O T T A W A July 3rd, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1043.

Examination of Armour Plate Samples.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
ORE DRESSING AND
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CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Origin of Request:

Major J. L. McAvity (for Director of Technical Research, Department of National Defence - Army, Ottawa, Ontario) in a letter dated June 17th, 1941, File No. H.Q.S. 46-1-73, Vol. 3, (D.T.R.), requested an examination and report on three samples of armour plate submitted by Mr. L. V. Sullivan.

The following claims were reported for this plate:

(Continued on next page)

(Origin of Request, cont'd) -

(1) It can be produced in any Canadian mill.

(2) It is readily machineable.

Requested:

1. To have chemical analysis checked.
2. The hardness to be determined.
3. To ascertain to what depth the surface hardening had penetrated.

Description of Material:

For purposes of identification, the three samples of plate were designated as follows:

Thin - section approximately 6 inches square by 0.227 inch in thickness.

Medium - section approximately 4 in. x 5 in. by 0.372 inch in thickness.

Large - section approximately 12 in. x 6 in. by 0.378 inch in thickness.

The large plate was planed down for approximately half of its long dimension to a thickness of 0.315 inch.

Chemical Analysis:

	As given approximately	As determined
Carbon, per cent	0.61	0.58
Manganese, "	0.68	0.64
Phosphorus, "	0.014	0.032
Sulphur, "	0.027	0.021
Silicon, "	0.20	0.19
Copper, "	0.16	0.04
Chromium, "	Not given.	0.03
Nickel, per cent	Not given.	None detected.
Molybdenum, "	" "	" "
Vanadium, "	" "	" "

Hardness Tests:

The Brinell hardness for this steel was given as 378.

The Brinell hardness on the three samples submitted was as follows:

Large - 351
Medium - 340
Thin - 460. Edge - 444.

The hardness was further checked by means of the Vickers pyramid hardness tester, on the centre of cross-sections of the plates taken for micrographical examination, with the following results:

Sample	Vickers Hardness Number.	Equivalent Brinell Hardness Number
Large	468	441 (approx.)
Medium	379	369 (")
Thin	477	448 (")
Thin, edge	451	427 (")

Microstructure:

Figure 1.

X100, unetched.
THIN PLATE.

Figure 2.

X100, unetched.
MEDIUM PLATE.

(Continued on next page)

(Microstructure, cont'd) -

Figure 3.

X100, unetched.
LARGE PLATE.

Inclusions shown above indicate that this is a fairly clean grade of steel.

Figure 4.

X2000, Nital etch.
THIN PLATE.

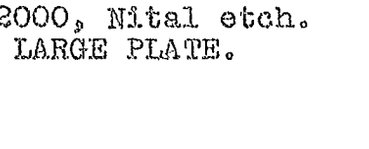
Figure 5.

X2000, Nital etch.
MEDIUM PLATE.

(Continued on next page)

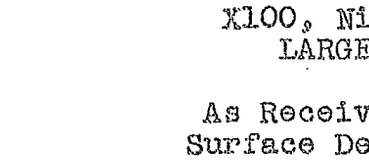
(Microstructure, cont'd) -

Figure 6.



X2000, Nital etch.
LARGE PLATE.

Figure 7.



X100, Nital etch.
LARGE PLATE.

As Received, showing
Surface Decarburization.

A piece of the large plate was oil-quenched and drawn at 600° F. The resulting structure is shown in Figure 8.

Figure 8.

X2000, Nital etch.
LARGE PLATE.

After Quench-and-Draw Treatment.

DISCUSSION OF RESULTS:

Chemical Analysis -

The chemical analysis as determined conforms closely to the analysis as given. Analysis falls within the range specified for S. A. E. Steel 1060. This is an ordinary grade of steel, which should not present much difficulty in manufacture.

Depth of Hardening -

With the exception of the large plate, which is softer on the surface than the interior, the plates are uniformly hard throughout. Decarburization is responsible for the surface softness of the large plate.

Machineability -

The medium plate is the only one that could be conveniently machined. The other two plates could be machined but with difficulty because of their high hardness. Results of ballistic tests would indicate, however, that these latter plates have hardnesses associated with optimum ballistic properties.

Microstructure -

Research has shown that while elongated inclusions are one of the causes of armour plate spalling, small equiaxed inclusions of the type present in the steel examined have no unfavourable effect on the ballistic properties of the plate. The microscopic examination confirms the findings of the hardness test in that it shows that the surface of the large plate is decarburized. This decarburization would probably have an unfavourable effect on the ballistic properties of the plate. Plate structures as revealed by the nital etch are of the type produced by austempering treatment, a

(Discussion of Results, cont'd) -

Microstructure, cont'd -

treatment which provides for transformation at elevated temperatures.

The difference in the structures of the large and medium plates and the plate that has been quenched and drawn is evident. The thin plate structure is similar to that of the quenched-and-drawn plate and it may have received a conventional heat treatment. It is probable, however, that all plates were given similar heat treatments (differences in section accounting for differences in structure) and the indications are that the heat treatment was not the conventional oil quench and draw.

We believe that austempered armour plate has considerable promise and have done a fair amount of work on the problem. Details of this work and a brief description of the austempering process are contained in our Investigation No. 1021, "Preliminary Report on Austempered Armour Plate," (May 28th, 1941).

Summary:

The investigation shows that the steel in the plate under examination is a well made 1060 carbon steel such as could be readily made by any competent steel maker. One of the samples submitted would be readily machineable. The other two plates, although heat treated to the optimum hardness for ballistic purposes, would be difficult to machine. One of these latter plates has been slightly decarburized in heat treatment. This might impair its ballistic properties. The indications are that the steels

(Summary, concluded) -

have been austempered rather than quenched and drawn.

Research work done in these laboratories and in United States arsenals indicates the following:

1. For light armour plate, ordinary commercial grades of steel are just as good as "special armour plate steels" providing they are properly heat-treated.

2. Austempered plate has ballistic properties superior to those of conventionally heat-treated plate.

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