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O T T A W A   May 26th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1412.

Examination of Ballistic Caps and Sheet Material.

(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

OTTAWA May 26th, 1943.

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Origin of Samples:

On May 15th, 1943, Mr. J. M. Gilmartin, for Inspector General, Inspection Board of the United Kingdom and Canada, 70 Lyon Street, Ottawa, Ontario, submitted (Analysis Requisition No. O.T. 3481) for examination four ballistic caps together with two pieces of sheet steel which were representative of the material from which the caps were formed.

Caps made from this type of steel (said to be SAE 1010) were reported to have performed satisfactorily in firing tests. The general specification for the part, however, requires that it conform with the tensile requirements of BSS 5007/215 steel which reportedly are 26 tons minimum ultimate tensile strength, 18 tons yield, and a bend of 180 degrees.

Object of Investigation:

Request was made for an examination to determine the tensile strength, chemical composition, and physical condition of the sheet material and possibly also of the finished caps.

Comments on whether or not rimmed steel, because of its ageing propensities, should be prohibited for this purpose were requested.

Chemical Analysis:

Samples for chemical analysis were removed from the sheet and a cap in a milling machine. They gave the following results:

		Sheet Material	Ballistic Cap
		- Per cent -	
Carbon	-	0.07	0.06
Manganese	-	0.32	0.34
Silicon	-	0.010	0.01
Sulphur	-	0.040	0.032
Phosphorus	-	0.016	0.015
Nickel	-	Not detected.	Not detected.
Chromium	-	0.02	Trace.
Molybdenum	-	Trace.	Not detected.

Chemical and spectrographic analyses of the samples indicated that aluminium was present in both of them.

Macro-Examination:

The appearance of cross-sections from the sheet and caps after they had been macro-etched in a hot 50 per cent aqueous solution of hydrochloric acid is shown in Figure 1.

Physical Examination:

Hardness tests (taken on a Vickers machine with a 10-kilogram load) on the sheet material and a finished cap gave the following results:

		Vickers hardness number
Sheet	-	88.4 - 90.4
Cap	-	185 - 209 (Nose of cap, 172)

(Continued on next page)

(Physical Examination, cont'd) -

Two standard sheet tensile specimens of 2-inch gauge length were removed from the sheet steel. These gave the following results at test:

		No. 1	No. 2
Ultimate stress, p.s.i.	-	46,640	47,280
Yield point (0.2 per cent proof stress), p.s.i.	-	29,400	29,000
Elongation in 2 inches, per cent	-	40	38.5

A $1\frac{1}{2}$-inch strip from the sheet material was bent double upon itself in a vise with no sign of cracking.

Two micro-tensile specimens from one of the finished caps had tensile strengths of 94,900 p.s.i. and 88,000 p.s.i.

Of three $\frac{1}{2}$-inch bend test specimens removed from the finished cap and bent double upon themselves in a vise, two passed the test and one opened up partially.

A cap was compressed in a vise until the inner edges of the larger end were 3/16 inch apart before the "click" of a crack was heard.

Tests for Ageing Susceptibility:

Strips from the sheet and cap were water-quenched from 1255° Fahrenheit. The following hardness readings were obtained:

		Vickers hardness number
As Quenched		
Sheet	-	122
Cap	-	133
After Air Ageing Three Days		
Sheet	-	191
Cap	-	175

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Microstructure:

Specimens for the microscope were removed and polished on faces approximately parallel to the long axes of the sheet and the ballistic cap. The carbide constituent of both samples was found to be spheroidal. This is shown, at 1000 diameters, in Figures 2 and 3.

Comparative Ageing Propensities of Various Types of Mild Steel:

Two of the conclusions reached by C. H. Herty, Jr. and B. N. Daniloff in "The Effect of Deoxidation on the Ageing of Mild Steels," (Cooperative Bulletin 66, Min. Met. Advisory Boards to Carnegie Inst. Tech. and Bur. Mines, Pittsburgh, 1934) are quoted:

> "The susceptibility of normalized rimmed steels to quench ageing is very high, the maximum being reached in steels containing 0.04 to 0.05 per cent carbon. In semi-killed steels this ageing is considerably less than in rimmed steels, and the susceptibility to this ageing shows the same general tendency to diminish with increasing carbon content. The silicon-killed steels quench-age considerably, but only about one-half as much as the rimmed steels."

> "Rimmed, semi-killed, and silicon-killed steels are very susceptible to strain ageing even in the higher carbon range. Aluminium-killed steels strain-age considerably less, the embrittling effect of the strain-ageing treatment decreasing with degree of deoxidation. There are indications that the degree of oxidation of steel in the furnace has a considerable bearing on the strain ageing of aluminium-killed steels."

Discussion of Results:

Chemical compositions of the sheet material and the ballistic caps conform to the specification requirements of SAE 1010 steel.

The macro-etch of the steel in the sheet and caps shows (as might be expected from their chemical compositions) that these parts are made from rimming steel.

