OTTAWA July 30th, 1941.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1057.

Salvaging Austenitic Manganese Steel for Helmets.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

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METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Origin of Problem:

Tests carried out by the Inspection Board of the United Kingdom and Canada revealed that there were on hand approximately 50,000 blank sheets of austenitic manganese steel which would not pass the required tests for material to be used in making steel helmets. Mr. L. L. Price, general purchasing agent for the Department of Munitions and Supply, Ottawa, Ontario, in a letter dated June 10th, 1941, requested that the Bureau of Mines and Colonel R. A. H. Galbraith, of the Inspection Board of the United Kingdom and Canada, work together to develop, if possible, a salvaging process for the defective material.

Nature of Problem:

Previous experience has demonstrated the fact that there is a definite relation between the magnetic and ballistic properties of austenitic manganese steel helmets. Therefore, a standard magnet deflection test has been developed and is used as an acceptance test on the finished helmet. The 50,000 blanks referred to in this report were considered defective because of excessive magnetic properties. Investigations carried out by this laboratory have shown that magnetic properties are related to:

(a) Rolled-in scale and rough surface.

(b) Unstable austenite caused by low carbon and/or low manganese. 1.10 per cent carbon minimum and 12.0 per cent manganese minimum have been adopted in the specification.

(c) Severe decarburization.

CARBURIZING TREATMENT:

Rough surface, of course, cannot be changed. Decarburization, however, can be corrected by adding carbon to the surface of the metal and quenching from the proper temperature. With this idea in mind five of the most defective blanks were selected and treated in a cyanide bath for 45 minutes at 1800° F. and then quenched in oil. These blanks were sent to the General Steel Wares, Toronto, to be formed into helmets. Ballistic tests were carried out at 479 Bank Street, Ottawa.

The results of the complete examination of the helmets are given on the following pages.

Magnetic Deflection Tests: (Reported by G. Brackenbury, Inspection Board of the United Kingdom and Canada.)

MAGNETIC DEFLECTION, INCHES Helmet Identification Number® E	G	I	J	2B	Position	Side	Stage of Process
8.5	8.0	8.5	8.5	10.0	1	Rough	Blanks as received.
9.0	9.0	10.0	9.0	15.0	2	"	
8.0	6.0	10.0	7.5	7.5	3	"	
10.0	10.0	11.0	8.0	13.0	4	"	
7.0	6.5	6.0	10.0	10.0	1	Smooth	Blanks as received.
7.75	6.0	7.5	9.5	10.0	2	"	
7.0	6.5	6.5	9.0	7.5	3	"	
8.5	6.0	6.5	11.0	15.0	4	"	
0.5	2.0	8.0	2.0	7.0	1	Rough	Blanks after carburizing.
4.5	4.0	5.5	4.0	2.0	2	"	
1.0	6.25	7.0	6.25	8.0	3	"	
1.5	4.5	7.5	4.5	7.0	4	"	
1.0	3.5	3.0	3.5	5.0	1	Smooth	
3.5	4.5	2.5	4.5	1.75	2	"	
0.0	7.0	3.0	7.0	4.75	3	"	
1.0	5.25	6.0	5.25	6.5	4	"	
3.75	2.75	4.25	3.5	4.0	1		Helmets after forming, (all with smooth side out except Helmet I).
4.125	2.75	3.5	4.625	4.0	2		
2.875	2.875	5.75	4.25	6.5	3		
3.375	4.25	3.125	3.25	5.375	4		

® Above figures represent the number of inches a standard magnet was deflected when the steel was touched to it and slowly pulled away through a horizontal plane. The magnet was suspended from a seven-foot cord.

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Ballistic Tests:

Helmet No.	Ammunition	Position	BULGE Depth, inches	BULGE Dimensions, inches	Weight of Helmet, ounces
E	.44-40	End (a)	0.8125	3.25 x 3.3125	
	"	" (b)	0.8125	3.375 x 3.0625	23.0
	.45	Side (b)	1.0	3.875 x 3.125	
G	.44-40	End (a)	Bullet	pierced	
	"	End (b)	0.875	3.5 x 3.0625	24.0
	.45	Side (b)	1.1875	4.5 x 4.25	
	.45	" (b)	1.4375	4.5 x 4.75	
I	.44-40	End (a)	0.9375	3.375 x 3.125	
	"	End (b)	0.875	3.375 x 3.25	25.0
	.45	Side (b)	1.0	3.875 x 3.375	
J	.44-40	End (a)	0.875	3.4375x 3.125	
	"	End (b)	0.75	3.5 x 3.0	23.0
	.45	Side (b)	1.125	4.0 x 3.0625	
2B	.44-40	End (a)	0.8125	3.125 x 3.0	
	"	End (b)	0.75	3.125 x 3.25	23.5
	.45	Side (b)	1.25	4.1875x 4.25	

(a) Helmet struck at right angles.
(b) Bullet travels in a path parallel to the base of the helmet.

Comparison of Effects of Two Kinds of Ammunition.

The .45 calibre revolver bullet is a more severe ballistic test. 10 helmets were fired at with a .45 calibre revolver bullet at one end, and with a .44-40 Gamegetter ball at the other end. Average results were:

Ammunition	Average Depth of Bulge, inches	Average "Area" of Bulge,⊕ square inches
.45	1.11	13.6
.44-40	0.84	8.4

⊕ "Area" was taken as the product of two dimensions of the bulge, vertical and horizontal measurements being taken.

