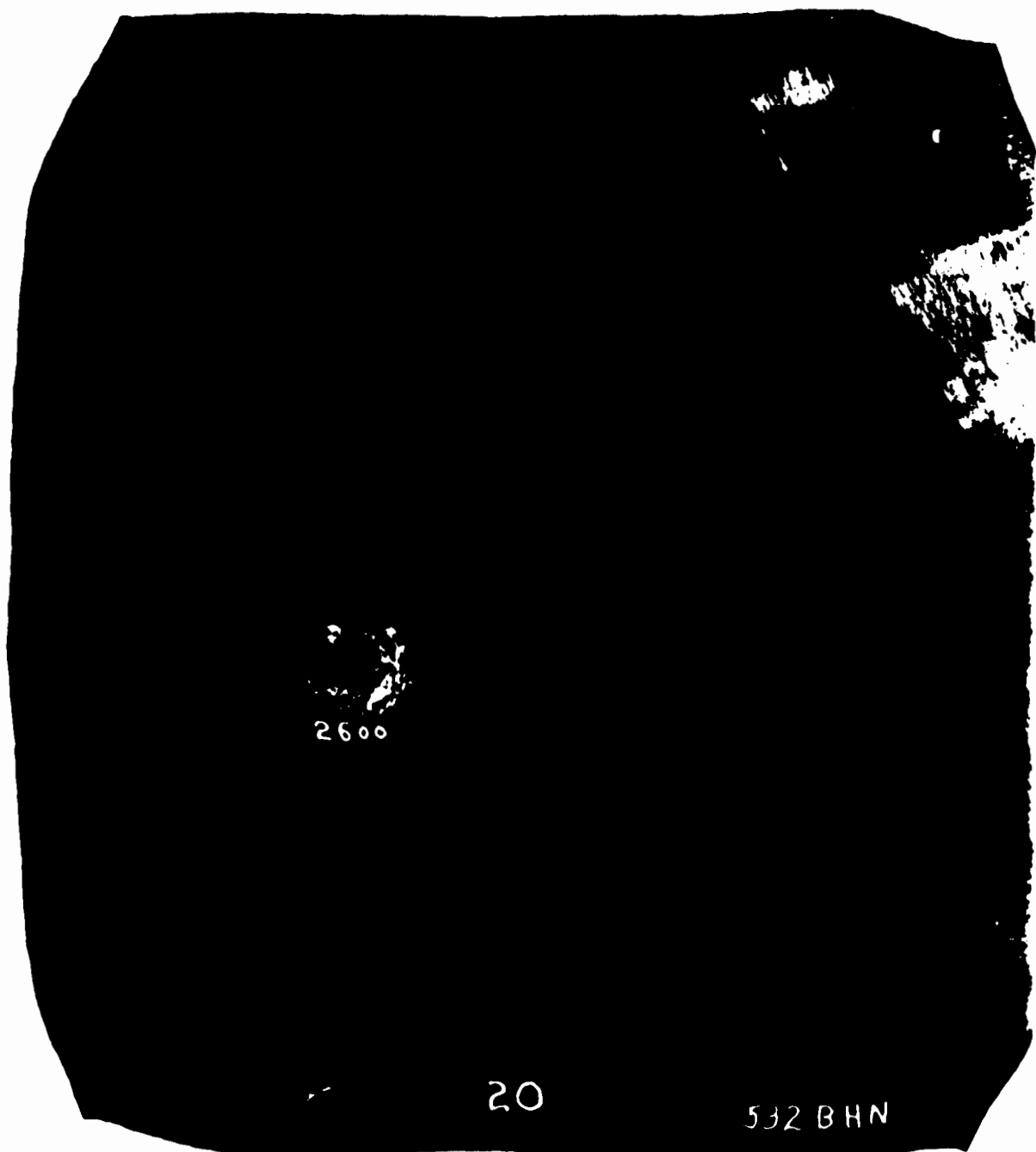


ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

17X Back 3-20-37 710-272

Figure 6 - Back

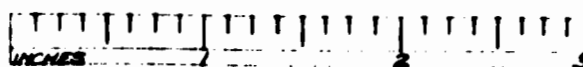
Plate No. 20



2600

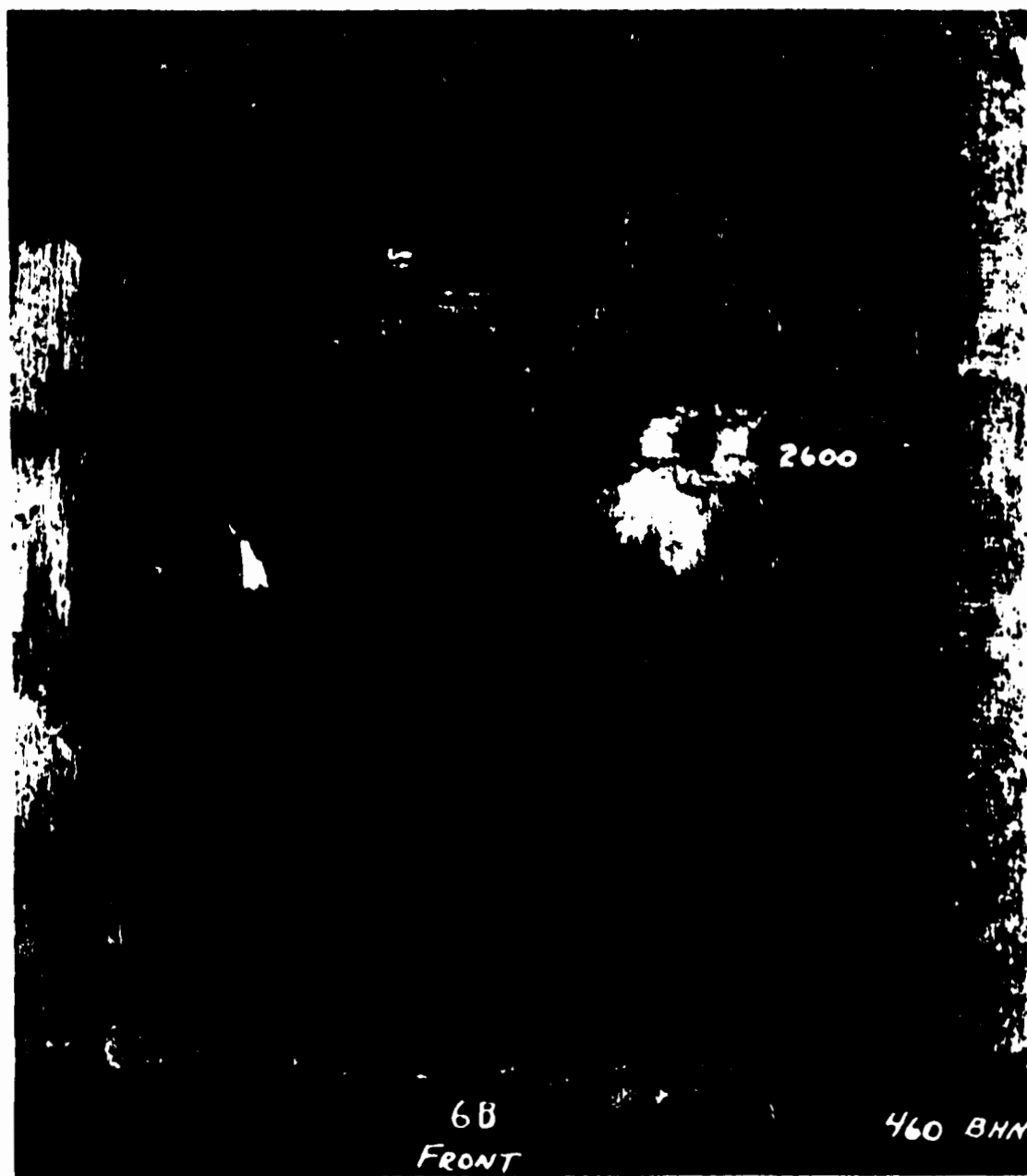
20

532 BHN



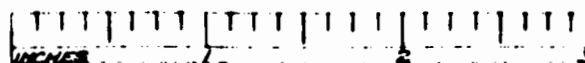
ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

