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BALLISTIC PROPERTIES
OF AN
AIR HARDENING STEEL

RESEARCH REPORT

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E. L. Reed

February 1936

WATERTOWN ARSENAL
WATERTOWN, MASS.

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Report No. 710/47
Watertown Arsenal

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BALLISTIC PROPERTIES
OF AN
AIR HARDENING STEEL

January 6, 1936

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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. O-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.

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Chemical Composition

<u>C %</u>	<u>Mn %</u>	<u>P %</u>	<u>S %</u>	<u>Si %</u>
.35/.45	.40/.70	<.02	<.02	.15/.25
<u>Ni %</u>	<u>Cr %</u>	<u>Mo %</u>	<u>Va %</u>	
2.40/2.60	1.10/1.30	.60/.80	.20/.30	

Physical Properties
(Heat Treated forged bars)

<u>Y.S./ .00% Set</u> <u>lb/sq. in.</u>	<u>Tensile Strength</u> <u>lbs/sq. in.</u>	<u>True Breaking Strength</u> <u>lbs/sq. in.</u>
175,000	199,500	271,000
<u>Elongation %</u> <u>in 2 in.</u>	<u>Reduction of Area</u> <u>%</u>	<u>Charpy Tension Impact</u> <u>Ft/lbs</u>
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:

<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>
.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:

<u>Casting No.</u>	<u>Brinell Hardness</u>
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.

<u>Rd</u>	<u>Str</u>	<u>AxS-54</u>	<u>Location</u>	<u>Dia of</u>	<u>Height</u>	<u>Depth of</u>
<u>No</u>	<u>Vel</u>	<u>Rev 2</u>	<u>of</u>	<u>Hole</u>	<u>of bulge</u>	<u>Pene-</u>
	<u>f/s</u>	<u>Penetration</u>	<u>Shot</u>	<u>Back</u>	<u>back</u>	<u>tration</u>
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.

<u>Rd</u>	<u>Str</u>	<u>AxS-54</u> <u>Rev 2</u>	<u>Location of</u>	<u>Dia of</u>	<u>Height</u>	<u>Depth of</u>
<u>No</u>	<u>Vel</u>	<u>Penetration</u>	<u>Shot</u>	<u>Hole</u>	<u>of bulge</u>	<u>Pene-</u>
				<u>Back</u>	<u>back</u>	<u>tration</u>
1	1900	Partial	Top of crown		--	.42"
2	"	Partial Pun- ching 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 Pun- ching 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.

<u>Rd</u> <u>No</u>	<u>Vel</u> <u>f/s</u>	<u>AxS-54</u> <u>Rev. 2</u> <u>Penetration</u>	<u>Location</u> <u>of</u> <u>Shot</u>	<u>Dis of</u> <u>hole</u> <u>back</u>	<u>Height</u> <u>of bulge</u> <u>back</u>	<u>Depth</u> <u>of Pene-</u> <u>tration</u>
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 " 1932 A.P. 165 gr. Core 87.5 gr.

<u>Rd</u> <u>No</u>	<u>Str</u> <u>Vel</u> <u>f/s</u>	<u>AxS-54</u> <u>Rev. 2</u> <u>Penetration</u>	<u>Location</u> <u>of</u> <u>Shot</u>	<u>Dia of</u> <u>hole</u> <u>back</u>	<u>Height of</u> <u>bulge</u> <u>back</u>	<u>Depth of</u> <u>Pene-</u> <u>tration</u>
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.