A report from England states that a fairly representative bulge measures 0.8 inch deep and 3.75 x 3.375 inches across. It is fired at right angles to the surface with an 0.5 inch round lead ball.

(Continued on next page)

(Ballistic Tests, cont'd) -

Complete information on charges, velocities, and other ballistic data is not included in this report. However, this may be obtained from Colonel R. A. H. Galbraith of the Inspection Board of the United Kingdom and Canada, 479 Bank Street, Ottawa, Ontario.

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Chemical Analysis:

	Helmet Designation.				
	E	G	I	J	2B
Carbon, per cent	0.99	0.94	1.22	0.99	1.15
Manganese, "	12.15	11.89	11.79	12.65	12.09
Silicon, "	0.15	0.30	0.14	0.13	0.12
Sulphur, "	0.011	0.011	0.013	0.018	0.016
Phosphorus, "	0.044	0.043	0.038	0.044	0.043

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Microstructure:

Typical structures were photographed to illustrate conditions found in the helmets. Figure 1 shows a normal structure resulting from the carburizing treatment. Helmet G has a rough, indented surface. Figure 3 illustrates what happens when carburizing time is too long. In this case the metal was made slightly magnetic, due to the presence of carbides at the surface.

(Figures follow on page 6)

(Microstructure, cont'd) -

Figure 1.

X500, nital etch.
HELMET (E).
Normal Structure.

Figure 2.

X500, nital etch.
HELMET (G).
Sharp Jagged Cavity.

Figure 3.

X500, nital etch.
HELMET (I).
Carbides Due To Over Carburizing.

DISCUSSION:

Carbon can be added to the surface of the metal by any of the following four processes:

(1) Liquid carburizing.

(2) Gas carburizing.

(3) Pack carburizing, using solid carburizer.

(4) Carburizing paint.

The process used will depend upon equipment available for the job. Liquid carburizing was done in the experimental work because equipment was readily available. In mass production, cyanide baths may prove difficult to operate at 1800° F., due to the rapid decomposition of the bath, also some salt would be dragged out of the bath with the work.

Gas carburizing is less costly and easier to operate, providing a suitable furnace is available. Natural gas may be used providing no moisture is present and the hydrogen content kept low.

Pack carburizing, using solid carburizing compounds, involves a serious difficulty in that the work must be removed from the box and quenched before its temperature falls below 1800° F.

Another method occasionally used to add a small case to metal parts is to coat the sheet with a cyanide paint or a graphite paint. On heating to 1800° F. the coating will carburize the metal, providing a neutral or slightly carburizing atmosphere is maintained in the furnace.

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(Discussion, cont'd) -

In all cases the blank sheets must be quenched in oil or water from a temperature well in excess of 1800° F. Time of carburizing will depend upon the condition of the plate and the speed of carbon absorption. Magnet tests will show what length of time produces the best results. Overcarburizing will result in an increase in magnetism, coupled with the carbide structure shown in Figure 3.

Magnetic and Other Tests.

Investigation No. 1007, after correlating data on helmets, concludes:

"The helmets examined which have acceptable ballistic properties[⊕] also have the following properties:

(a) Magnet deflection of less than 7 inches.[⊕]

(b) Smooth surface.

(c) Carbon content, 1.10 per cent minimum.

(d) Manganese content, 12.0 per cent minimum.

(e) Austenitic, fine-grained microstructure."

In these experiments, magnet deflection has been reduced by raising the carbon content of the sheets. This practice will salvage sheets which are defective solely due to decarburization.

Rough Surface.

Micro-examination of rough sheets (see Investigation No. 1007) has shown that jagged irregular indentations serrate the surface. This condition has been proved responsible for low impact strength in structural members.

(Continued on next page)

⊕ Testing procedure developed and carried out by I. B. U. K. & C., 479 Bank Street, Ottawa.

(Discussion, cont'd) -

A rough-surfaced helmet, therefore, offers less protection than a smooth helmet. It is considered advisable, therefore, that some standard of surface finish be maintained in the helmet steel. Colonel Galbraith has suggested that a profileometer be used to check the quality of surface finish on the sheet. This instrument would give far more accurate evaluation of surface condition than can be obtained by visual or manual inspection methods. If high-quality helmets are to be produced, surface finish must be closely watched.

Chemical Analysis.

The helmet which had carbides present in the surface was the highest in carbon content. The lowest carbon content was found in the helmet which allowed a bullet to pierce it. Decarburized metal does not have the same chemical and physical properties throughout its cross-section, and in the case of austenitic manganese steel a weak, brittle skin is formed on the metal. It is obvious that a chemical analysis will not always detect decarburization, but in steel containing above 1.10 per cent carbon it has been demonstrated that ordinary decarburization does not lower the ballistic properties of helmets appreciably. Below 1.10 per cent carbon, ordinary decarburization results in a decomposition of the austenite with a great loss of projectile penetration resistance.

The five samples analysed do not meet the required chemical specifications now set up (carbon 1.10 per cent minimum, manganese 12.0 per cent minimum). However, by restoring the surface of these helmets back to the austenitic form good ballistic properties have been obtained.

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(Discussion, cont'd) -

Magnet tests, rather than chemical tests, will have to be used to determine when carburizing treatment has proceeded to the point where maximum ballistic properties are obtained.

CONCLUSIONS:

1. Decarburized austenitic manganese sheet can be reclaimed by a simple carburizing treatment.

2. Rough surfaced sheet is a source of helmet failure; therefore, surface condition should be closely watched.

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