20 Front 3-22-37 710-278



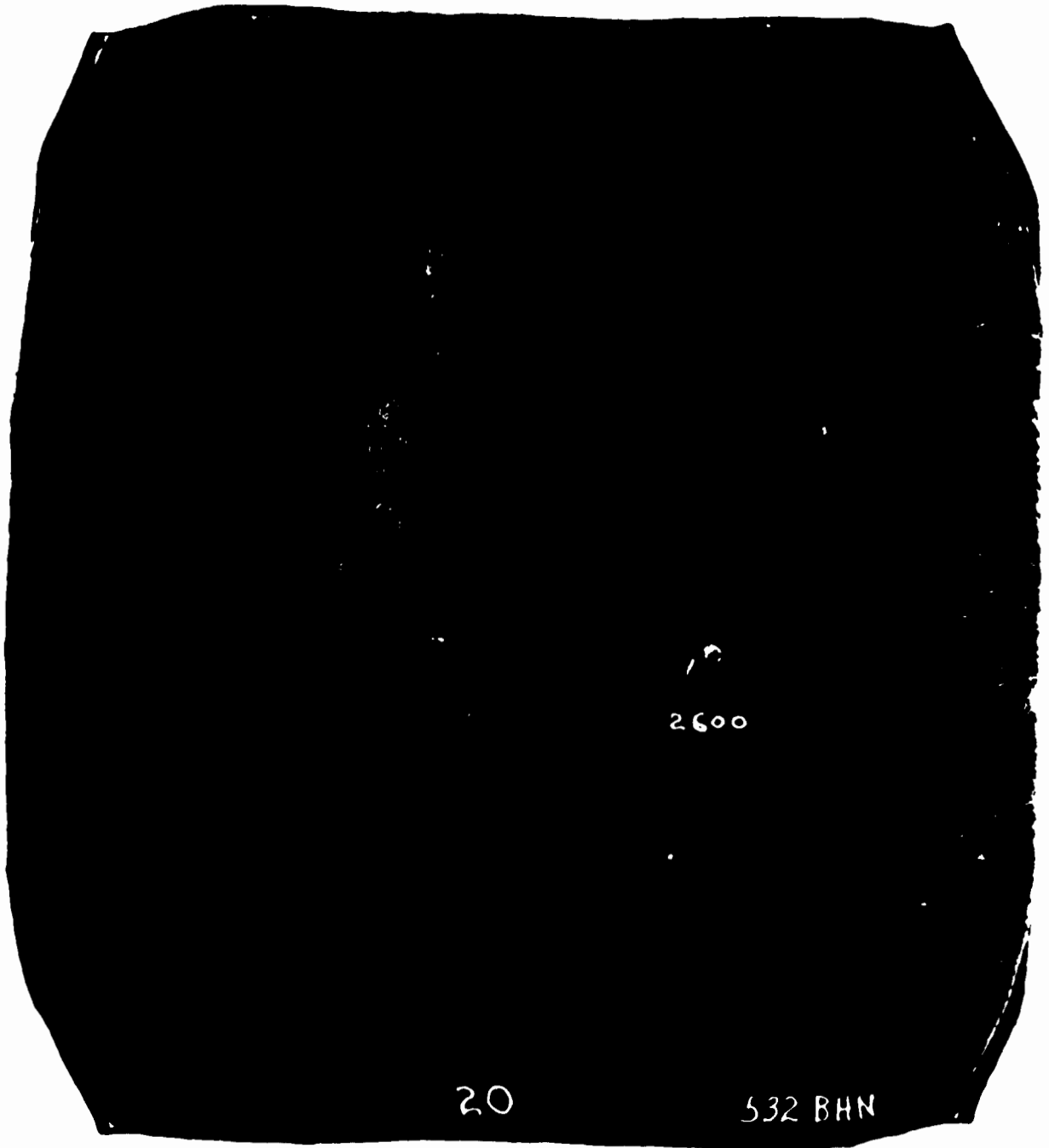
6B
FRONT

460 BHN



ORDNANCE DEPT USA
WATERTOWN ARSENAL

Front 6-2-37 710-310



ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

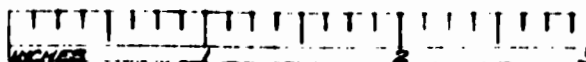
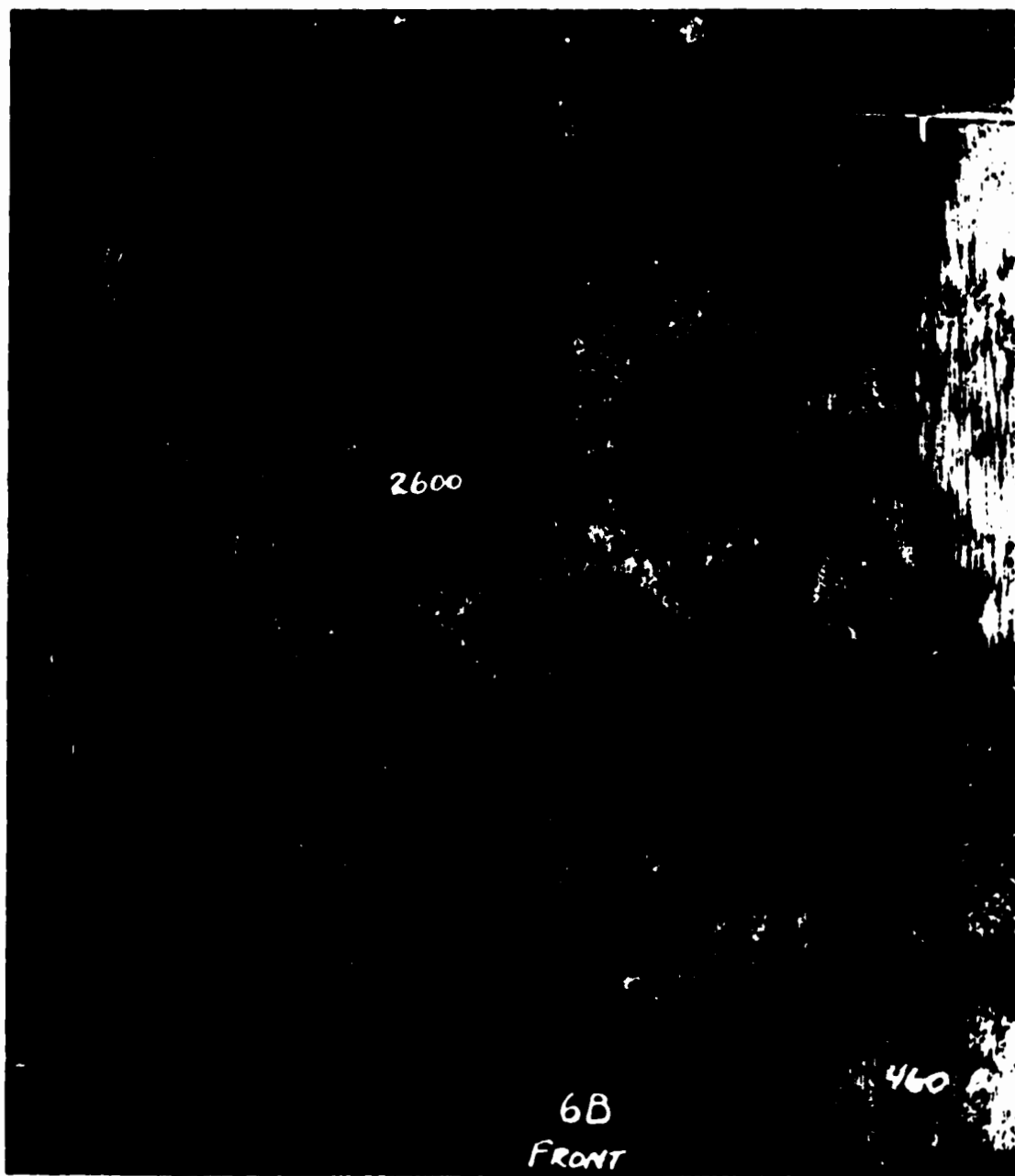
7-50-11

Figure 7 - Front

Plate No. 6B

Defeated Cal .30 A.P. M1922 bullet, striking velocity, 2600 f.s. at 460 Brinell hardness with no buttons or spalls.

