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REPORT NO. 710/17

BALLISTIC PROPERTIES OF AN AIR HARDENING STEEL

E. L. Reed

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Report No. 710/47
Watertown Arsenal

January 6, 1936

BALLISTIC PROPERTIES OF AN AIR HARDENING STEEL

Purpose

The purpose of this investigation was to determine the ballistic properties of an air hardening armor plate composition proposed for the casting of the experimental tank turret, L-31-23462.

Conclusions

1. The resistance of the castings was in excess of the requirements of Par. 0-5 Special Specifications for steel castings, dated July 25, 1935.

2. The ballistic properties of this particular cast steel were slightly less than the requirements for rolled plate of the same thickness.

3. The areas subjected to ballistic test demonstrated toughness and ductility.

4. Good ballistic properties were obtained on castings with a Brinell hardness of 364.

Experimental Procedure

An air hardening steel of the following chemical composition and physical properties was selected for test.

Chemical Composition

C %	Mn %	P %	S %	Si %
.35/.45	.40/.70	<.02	<.02	.15/.25

Ni %	Cr %	Mo %	Va %
3.40/3.60	1.10/1.30	.60/.80	.20/.30

Physical Properties
(Heat Treated forged bars)

Y.S./.00% Set lb/sq. in.	Tensile Strength lbs/sq. in.	True Breaking Strength lbs/sq. in.
175,000	199,500	271,000

Elongation % in 2 in.	Reduction of Area %	Charpy Tension Impact Ft/lbs
11.4	41.9	323

Four generator covers of this composition were cast from Heat 995 and radiographed, heat treated and subjected to a ballistic test.

Results of Test

1. Radiographic Examination. No pronounced casting defects were revealed by X-Ray examination.

2. Heat Treatment. The castings were heat treated as follows:

Heat 8 hours at 1150° C, transfer to furnace preheated to 850°C, furnace cool. Reheat to 950°C for

5 hours, furnace cool. Reheat to 825°C for 5 hours, furnace cool. Heat 2 hours at 785°C, air quench. Draw 2 hours at 800°F, air cool.

3. Chemical analysis. Chemical analysis of Heat 995 is given below:

C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Va %
.45	.57	.007	.015	.22	2.55	1.19	.66	.27

4. Brinell Hardness. The Brinell hardness of the heat treated castings is as follows:

Casting No.	Brinell Hardness
1	418
2	364
3	364
4	364

Ballistic Tests. Ballistic tests of each casting are given in detail on Pages 3, 4, 5 and 6.

GENERATOR COVER NO. 1

Actual Thickness - 1/2" - Top of crown

Brinell Hardness 418

Range to plate 100 yards

Bullet-Caliber .30 M1922 A.P. 165 gr. Core 87.5 gr.

Rd No	Str Vel f/s	AxS-54 Rev 2 Penetration	Location of Shot	Dia of Hole Back	Height of bulge back	Depth of Pene-tration
1	1900	Partial	Top of Crown	--	Slight	---
2	1900	"	" " "	--	Slight	---
3	1900	Complete	" " "	--	---	---
4	1900	"	" " "	--	---	---

GENERATOR COVER NO. 2

Actual Thickness - 9/16" - Top of crown

Brinell Hardness - 364

Range to plate 100 yards

Bullet-Caliber .30M 1922 AP 165 gr. Core 87.5 gr.

Rd No	Str Vel	AxS-54 Rev 2 Penetration	Location of Shot	Dia of Hole Back	Height of bulge back	Depth of Pene-tration
1	1900	Partial	Top of crown		--	.42"
2	"	Partial Punching Started	" " "		1/8"	.5"
3	"	Glanced	rim		--	---
4	"	"	"		Slight	---
5	"	"	"		"	---
6	"	Partial	Top of crown		"	.45"
7	2000	"	" " "		"	.42"
8	2100	"	" " "		"	.5"
9	2200	Partial Punching Started	" " "		"	.41"

GENERATOR COVER NO. 3

Actual Thickness - 9/16" - Top of Crown

Brinell Hardness - 364

Range to plate - 100 yards

Bullet - Caliber .30 M 1922 AP 165 gr. Core 87.5 gr.

Rd No	Vel f/s	AxS-54 Rev. 2 Penetration	Location of Shot	Dia of hole back	Height of bulge back	Depth of Penetration
1	1900	Partial	Top of crown	---	---	.42"
2	"	"	" " "	---	---	.34"
3	"	"	" " "	---	---	.38"
4	"	Glanced	rim	---	---	---
5	"	Partial	Top of crown	---	Slight	.43"
6	2000	"	" " "	---	"	.46"
7	2100	"	" " "	---	"	.41"
8	2200	"	" " "	---	"	.44"
9	2300	"	" " "	---	"	.5"
10	Service	Partial Punching Started	" " "	---	1/16"	.43"
11	Service	" "	" " "	---	1/16"	.59"

GENERATOR COVER NO. 4

Actual Thickness - 1/2" - Top of Crown

Brinell Hardness - 364

Range to plate - 100 yards

Bullet - Caliber .30 M 1932 A.P. 165 gr. Core 87.5 gr.