The steel in the finished caps passed the tensile strength requirements of the specification but the sheet steel did not. This would seem to indicate that the failure of sheet

(Discussion of Results, cont'd) -

material to pass the tensile requi ements of the specification is of no great importance because its physical properties will be greatly changed when it is made into caps. Rather crude tests show that the strained-and-aged material in the caps was not brittle.

The rise in hardness of the sheet and caps after the subcritical water quench indicated that both were susceptible to quench ageing and, by inference, to strain ageing. The low hardness of the sheet material would seem to indicate that it was very slowly cooled, as this procedure eliminates, to a large extent, quench ageing.

The spheroidal condition of the carbide in the sheet and caps shows that they were either cooled very slowly through the spheroidizing range or else held for a long time at high subcritical temperature.

From the work of Herty and Daniloff, it is evident that rimmed steels are much more susceptible to quench ageing than other types. This would be of no importance, however, in material given the heat treatment received by the samples submitted, because the low hardness of the sheet steel seems to indicate that it was pre-(quench)aged. Also, rimming steels are seemingly not much different from other low carbon steels, except those strongly deoxidized with aluminium, with respect merely to the strain-ageing phenomena. In view of this, the reportedly satisfactory service performance of caps made from the type of steel submitted, and the rather ductile condition of the finished caps examined, no reason for prohibiting the use of rimming steel is seen.

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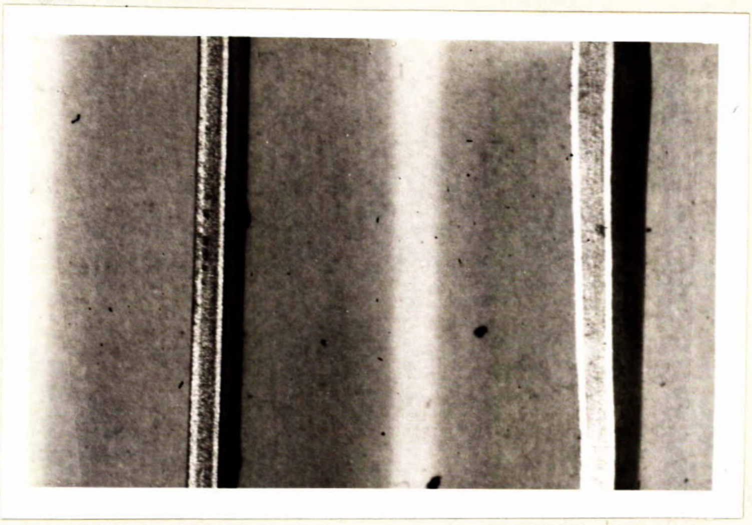
LPT:GHB.

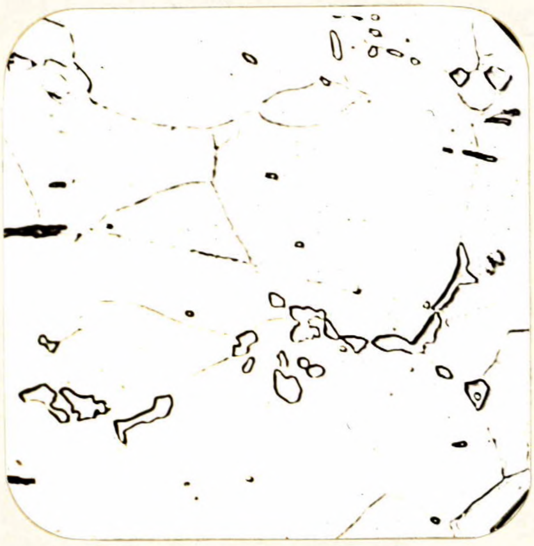
Figure 1.



Approximately X3, macro-etched.

SHEET ON LEFT. CAP AT RIGHT.

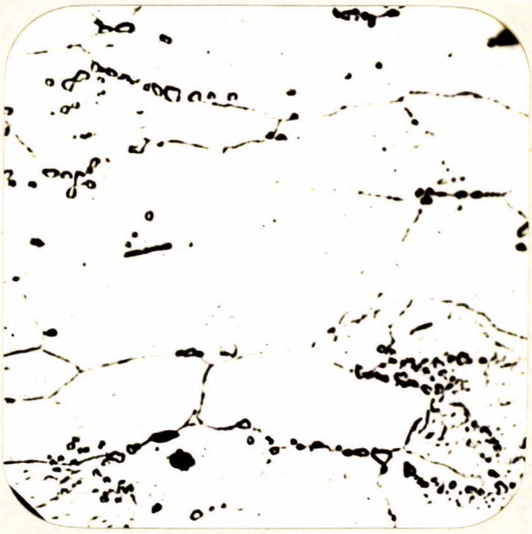
Figure 2.



X1000, unetched.

SHEET STEEL.

Figure 3.



X1000, unetched.

FINISHED CAP.

LPT:GHB.