C	Mn	P	S	Si	Cr	Mo	Va
.53	.71	.006	.016	.310	1.30	.74	.225



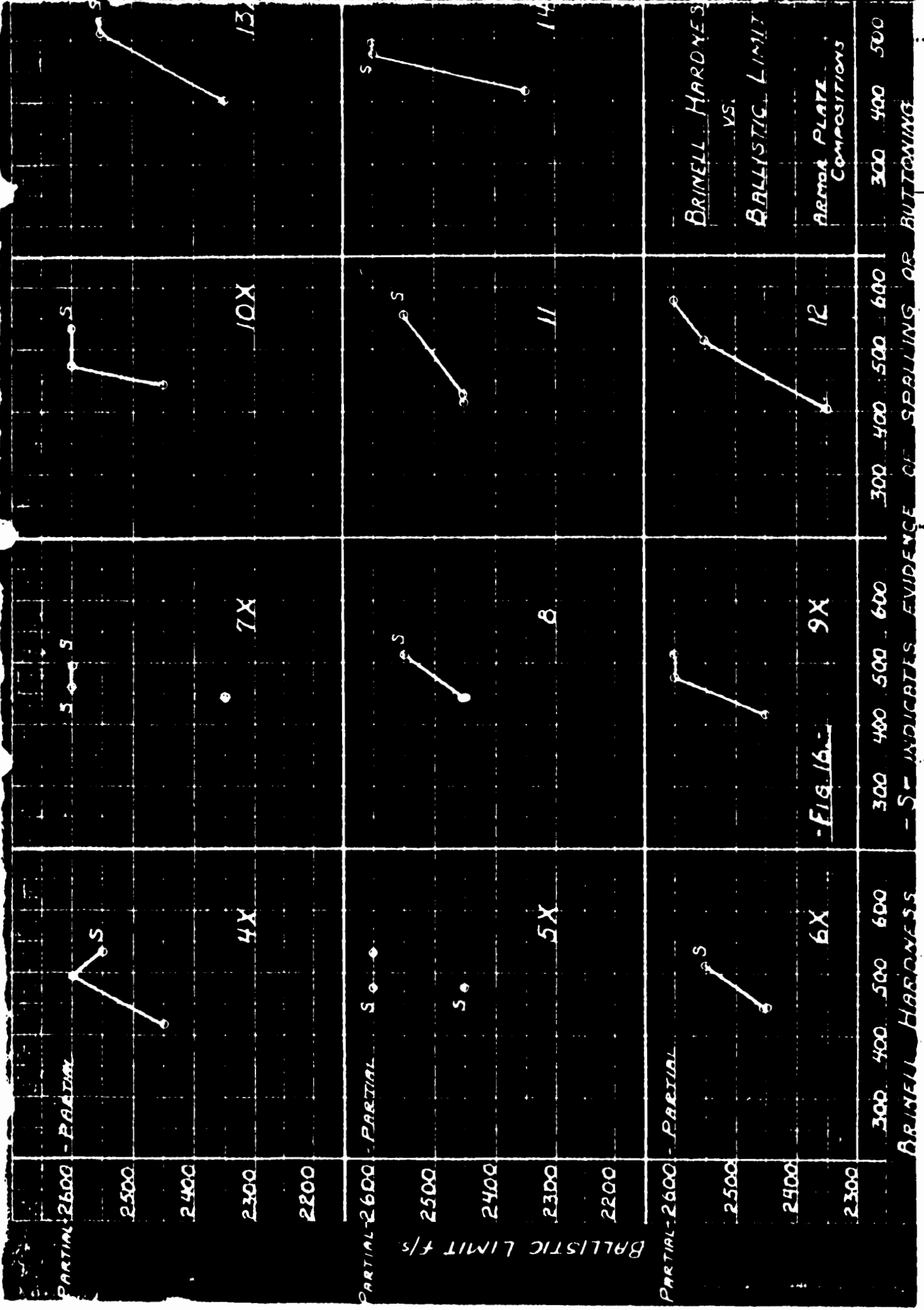
ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

Back 6-2-37 710-311

Fig. 8 - Back

Plate No. 6B

BALLISTIC LIMIT f/s



BRINELL HARDNESS

- S - INDICATES EVIDENCE OF SPALLING OR BUTTOWING

BRINELL HARDNESS
VS.
BALLISTIC LIMIT
ARMOR PLATE
COMPOSITIONS

Figure 9 - Front

Plate No. 7B

Buttons blown off with Cal .30 A.P. M1922 bullet,
striking velocity 2600 f.s. - 460 Brinell Hardness.

C	Mn	P	S	Si	Cr	Mo	Va	W
.515	.66	.010	.016	.327	1.35	.70	.225	2.94



ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

Front 7B.5-20-37 710-300

Figure 10 - Back

Plate No. 7B

2400

2400

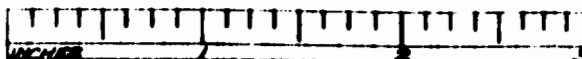
2600

2500

7B

BACK

BRINELL - 460



ORDNANCE DEPT. U.S.A.

WATERTOWN ARSENAL

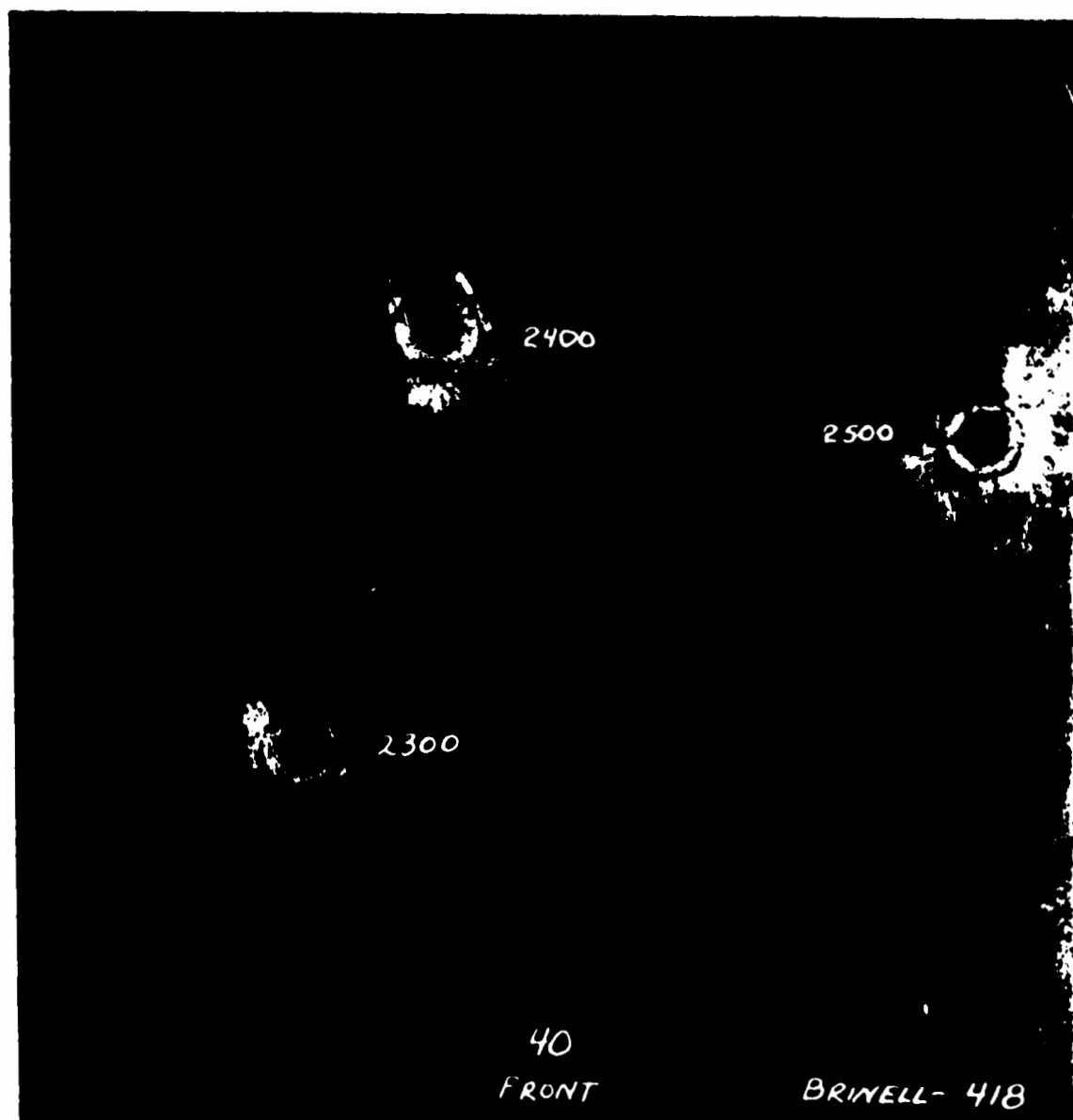
Back 7B. 5-25-37 710-301

Figure 11 - Front

Plate No. 40

Ballistic Limit 2450 f.s., Cal .30 A.P. M1922,
Brinell Hardness 418 - no buttons or spalls.