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

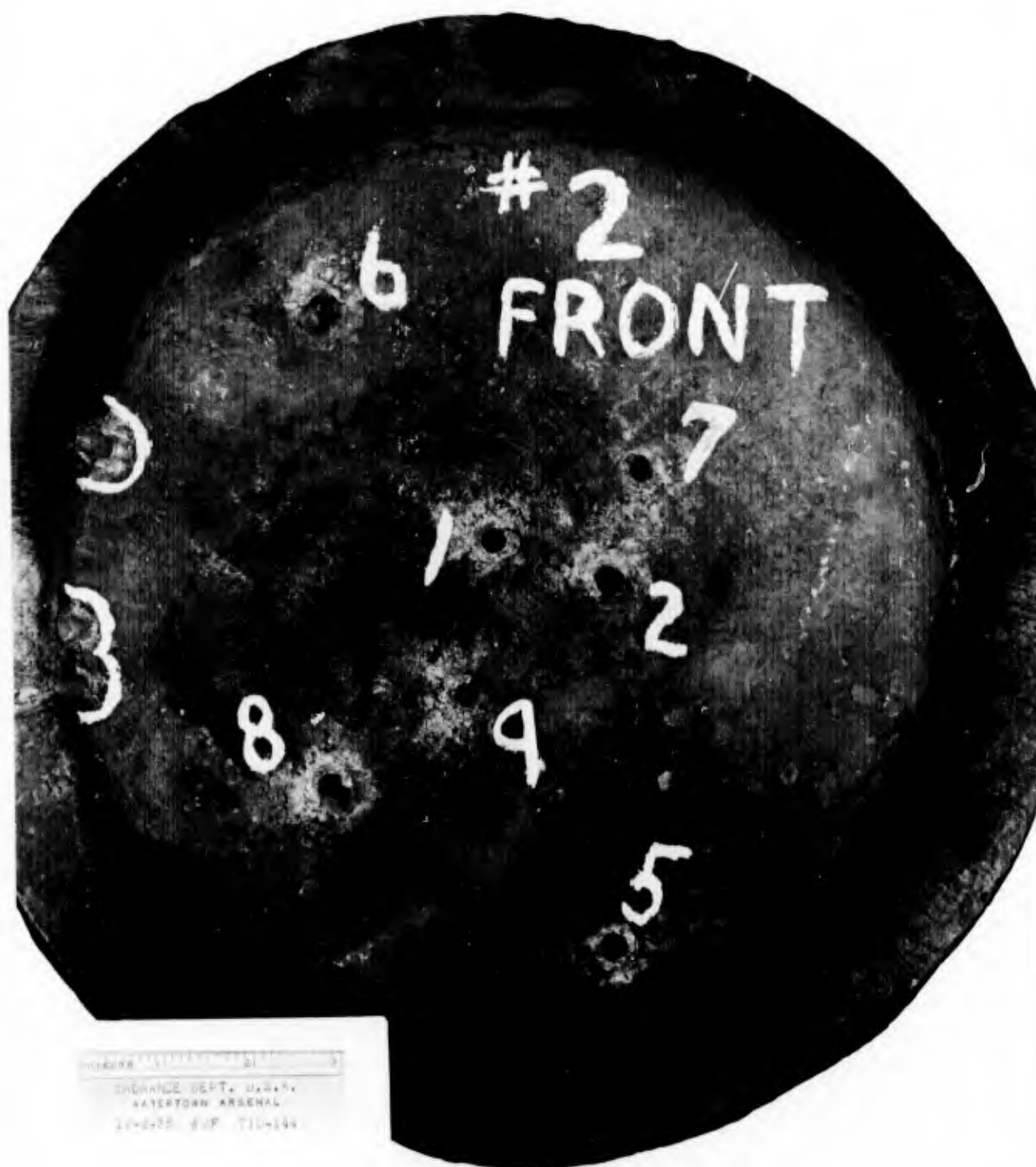
<u>Ni %</u>	<u>Cr %</u>	<u>Mo %</u>	<u>Va %</u>
2.40/2.60	1.10/1.30	.60/.80	.20/.30

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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SERIALS SECTION
ARMY DEPT. U.S.A.
WATERGATE ARSENAL
10-2425 SUP TID-144

Fig. 1.

