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REPORT NO. 710/203

BALLISTIC PROPERTIES OF PLOWSHARE STEEL

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AUGUST 20, 1953
WATERTOWN ARSENAL
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Report No. 710/203
Watertown Arsenal

August 20, 1937

BALLISTIC PROPERTIES OF PLOWSHARE STEEL

Purpose

The purpose of this investigation was to determine the microstructure, chemical analysis and ballistic properties of a sample of Plowshare Steel obtained from the Crucible Steel Company.

Conclusions

1. Heat treated plowshare steel is not suitable material for resisting armor piercing bullets according to Specification AXS-54K.

2. The sample submitted was a one-quarter inch thick three-ply steel made by hot rolling a .80/1.10% carbon steel plate on both faces of a low carbon steel core.

Description of Samples

Three samples of plowshare steel obtained from the Crucible Steel Company measured 5 x 5 x 1/4 inches.

The thickness of the layers of the composite plate are as follows:

Top layer - 5/64 inch

Central layer- 6/64 inch

Bottom layer - 5/64 inch

Method of Test

The plates were examined as follows:

1. Microscopic examination
2. Chemical Analysis
3. Heat Treatment
4. Hardness Surveys
5. Ballistic Tests

Results of Test

1. Microscopic Examination

The results of the microscopic examination are shown in Figures 1a, b, c, and d.

2. Chemical Analysis

The results of the chemical analysis are given in Table I.

Table I

	C	Mn	Si	S	P	Ni	Cr	Mo	Va
Front Face	.82	.45	.155	.028	.020	Nil	.15	Nil	Nil
Core	.30	.32	.075	.020	.013	Nil	.14	Nil	Nil
Back Face	1.045	.47	.190	.027	.022	Nil	.15	Nil	Nil

3. Heat Treatment

(a) A sample was heated one hour at 1450°F, quenched in brine and drawn 2 hours at 400°F, followed by cooling in air.

(b) The same sample was redrawn 2 hours at 700°F, followed by air cooling.

(c) Another sample was heated one hour at 1500°F, oil quenched and drawn one hour at 300°F, followed by air cooling.

4. Hardness Surveys

(a) The hardness values of the outer and central layers of the material as received is as follows:

Face (A) Front - 297 Vickers Brinell
Central Layer - 78.4 " "
Face (B) Back - 287 " "

(b) The hardness values after various heat treatments are given in Table II.

Table II.

Heat Treatment	Hardness Values	
	Rockwell C	Vickers Brinell
1450°F, 1 hr, Brine quench; 2 hrs. at 400°F, air cool.	61	775
1450°F, 1 hr, Brine quench; 2 hrs. at 700°F, air cool.	59	720
1500°F, 1 hr, Oil quench; 1 hr. at 300°F, air cool.	40	390

5. Ballistic Test

Ammunition - Cal .30 A.P. M1922

Distance from muzzle to plate - 100 yards.

The results of ballistic tests are given in Table III.

Table III

Plate No.	Round No.	Striking Velocity ft. secs.	Penetration	Heat Treatment	Remarks
1	1	2000	Complete	1450°F, 1 hr, brine quench, draw 2 hrs, 400°F.	Radial cracks.
1	2	2000	Complete	1450°F, 1 hr, brine quench, draw 2 hrs, 700°F.	Hit Round 1, broke out piece of plate.
1	3	2000	Complete	Same	1/4" dia. hole, spalled, crack to edge of plate.
1	4	1650	Complete	Same	1/4" dia. hole, spalled, radial cracks to edge of plate
2	1	1700	Complete	1500°F, 1 hr, oil quench, draw 2 hrs, 300°F.	Radial cracks.

Discussion

Microscopic examination showed the material to be in the annealed condition, as shown in Figure 1b. A slight amount of decarburization was evident at the surfaces of both high carbon layers, see Figure 1-d. The metal was properly rolled,

that is, there was no definite line of demarcation at the junction of the high carbon layers and the core, see Figure 1-a.

This material, after various heat treatments which promoted hard front and back faces on a relatively soft core, is not suitable for resisting armor piercing bullets. Plate having a front and back face of high hardness is not recommended, since a hard face on the back of the plate is subject to cracking and spalling.

Respectfully submitted,

E. L. Reed.

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Figure 1

Plowshare Steel

(a) X100. Junction of low carbon inner plate and high carbon outer plate, showing complete coalescence.

MA-799

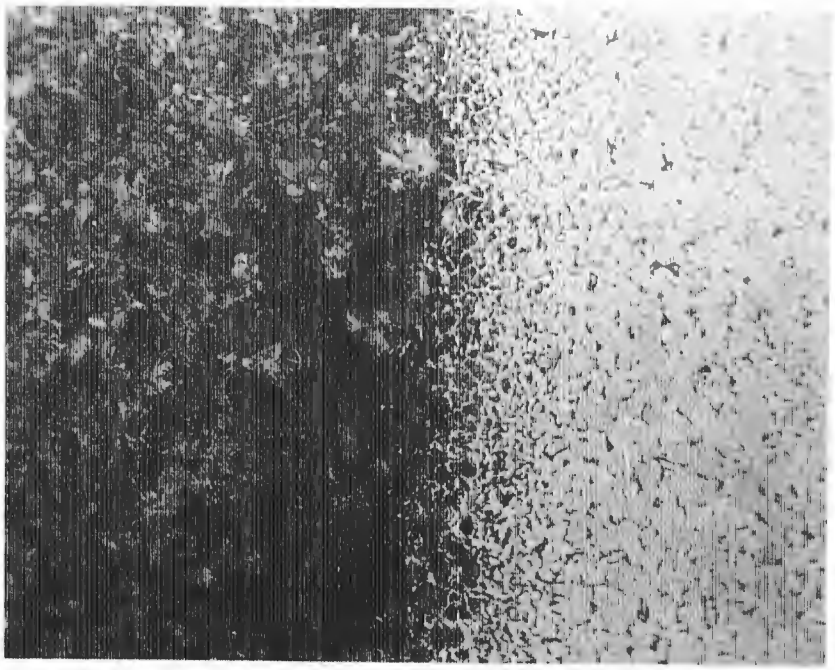
(b) X1000. High carbon outer-plate structure.

MA-796

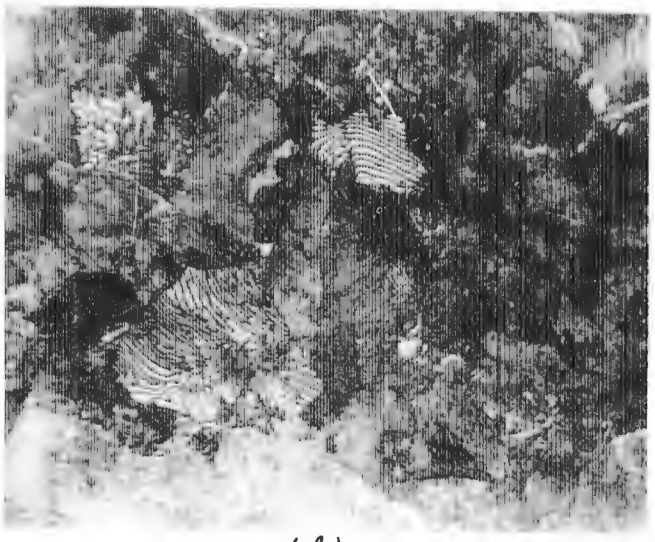
(c) X1000. Low carbon inner plate structure.

MA-797

(d) X1000. Decarburization at extreme edge of outer plate, goes in to an approximate depth of .001 inches.



(a)



(b)

(c)

(d)