C	Mn	P	Si	Mo	Va	W
.43	.55	.007	.33	2.14	.09	.32

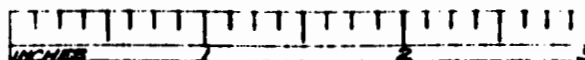
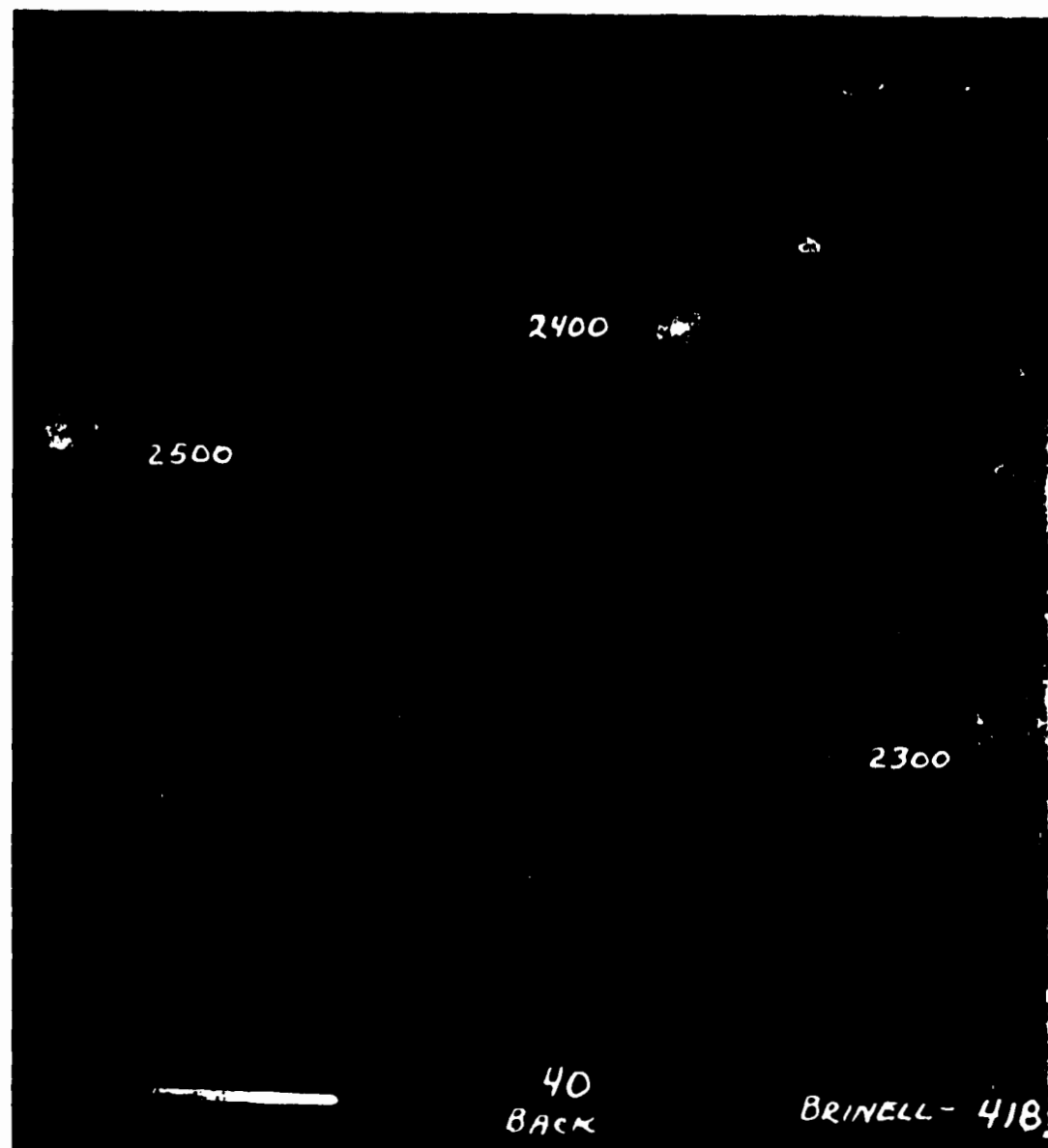


ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

Front 40. 5-20-37 710-306

Figure 12 - Back

Plate No. 40



ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

Back 40. 5-20-77 710-307

Figure 13

- (a) High ballistic Plate No. 6B. No spalling.
Brinell Hardness 600. Defeated 2600 f.s.
Cal .30 A.P. M1922 bullet.
Heat Treatment: 1650°F, 2 hrs, oil quench;
draw 350°F, 2 hrs, air cool

Absence of laminations. Fine nonmetallics
uniformly distributed.
Unetched MA 879
- (b) Same as "a" after etching in 1% Nital.
Relatively small grain. Martensite with some
acicular troostite. Resisted.
MA 870
- (c) Same as "b" after drawing at 850°F, 2 hours,
air cool. Brinell hardness 477.
Resisted 2600 f.s. Cal .30 A.P. M1922 bullet.
Fine troostite-sorbite.
1% Nital etch MA 884
- (d) Same as "c" after re-drawing at 950°F, 2 hours,
air cool. Brinell hardness 460.
Resisted 2600 f.s. Cal .30 A.P. M1922 bullet.
Fine troostite-sorbite.
1% Nital etch MA 890

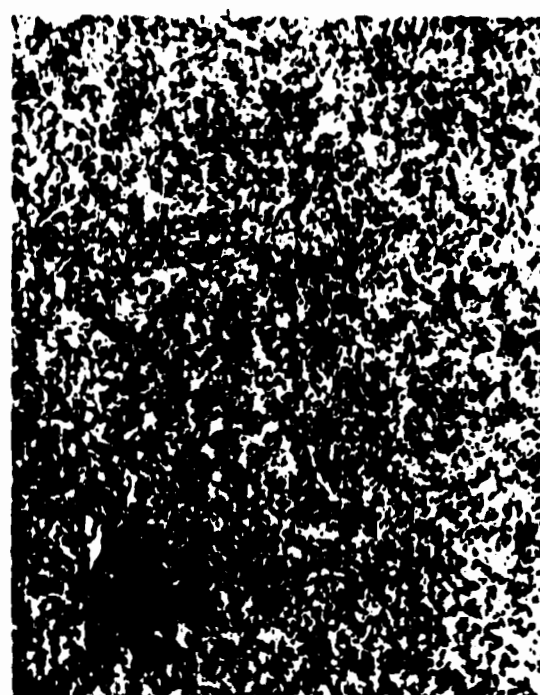
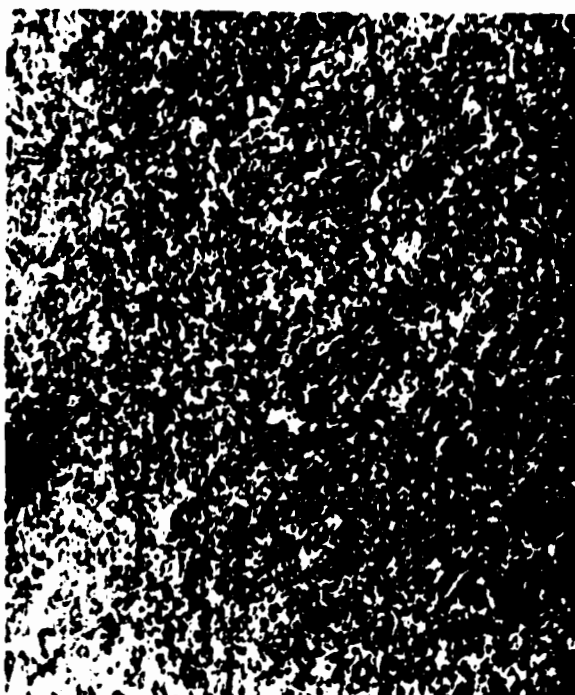


FIG. 13

W.A. 639-736

Figure 14

- (a) Plate which spalled badly. No. 17X. Brinell Hardness 512. Ballistic Limit 2450 f.s. Cal .30 A.P. M1922.
Heat Treatment: 1600°F, 2 hrs, oil quench;
draw at 350°F, 2 hrs, air cool;

Typical laminations in plate.

Unetched

MA 880

- (b) Same as "a" after etching in 1% Nital. Relatively large grain. Coarse martensite with some acicular troostite.

MA 867

- (c) High ballistic Plate No. 20. Brinell Hardness 532. Defeated 2600 f.s. Cal .30 A.P. M1922 bullet.
Heat Treatment: 1490°F, 2 hrs, oil quench;
draw at 350°F, 2 hrs, air cool;

Absence of laminations. Uniformly distributed fine nonmetallics.