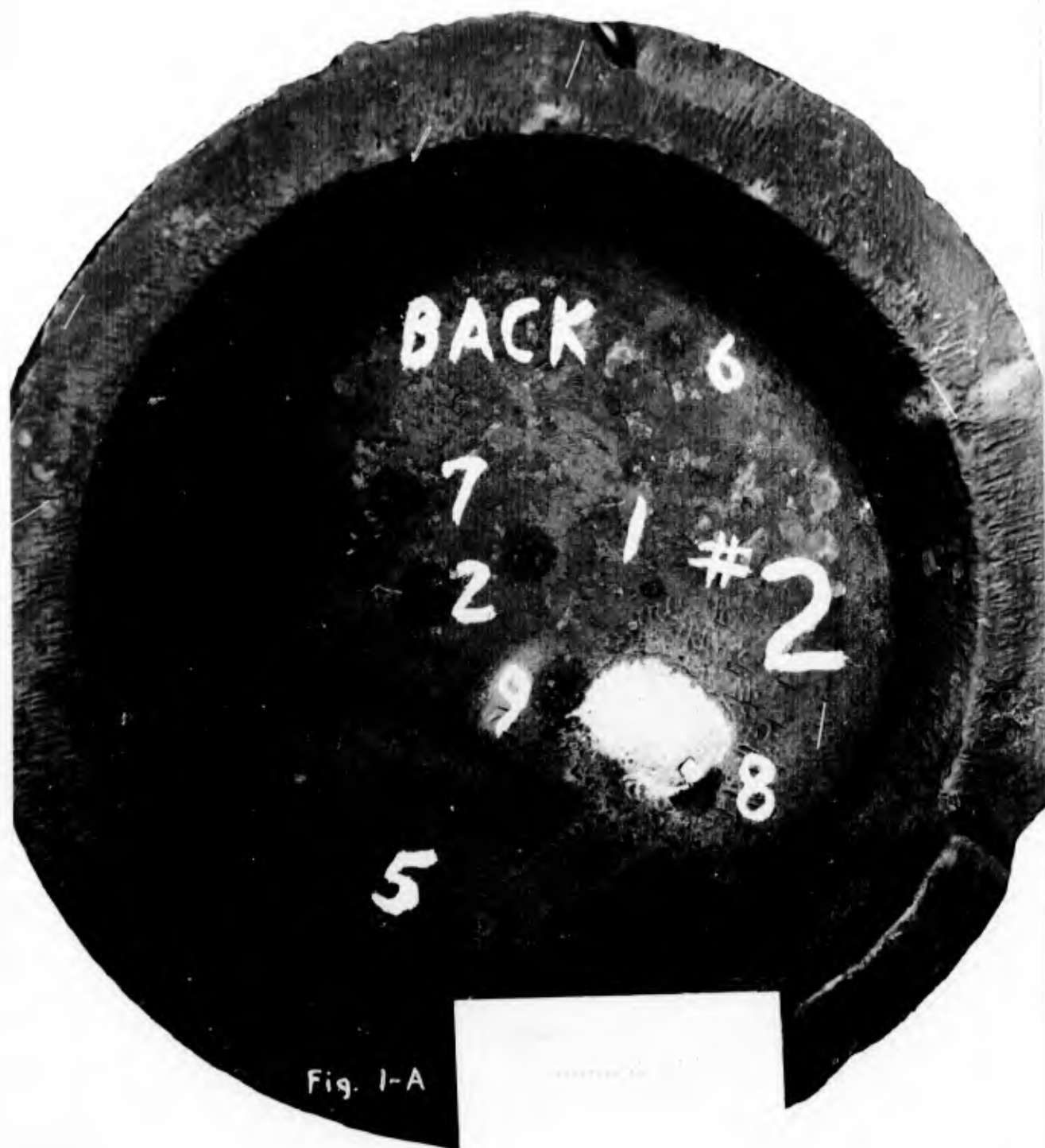


Fig. 1-A



ADVANCE SEPT. 1944
WATERTOWN ARSENAL
10-4-44 800 710-130

Fig. 2.



Fig. 2-A.



ORANGE SEPT. 1964
WATERTOWN ARSENAL
62-1-10 21P 710-14

Fig. 3



Fig. 3A