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OTTAWA   June 10th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1426.

Examination of 6-mm. Armour Plate.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch
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Origin of Material:

On May 24th, 1943, Mr. John A. Hoople, for Director of Inspection (Tanks-Armour), 5-157 General Motors Building, Detroit, Michigan, Inspection Board of United Kingdom and Canada (U.S.A.), submitted a piece of 6-mm. homogeneous bulletproof armour plate for examination. The accompanying request letter (dated May 22nd, File No. DA/TPS/15143) supplied the following information concerning this material:

The armour plate is manufactured by the Follansbee Steel Corporation and heat-treated by the National Armour Company. The supplier, at the request of the metallurgist of the National Armour Company, anneals the plate so that it is decarburized to a depth of 0.040-0.060 inch. The plate is then heat-treated by an undivulged process.

The ballistic tests of the armour plate, as put out

(Origin of Material, cont'd) -

by the National Armour Company, consistently give results averaging 200 ft./sec. above the specification requirements. Other manufacturers are unable to match these results.

The metallurgist of the National Armour Company states that decarburizing the annealed plate prevents or reduces back spall and that with his particular type of heat treatment he was able to obtain a very homogeneous centre core.

Procedure:

1. Hardness tests were made on the plate as received, using a Brinell machine and a 3,000-kilogram load. A layer of metal 0.060 inch thick was ground off and the hardness again checked. The following table gives the results obtained:

As Received	Core Hardness
269	375

2. A chemical analysis gave the following results. The sample for carbon content was taken after milling 0.060 inch from the surface of the plate. The analysis supplied by Mr. Hoople is also shown.

		Analysis	Analysis Supplied
		- Per cent -	
Carbon	-	0.23	0.26
Manganese	-	1.09	1.10
Silicon	-	0.99	1.05
Chromium	-	0.47	0.53
Nickel	-	0.20	0.23
Molybdenum	-	0.28	0.29

3. A transverse section of the plate was polished, etched, and examined under a microscope. Figure 1 shows the structure from the surface towards the core. Figure 2 shows the tempered martensitic structure of the core. Figure 3

(Procedure, cont'd) -

shows the structure 0.020 inch below the surface-tempered martensite, in a matrix of ferrite.

DISCUSSION:

The plate, in finished form, is to have a Brinell hardness of from 360 to 380. The surface is considerably below this but the core is well within the range. The low surface hardness is attributable to the partially decarburized surface areas.

The chemical analysis is in good agreement with that supplied by Mr. Hoople.

It is reported that after the annealing treatment the plate is heated to 1750° F. for an hour and quenched in oil. The extreme outer layer is slightly carburized, indicating that the heat treatment was done in a neutral atmosphere furnace. As a result of this comparatively high temperature treatment in a neutral atmosphere, a carbon diffusion from the core to the decarburized surface layers has taken place. The oil quench and subsequent draw has resulted in a core structure of tempered martensite and a subsurface structure comprised of approximately 70 per cent drawn martensite in a matrix of ferrite.

Any projectile would therefore encounter a gradually increasing resistance from the surface to the core, the maximum resistance of the core, and then the gradually reducing resistance towards the exit surface. If the surface layers were pure decarburized metal they would offer slight resistance to penetration and the overall effect would be to reduce the effective thickness of the plate by the total thickness of the decarburized metal.

It is possible that the gradations of toughness of the

(Discussion, cont'd) -

plate from surface to surface would account for the superior ballistic performance of the plate.

The remainder of the plate will be subjected to the Canadian ballistic tests at the range of Dominion Foundries & Steel Limited, Hamilton, Ontario. When the results of these testsare available they will be reported.

CONCLUSIONS:

1. The core hardness of the plate is within the specified Brinell range but the surface hardness is considerably lower.

2. After annealing, the heat treatment to which this plate has been subjected has resulted in carbon diffusion from the core into the decarburized metal.

3. The surface layers, as a result of this heat treatment, are comparatively soft and ductile but considerably tougher than decarburized metal would be. This would probably reduce back spall.

4. There is some evidence to the effect that the final heat treatment is conducted in a furnace with a controlled atmosphere. This is, undoubtedly, to prevent decarburization in this heat treatment.

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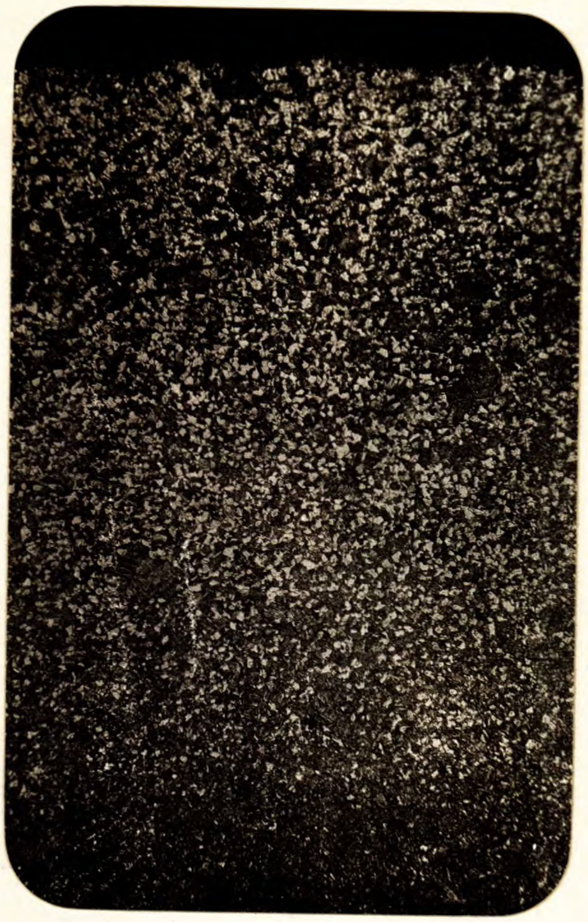
Figure 1.

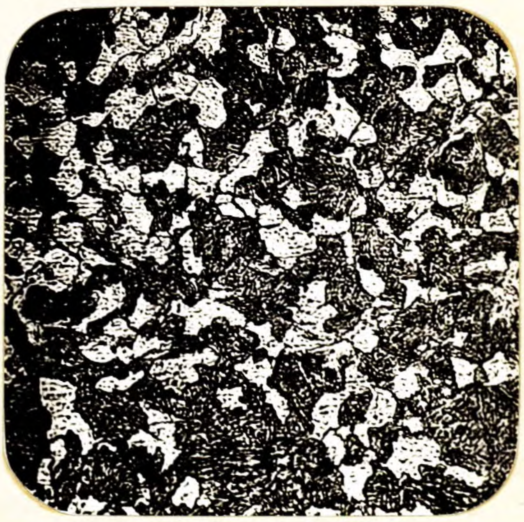


75X, etched in 2 per cent nital.
STRUCTURE FROM SURFACE TOWARDS CORE.

Figure 2.

500X, etched in 2 per cent nital.
CORE STRUCTURE - TEMPERED MARTENSITE.

Figure 3.



500X, etched in 2 per cent nital.
STRUCTURE 0.020 INCH FROM SURFACE, MARTENSITE IN MATRIX OF FERRITE.

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