Unetched

MA 881

- (d) Same as "c" after etching in 1% Nital. Relatively coarse martensitic pattern.

MA 869

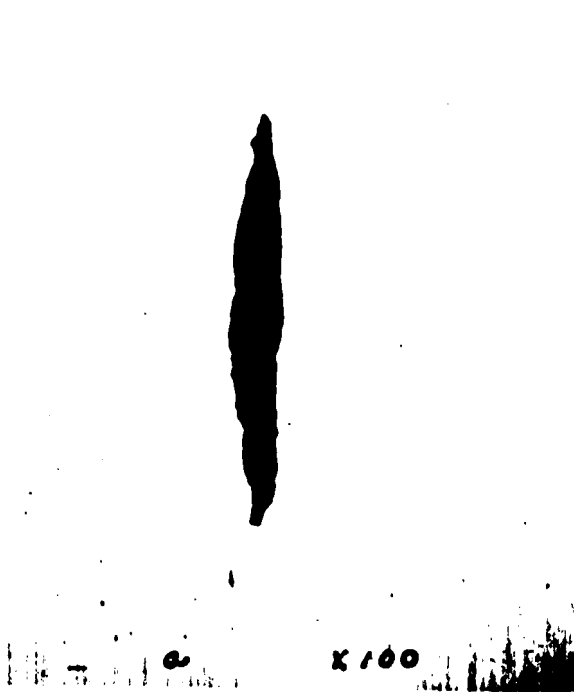


FIG. 14

WA 639-737

Figure 15

- (a) Plate which spalled badly - No. 15.
Brinell Hardness 477. Resisted 2600 f.s.
Cal .30 A.P. M1922 bullet.
Heat Treatment: 1490°F, 2 hrs, oil quench;
draw at 350°F, 2 hrs, air cool
Typical laminations in plate.
Unetched MA 878
- (b) Same as "a" after etching in 1% Nital.
Relatively coarse grain - Martensite.
MA 868
- (c) High Ballistic Plate - No. 40.
Brinell Hardness 532. Resisted 2600 f.s.
Cal .30 A.P. M1922 bullet.
Heat Treatment: 1650°F, 2 hrs, water quench;
draw at 350°F, 3 hrs, air cool;
Relatively fine troostite-sorbite with fine
carbide present.
No laminations.
1% Nital etch MA 883
- (d) High Ballistic Plate No. 5B.
Brinell Hardness 477. Defeated 2600 f.s.
Cal .30 A.P. M1922 bullet.
Heat Treatment: 1560°F, 2 hrs, oil quench;
draw at 1000°F, 2 hrs, furnace cool;
No laminations. Fine troostite-sorbite.
1% Nital etch MA 887

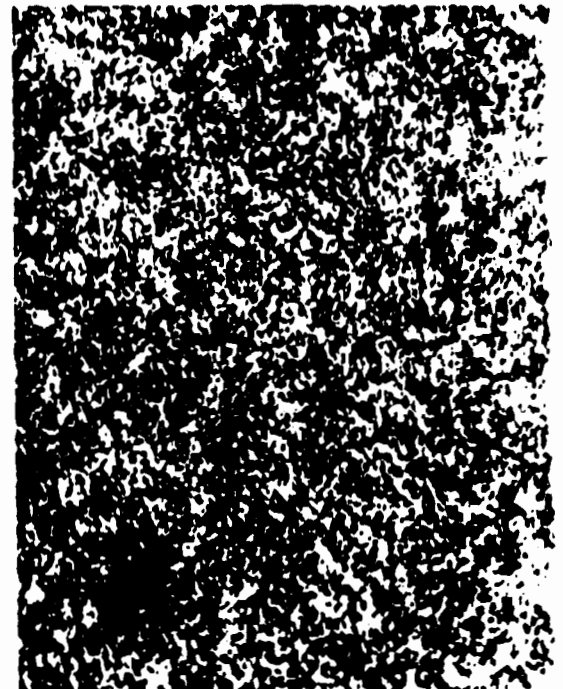


FIG. 15

WA 639-738

Figure 15

(e) Same as (d), after drawing 2 hours at 950°F.

Brinell Hardness 477. Defeated 2600 f.s.
Cal .30 A.P. M1922 bullet.
Fine troostite-sorbite.

1% Nital etch MA 888

(f) Same as (e) after redrawing 2 hours at 1050°F.

Brinell Hardness 477. Defeated 2600 f.s.
Cal .30 A.P. M1922 bullet.
Fine troostite-sorbite.

1% Nital etch MA 889

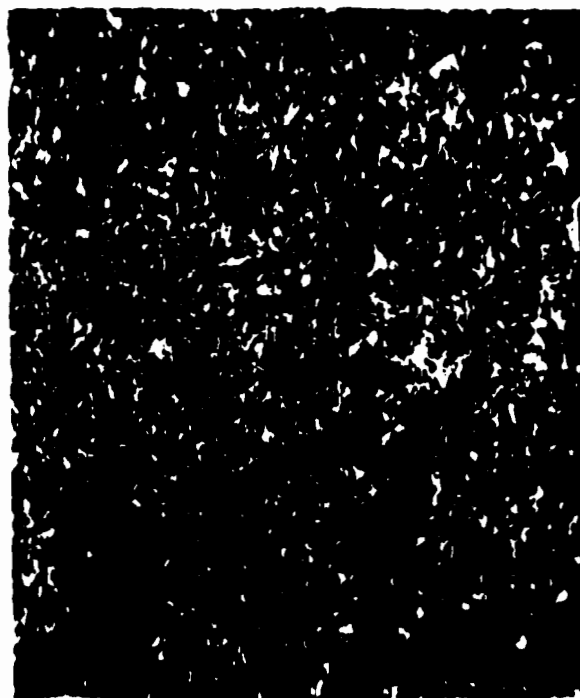


FIG. 15

WA 639-739

TABLE

PLATE NO	THICK- NESS	CHEMICAL ANALYSIS									HEAT BRINEL HARDNESS
		C	MN	SI	NI	CR	MO	VN	W	PI	
7B	.495"	.515	.66	.327		1.35	.70	.225	.294		477
39	.495"	.36	.65	.30			1.22	.10	.16		512
40	.505"	.43	.55	.33			2.14	.09	.32		532
21B	.503"	.235	.53	.188		.62		.20	3.36		430
22B	.501"	.325	.56	.216		.56	.44	.21	2.92		444
10B	.505"	.525	.67	.415		1.31	.68	.225		.03	477
9B	.498"	.585	.63	.41		1.32	.68	.24		.04	477
8B	.510"	.535	.59	.63		1.34	.79	.24		.11	535

P. SIGNIFIES PARTIAL PENETRATION AT 2600.
S. SIGNIFIES EVIDENCE OF SPALLING, BUTT

TABLE 3

CONT

N	Ti	HEAT TREATMENT 1		HEAT TREATMENT 2		HEAT TREATMENT 3	
		BRINELL HARDNESS	BALLISTIC LIMIT F.S.	BRINELL HARDNESS	BALLISTIC LIMIT F.S.	BRINELL HARDNESS	BALLISTIC LIMIT F.S.
94		477	2350 S.	460	2350 S.	444	2600 P.
6		512	2350-S	444	2350	402	2350
2		532	2600-P.	477	2350	418	2450
36		430	2350	450	WAS MAXIMUM HARDNESS		
92		444	2550	444	WAS MAXIMUM HARDNESS		
	.03	477	2600 P.	444	2600 P.	444	2600 P.
	.04	477	2600 P.S.	477	2350 S.	444	2450
	.11	555	2600 P.	477	2600 P.	460	2600-P.

AT 2600 FEET/SEC.

ING, BUTTONING, OR ANY OTHER SIGN OF BRITTLENESS.

