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WATERTOWN ARSENAL  
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in the name of the Arsenal  
380-5, dtd 6 Jul 61

Date

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MEMORANDUM REPORT

NO. WAL 710/632

Effect of Hardness on Resistance of Thin-Gauge (.040" to .044")

Hadfield Manganese Steel to Perforation by

Fragment-Simulating Projectiles

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BY

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Arsenal.

26 May 1961  
Date

Paul O'Meara  
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DATE 17 May 1944

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WATERTOWN ARSENAL LABORATORY

Memorandum Report No. WAL 710/632

Sixth Partial Report on Problem B-8.2

17 May 1944

Effect of Hardness on Resistance of Thin-Gauge (.040" to .044")

Hadfield Manganese Steel to Perforation by

Fragment-Simulating Projectiles

1. In response to a request from the Office, Chief of Ordnance<sup>1</sup>, a program of development of improved body armor components is in progress at this arsenal. As part of this program tests have recently been conducted on samples of Hadfield manganese steel as currently furnished for fabrication into body armor assemblies and as half-hardened and three-quarter hardened. Test samples have been supplied by the Carnegie-Illinois Steel Corporation.

2. The results of these tests indicate that hardening to 38/39 Rockwell "C" produces a Hadfield manganese steel whose resistance to perforation by standard caliber .45 ball ammunition (230 grains - steel jacketed) and by fragment-simulating projectiles developed at this arsenal<sup>2,3</sup> is appreciably inferior to that of the same steel in the annealed condition.

3. Although there were nominally three different conditions of hardness represented by these samples, the hardness readings taken at this arsenal indicated that the so-called half-hard and three-quarter hard specimens were vertically identically hard ( 37/39 Rockwell "C"). Subsequent ballistic test values of these two types were substantially identical.

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1. O.O. 422.3/71(c) - Wtn 470.5/7443(c) dated 28 September 1943.
  2. WAL Memorandum Report No. 762/247(c) - "Development of Projectiles to Be Used in Testing Body Armor to Simulate Flak and 20 mm. H.E. Fragment" - 17 December 1943.
  3. WAL Memorandum Report No. 762/253(c) - "Development of a Projectile, to Be Used in Testing Body Armor, to Simulate Fragments of a 20 mm. H.E. Projectile" - 7 January 1944.

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4. Samples were rigidly clamped to wooden ballistic frames which allow an 8"x8" area to be unsupported from the rear. Into the face of these areas there were directed impacts of caliber .45 ball projectiles (steel jacketed) and three types of fragment simulators developed here. The results of these tests are set forth in Table I.

5. Under impact of the caliber .45 ball projectile the resistance of the as annealed sample (949 feet-per-second for purposes of comparison with .040" samples) was greatly superior to that of the other two types (613 feet-per-second and 625 feet-per-second).

6. Under impact of the light-weight (17 grains) fragment simulator, G-2, the resistance of the as annealed .044" specimen (1570 feet-per-second, corrected to 1510 feet-per-second) was considerably better than that of the other two types (1232 feet-per-second and 1184 feet-per-second) although it is somewhat inferior to that of average "as-annealed" Hadfield steel previously tested here (1600 feet-per-second).

7. Under impact of the other fragment simulators, G-1-A and G-1-S the same superiority was evident.

8. Thus it is apparent that any attempt to improve the resistance characteristics of Hadfield manganese steel should not be directed along the lines of hardening, since hardness with its consequent loss of ductility seems detrimental to the resistance of this type of steel, which in these gauges (.040" to .050") appears to be supreme in its dead-soft condition.

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Table I

Summary of Ballistic Tests Conducted at Watertown Arsenal  
on Hadfield Manganese Steel, As Annealed and  
After Hardening by Cold Reduction

<u>Sample</u>	<u>Gauge</u>	<u>Hardness</u>	<u>Ballistic Limit</u>			
			<u>G-1-A<sup>1</sup></u>	<u>G-1-S<sup>2</sup></u>	<u>G-2<sup>3</sup></u>	<u>Cal. .45<sup>4</sup></u>
As Annealed	.044"	89 Rb	---	---	---	949
		88 Rb	---	1144	---	---
		87 Rb	485	1083	1570	---
Half-Hard (Nominal)	.040"	38 Rc	---	814	1232	---
		39 Rc	345	---	---	613
3/4 Hard (Nominal)	.040"	37 Rc	---	---	---	625
		38 Rc	---	---	1184	---

Corrected for  
thickness difference:

As Annealed	.040"	-----	(factor	1510 <sup>5</sup>	909 <sup>6</sup>
			undetermined)		

<sup>1</sup>Caliber .30 fragment-simulating projectile (150 grains)

<sup>2</sup>Caliber .30 fragment-simulating projectile (34 grains)

<sup>3</sup>Caliber .22 fragment-simulating projectile (17 grains)

<sup>4</sup>Caliber .45 ball ammunition (230 grains - steel jacketed)

<sup>5</sup>1570 - (4x15) = 1510

<sup>6</sup>949 - (4x10) = 909