Rd No	Str Vel f/s	AxS-54 Rev. 2 Penetration	Location of Shot	Dia of hole back	Height of bulge back	Depth of Pene-tration
1	1900	Partial	Top of Crown	--	--	.42"
2	"	"	" " "	--	--	.46"
3	"	Glanced	Rim	--	--	---
4	"	Yaw C.I.P.	Top of Crown	--	--	---
5	2000	Partial	" " "	--	slight	.51"
6	2100	"	" " "		slight	.48"
7	2200	Complete	" " "		--	---

Discussion

The castings made of the air hardening composition demonstrated ductility and toughness when subjected to ballistic tests.

The resistance of the castings was slightly lower than the requirements for rolled plate of the same thickness.

The Brinell Hardness of three of the generator covers, Nos. 2,3, and 4 was 364 and on the other hand these castings had relatively good ballistic properties.

The ballistic properties of Cover No. 1 which had a Brinell hardness of 418 were not superior to covers 2,3, and 4.

An increase in thickness of the casting over the specifications was responsible for high resistance as noted in Covers Nos. 2 and 3.

Photographs of Casting Nos. 2,3, and 4 after ballistic test are shown in Figs. 1, 1A, 2, 2A, 3 and 3A.

Recommendations

It is recommended that an air hardening steel of the following chemical composition be used in the

manufacture of the experimental tank turret.

C %	Mn %	P %	S %	Si %
.35/.45	.40/.70	<.02	<.02	.15/.25

Ni %	Cr%	Mo %	Va %
2.40/2.60	1.10/1.30	.60/.80	.20/.30

Respectfully submitted,

E. L. Reed,
Research Metallurgist.

References:

W. A. Report 115/1
W. A. Report 115/24
W. A. Report 115/29
W. A. Report 115/30

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Fig. 1

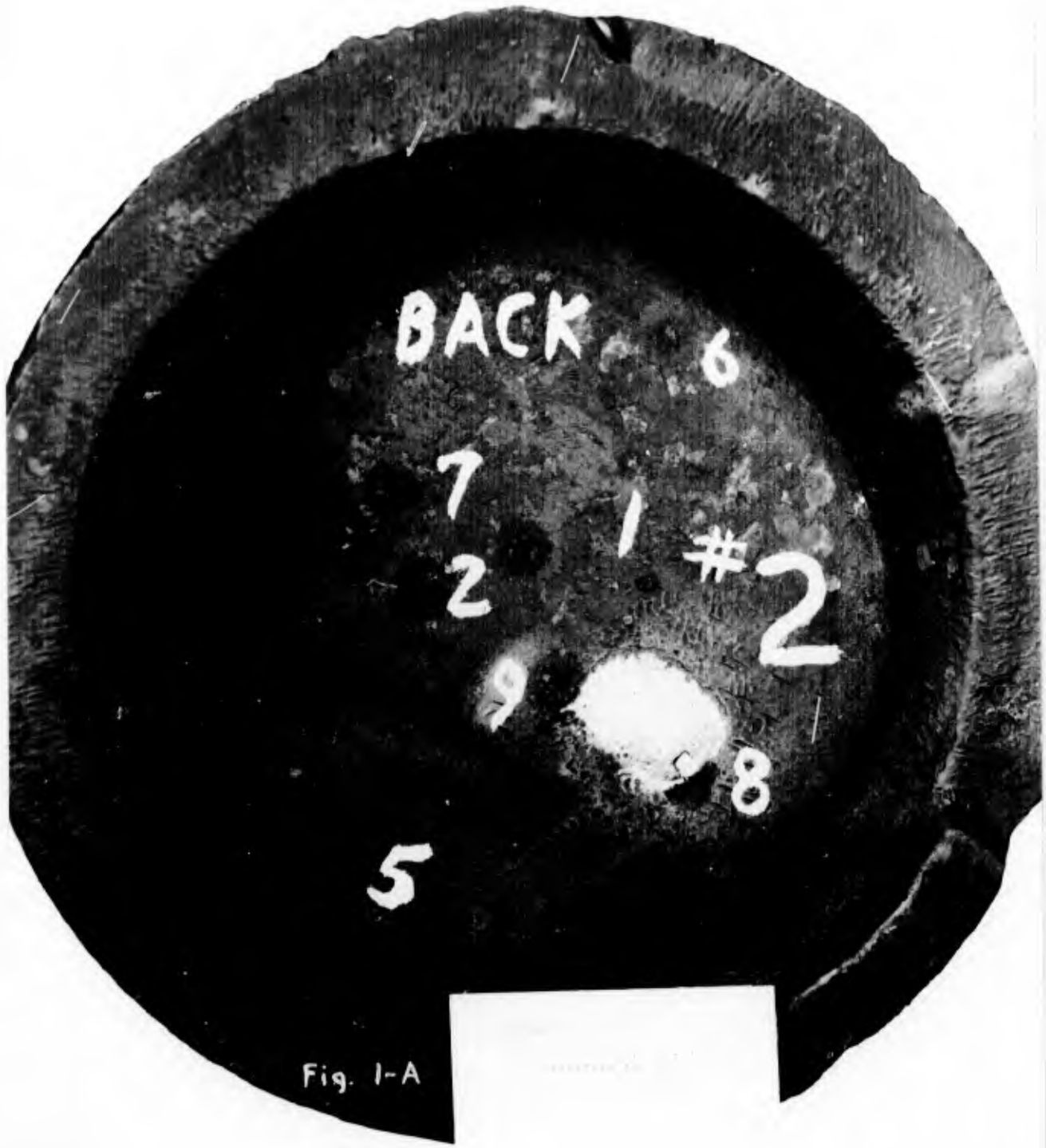

Fig. 1-A

Fig. 2.

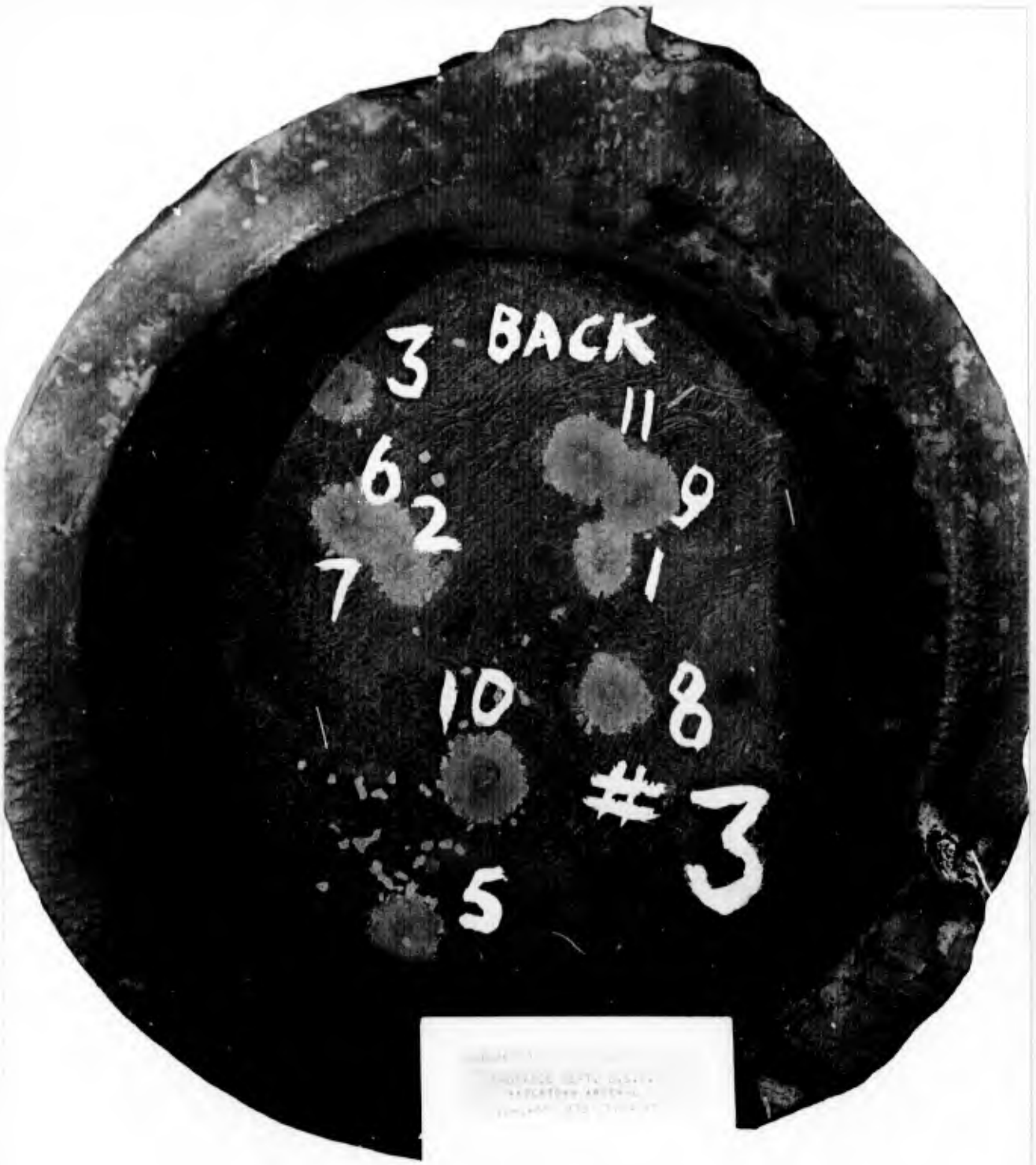

Fig. 2-A.

Fig. 3

Fig. 3A