TABLE 3

PLATE NO.	THICK- NESS	CHEMICAL ANALYSIS									HEAT TREAT	
		C	MN	SI	NI	CR	MO	VA	W	Ti	BRINELL HARDNESS	TEMP.
17B	.506"	.365	1.38	1.955	—	—	.59	.11	—	—	495	
24	.509"	.40	.85	2.20	3.20	—	—	—	—	—	555	
18B	.505"	.35	.86	2.635	3.23	—	.76	—	—	—	512	
20B	.506"	.37	.80	2.63	3.09	—	1.21	—	—	—	512	
13B	.509"	.345	.76	2.48	3.09	—	.64	.27	—	—	477	
26	.504"	.44	.68	.39	—	—	2.08	.10	—	—	512	
28X	.503"	.44	.56	.34	—	—	4.07	.12	—	—	495	
29X	.506"	.47	.63	.33	—	—	5.07	.11	—	—	477	
19B	.504"	.34	1.38	.415	2.64	—	.82	—	—	—	495	
12B	.507"	.49	1.45	.35	—	—	2.66	—	.86	—	555	
32	.502"	.37	.57	.19	—	2.18	.60	—	—	—	512	
14B	.504"	.435	.69	.200	—	2.12	.66	—	—	—	512	
33	.512"	.41	2.40	.37	—	—	.61	—	—	—	512	
11B	.510"	.41	.77	.18	2.54	—	1.10	—	—	—	512	
34	.506"	.40	.44	.15	3.88	—	.60	—	—	—	477	
35	.509"	.56	.26	.23	2.16	1.92	—	—	—	—	600	
36	.508"	.61	.18	.28	2.66	2.59	—	—	—	—	532	
37	.509"	.36	.38	.21	3.86	2.07	—	—	—	—	495	
38	.504"	.28	.45	.19	3.90	1.87	—	—	—	—	477	
4B	.506"	.515	.70	.244	—	1.34	.85	.24	.62	—	495	
24B	.506"	.47	.91	.198	—	1.51	.34	.285	.68	—	512	
25B	.505"	.45	.90	.168	—	1.45	.35	.26	1.35	—	477	
1B	.505"	.52	.64	.263	—	1.33	.44	.24	1.47	—	477	
3B	.504"	.54	.59	.287	—	1.30	.75	.24	1.45	—	477	

TABLE 3.

CONT.

W	T _i	HEAT TREATMENT 1		HEAT TREATMENT 2		HEAT TREATMENT 3	
		BRINELL HARDNESS	BALLISTIC LIMIT f/s	BRINELL HARDNESS	BALLISTIC LIMIT f/s	BRINELL HARDNESS	BALLISTIC LIMIT f/s
—	—	495	2550 S.	477	2350	387	2350
—	—	555	2550	495	2550-S.	387	2350
—	—	512	2600-P.	417	2600-P.	444	2600-P.
—	—	512	2550-S.	477	2600 P.	444	2600-P.
—	—	477	2450-S.	430	2550-S.	—	—
—	—	512	2350	444	2450	364	2250
—	—	495	2600-P.	477	2600-P.	418	2350
—	—	477	2350	444	2350	PLATE	BROKE
—	—	495	2550-S.	387	2350	387	2350
.86	—	555	2600-P.	495	2600-P.	418	2550
—	—	512	2550-S.	477	2550	444	2550-S.
—	—	512	2600 P.	495	2550-S.	418	2450
—	—	512	2600 P.	477	2550	444	2450
—	—	512	2600-P.	477	2450 S.	444	2600-P.
—	—	477	2450-S.	444	2350	364	2250
—	—	600	2600 P.	444	2550	375	2450
—	—	532	2550-S.	477	2450 S.	387	2250
—	—	495	2600 P.S.	477	2550-S.	340	2250
—	—	477	2550-S.	460	2350-S.	418	2350
.62	—	495	2600 P.	477	2600-P.	444	2600 P.
.68	—	512	2600 P.S.	512	2600-P.S.	444	2550
1.35	—	477	2600 P.S.	477	2600 P.	444	2600 P.
1.47	—	477	2600 P.	477	2600 P.	444	2600-P.
1.45	—	477	2600 P.S.	477	2600-P.	460	2550-S.

TABLE 3.
BALLISTIC PROPERTIES OF ARMOR PLATE
AFTER HEAT TREATMENT

PLATE No	THICK- NESS	CHEMICAL ANALYSIS									HEAT TREATMENT	
		C	MN	SI	NI	CR	MO	VN	W	TI	BRINELL HARDNESS	BALL LIMIT
6B	.506"	.53	.71	.310	—	1.30	.74	.225	—	—	600	260
4X	.502"	.39	.85	.32	—	2.82	.63	.23	—	—	532	255
5X	.502"	.37	.53	.37	—	5.36	.65	.24	—	—	532	265
6X	.508"	.41	.73	.23	1.22	1.20	.65	.21	—	—	512	255
7X	.511"	.41	.67	.20	2.38	1.20	.60	.20	—	—	495	26
15B	.510"	.355	.69	.175	3.27	1.08	.59	.11	—	—	477	260
8	.509"	.40	.88	.31	4.60	1.15	.62	.23	—	—	512	25
2B	.497"	.485	.65	.36	—	1.30	1.13	.21	—	—	477	26
5B	.505"	.52	.69	.32	—	1.30	1.54	.225	—	—	477	26
23B	.506"	.455	.85	.23	—	1.47	2.92	.25	—	—	532	PIPE
9X	.504"	.44	.60	.14	1.26	—	.68	.20	—	—	512	26
10X	.504"	.43	.66	.24	2.36	—	.61	.21	—	—	532	26
11	.509"	.42	.60	.21	4.55	—	.60	.23	—	—	555	25
12	.509"	.42	.69	.28	3.71	—	.27	.23	—	—	578	26
13X	.508"	.41	.67	.30	4.02	—	.49	.30	—	—	532	25
14	.505"	.37	.59	.28	3.57	—	.65	.21	—	—	495	26
15	.506"	.40	.62	.25	3.45	—	.88	.22	—	—	477	26
16	.507"	.39	.68	.17	3.65	1.15	.31	.20	—	—	512	260
17X	.504"	.44	.63	.27	3.86	1.26	.47	.27	—	—	512	245
16B	.511"	.365	.66	.155	4.08	1.22	.62	.255	—	—	512	26
18X	.506"	.37	.60	.290	5.57	1.15	.78	.225	—	—	555	26
20	.502"	.38	.68	.22	4.00	1.12	.68	.10	—	—	532	26
23	.509"	.40	1.68	1.73	—	—	.78	—	—	—	512	26

TABLE 3.
S OF ARMOR PLATE COMPOSITIONS
ER HEAT TREATMENT

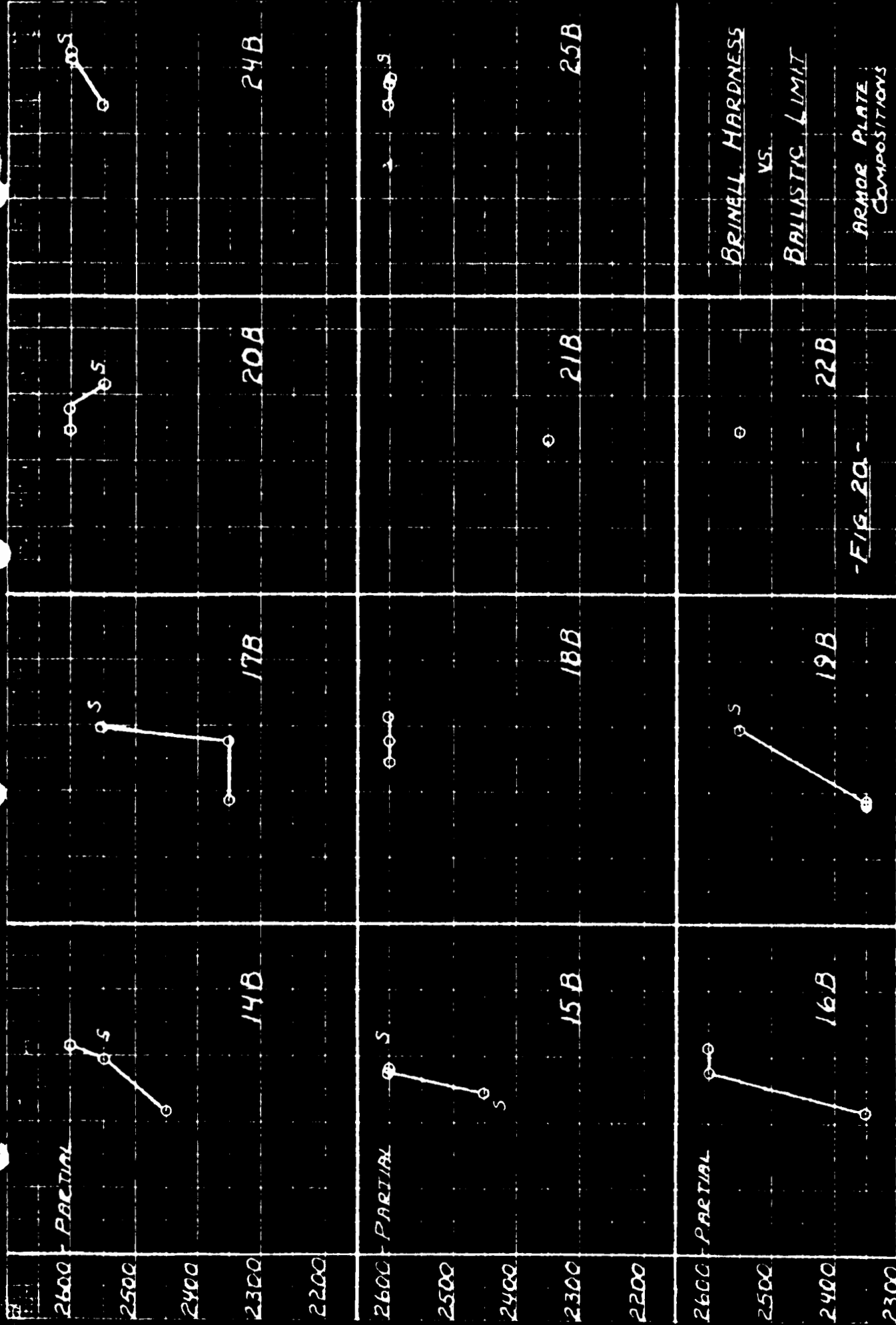
W	Ti	HEAT TREATMENT 1.		HEAT TREATMENT 2.		HEAT TREATMENT 3.	
		BRINELL HARDNESS	BALLISTIC LIMIT F.S.	BRINELL HARDNESS	BALLISTIC LIMIT F.S.	BRINELL HARDNESS	BALLISTIC LIMIT F.S.
—	—	600	2600 - P.	477	2600 - P.	460	2600 P.
—	—	532	2350 - S.	495	2600 - P.	418	2450
—	—	532	2600 - P.	477	2450 - S.	477	2600 P.S.
—	—	512	2550 - S.	444	2450	444	2450
—	—	495	2600 P.S.	460	2600 P.S.	444	2350
—	—	477	2600 - P.S.	477	2600 - P.	444	2450 - S.
—	—	512	2550 - S.	444	2450	444	2450
—	—	477	2600 - P.	477	2600 P.S.	477	2600 P.S.
—	—	477	2600 - P.	477	2600 P.	477	2600 P.
—	—	532	PIPE IN INGOT CAUSED PLATE TO CRACK.				
—	—	512	2600 - P.	477	2600 - P.	418	2450
—	—	532	2600 - P.S.	477	2600 - P.	444	2450
—	—	555	2550 - S.	430	2450	418	2450
—	—	578	2600 - P.	512	2350	402	2350
—	—	532	2550 - S.	512	2550	402	2350
—	—	495	2600 - P.	477	2600 - P.S.	418	2350
—	—	477	2600 - P.S.	477	2550 - S.	418	2350
—	—	512	2600 - P.S.	512	2450 - S.	402	2450
—	—	512	2450 - S.	495	2550 - S.	418	2350
—	—	512	2600 - P.	477	2600 - P.	418	2350
—	—	555	2600 - P.	460	2350 - S.	444	2450
—	—	532	2600 - P.	495	2550	430	2450
—	—	512	2600 - P.	477	2550	418	2450

SK. No 710/130

Ref. No 710/196

22/2

BALLISTIC LIMIT - F.S.



BRINELL HARDNESS

300 400 500 600

300 400 500 600

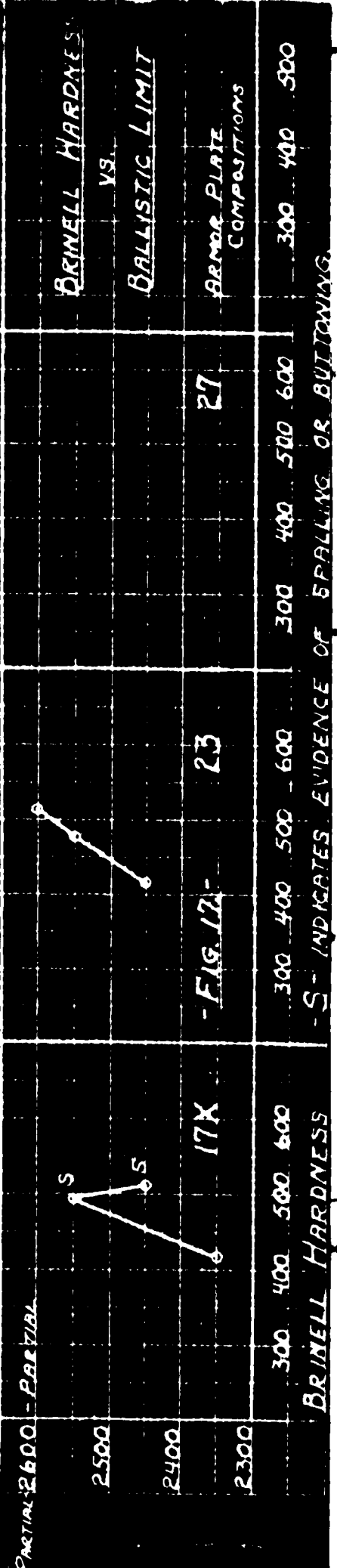
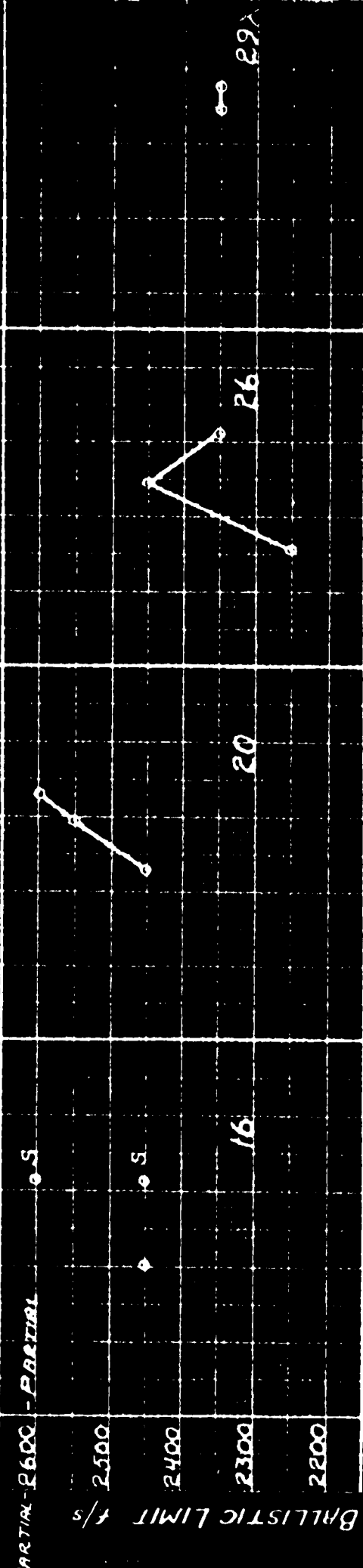
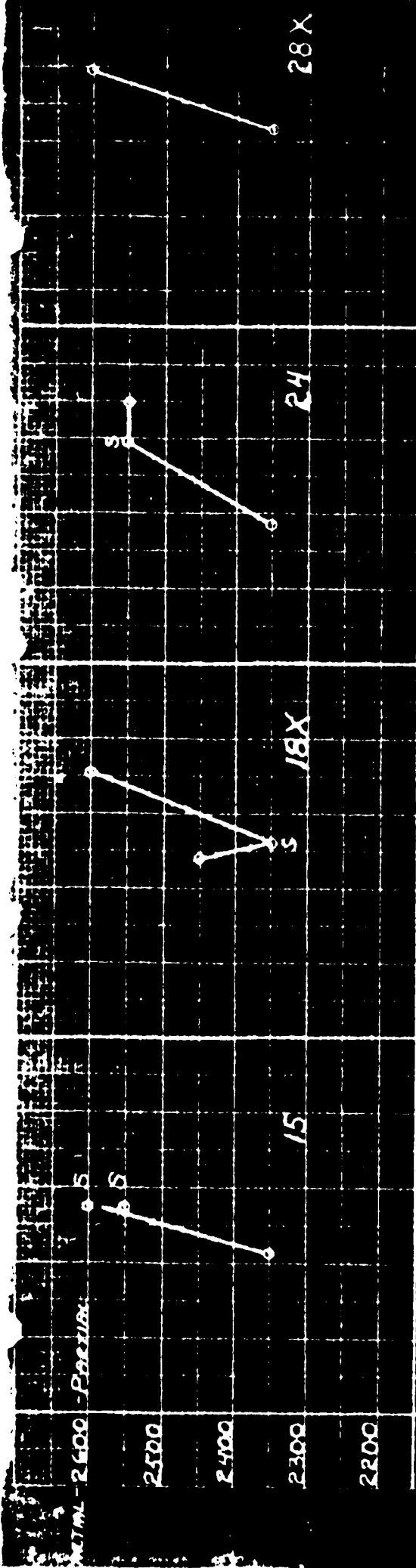
-S- INDICATES EVIDENCE OF SPALLING OR BUTTONING.

-FIG. 20-

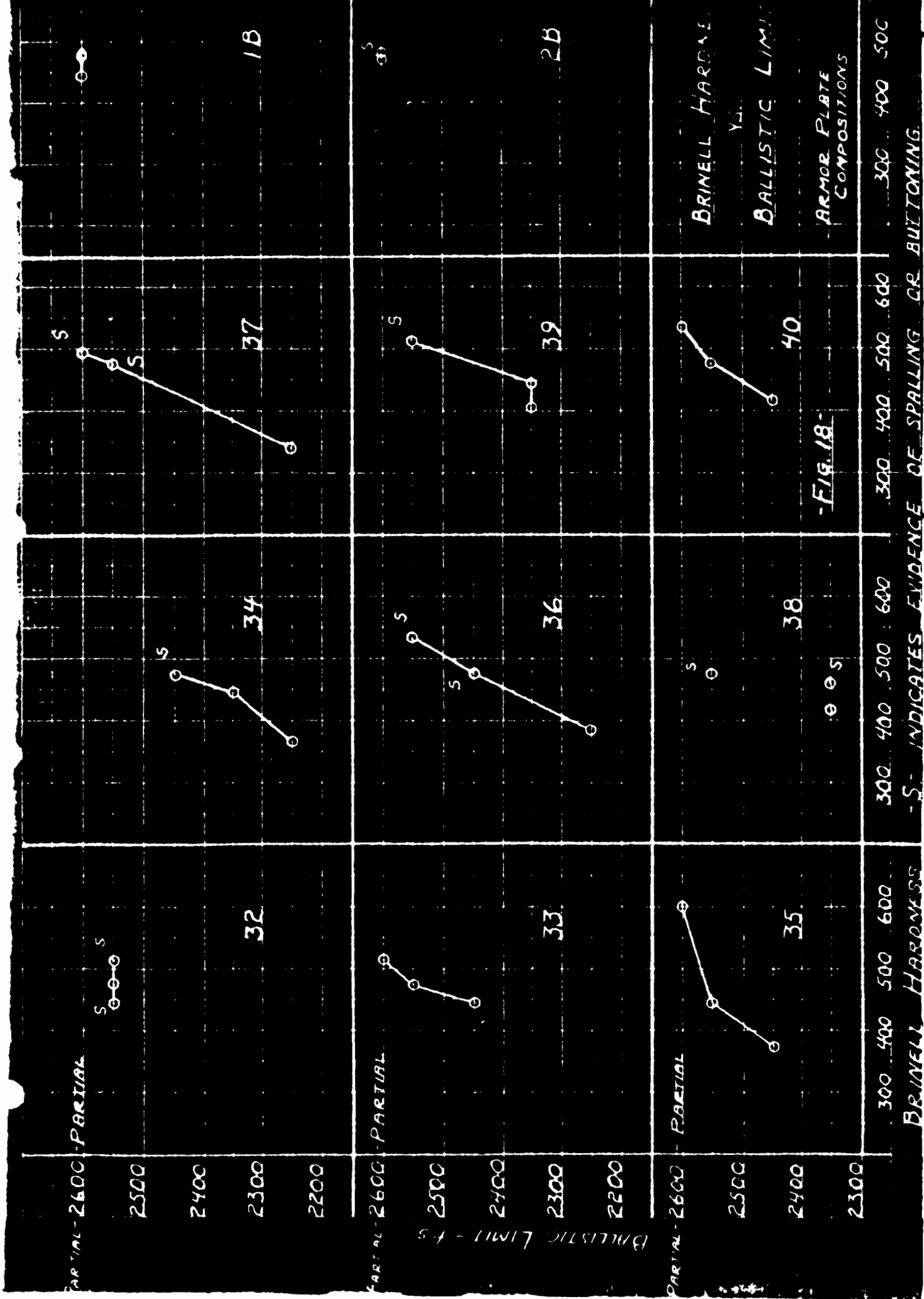
BRINELL HARDNESS
VS.

BALLISTIC LIMIT

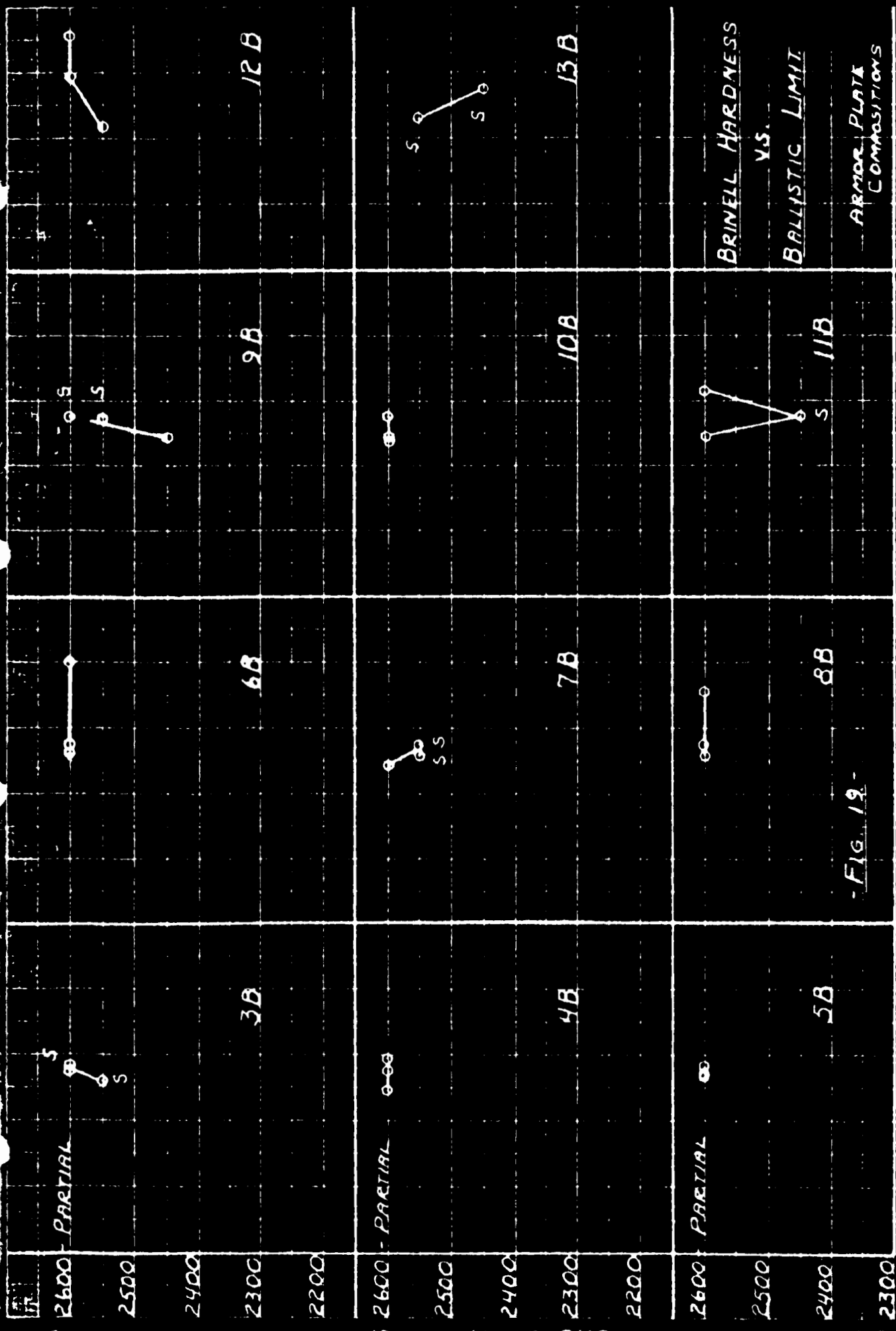
ARMOR PLATE
COMPOSITIONS



- S - INDICATES EVIDENCE OF SPALLING OR BUTTURING



Ballistic Limit - F 5



- Fig. 19 -

BRINELL HARDNESS

300 400 500 600

300 400 500 600

300 400 500

- S - INDICATES EVIDENCE OF SPALLING OR BUTTONING

BRINELL HARDNESS

VS.

BALLISTIC LIMIT

ARMOR PLATE COMPOSITIONS