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O T T A W A July 27th, 1942.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1274.

Examination of Defective 6-Pdr.
Mark III Breech Block 457.

(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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Source of Material and Object of Investigation:

On June 11th, 1942, these laboratories received a defective 6-Pdr. Mark III Breech Block 457 for examination. This block was accompanied by Analysis Requisition No. O.T. 3039, issued by the Materials Division of the Inspection Board of the United Kingdom and Canada, and also by a letter (file No. 7/4/22, cc: 4/4/344/CD.LV.283/6 and 4/6/O/1) dated June 11th, 1942, and signed by M. W. Hollands, for the Inspector

(Source of Material and Object of Investigation, cont'd) -

General, Inspection Board of the United Kingdom and Canada, 58 Lyon Street, Ottawa, Ontario. This letter is quoted below:

"Dear Sirs:

Re: Defective 6 Pdr., Mk. III. Breech Block 457.

I am forwarding to you by hand a breech block which has developed a defect during proof trials. In the forward face of this block is seated a bushing through which the firing pin mechanism operates. During firing this bushing has set back into the block some two or three thousandths of an inch.

The method of assembling this portion of the mechanism is to screw the bushing into position to test the fitting and seating in the block proper. This is done by means of a lug on the face of the bushing, which is subsequently cut off after final assembly. All surfaces of the block and the seat in the block are coated with pattern-maker's ink so that any irregularities or errors in machining, which prevent proper seating of the bushing, are forthwith detected. This procedure is followed on each and every block, so that the set developed in the block which is being sent to you does not reasonably appear to have resulted through machining errors.

It is, therefore, suspected that this set-back is due to the steel in the breech block being too soft. In order to check this point, it is requested that you cut off one block (about one inch thick) from the square section in which the bushing is seated. It is then desired that you cut the square block thus obtained at right angles (not along the diagonals) so that the closeness of fit between the bushing and the block can be examined in detail. It is also desired that Vickers or Rockwell hardness determinations be made along the faces of such cuts to determine the homogenity of the hardness and thereby obtain perhaps an indication as to the effectiveness of heat treatment of the breech block forging.

It is also requested that two full sets of tensile test pieces be cut from this breech block; one set along the narrow dimension and parallel to the forward face, and one set taken in the longitudinal direction of this gun component. For your information, the breech block is made from S40 "D" nickel steel and has been heat treated completely in accordance with that specification.

The Requisition number for this investigation will be O.T. 3039.

Yours faithfully,

(Signed) M. W. Hollands

for Inspector-General."

(Source of Material and Object of Investigation, cont'd) -

The investigation of this breech block was carried out along the general lines outlined in the above letter.

Macro Examination:

Figure 1 is a view of the breech block as received, showing the bushing through which the firing pin mechanism works.

A section was cut out of the breech block where the bushing was inserted and the fit of the bushing was examined. It appeared to be a good fit. This section is shown in Figure 2.

Physical Tests:

Two tensile bars were obtained from the block, one in the longitudinal direction and one along the narrow dimension. The results are given in Table I.

Table I. - Physical Tests.

	Spec. S40, "D" Steel	Longitudinal	Transverse
Ultimate tensile, p.s.i. -	93,000-123,400	96,000	95,700
Yield strength, p.s.i. -	60,500 min.	73,000	70,000
Reduction in area, per cent -	Not specified	52	38.4
Elongation, per cent -	16 min.	23*	24*
Brinell hardness number -		196	

* Diameter of longitudinal bar, 0.505". Elongation given on 2" gauge length. Diameter of transverse bar, 0.279". Elongation given on 1" gauge length.

The Brinell value was determined on the section shown in Figure 2.

Chemical Analysis:

The chemical analysis of the steel in the breech block is reported in Table II.

Table II. Chemical Analysis.

		S40, "D" Steel, per cent	Obtained, per cent
Carbon	-	0.40 max.	0.31
Manganese	-	0.50 - 0.85	0.75
Silicon	-	0.05 - 0.30	0.44
Sulphur	-	0.05 max.	0.017
Phosphorus	-	0.04 max.	0.010
Nickel	-	3.0 min.	3.19
Chromium	-	0.25 max.	0.24
Molybdenum	-	0.10 max.	0.076

Microscopic Examination:

A section was taken about half an inch below the surface of the block for microscopic examination. A photomicrograph showing the structure of the steel at magnification of 1000 diameters is shown in Figure 3. Note the large amount of ferrite present.

Heat Treatment Tests:

The heat treatment as specified in the Specification S40 for "D" steel is an oil quench from a temperature not lower than 1550° F. followed by a draw at a temperature not higher than 1220° F. Apparently, from Figure 3, the block in question had not been cooled fast enough on the quench to suppress the formation of ferrite.

A piece 1½" x 1¾" x 6" was cut out of the block and given the following heat treatment:

1. Heat to 1550° F., soak for 2 hours, oil quench.
2. Temper at 1200° F. for 2 hours and oil quench.

(Continued on next page)

(Heat Treatment Tests, cont'd) -

After this treatment the Brinell hardness on the outside was 248 and at the inside, 223.

Figure 4 shows the microstructure of the steel at the centre of this piece at 1000 diameters magnification. Note that there is still a little ferrite present but less than in original. It is estimated that the cooling rate at the centre of this piece at 1300° F. would be about 28 fahrenheit degrees per second.

The remainder of the breech block was heat-treated next. To measure this cooling rate a thermocouple was welded on half an inch below the surface. The block was heated to 1500° F. very slowly, soaked for one hour, quenched to below 800° F. in water, and then transferred to oil. It was removed from the oil at 250° F. The resulting cooling curve is shown in Figure 5. From this curve, the cooling rate of this block at 1300° F. would be about 50 fahrenheit degrees per second, ½ inch below the surface.

The block was then drawn at 800° F. A tensile bar, a 0.45" diam. izod impact bar, and a specimen for the microscope were cut out. Hardness values were also obtained. A section from the block was then tempered again at 1200° F. and another 0.45" diam. izod bar obtained. The results of the physical tests are given in Table III.

Table III. - Physical Tests after Heat Treatment.

	Spec.	Draw, 800° F.	Draw, 1200° F.
Tensile strength, p.s.i.	- 93,000-123,000	152,200	
Yield strength, p.s.i.	- 60,500 min.	140,400	
Elongation, per cent	- 16 min.	12.5	
Reduction in area, per cent	- Not specified	38.5	
Izod impact, foot pounds	- 20	29	59
Brinell hardness number	-	293	235

(Heat Treatment Tests, cont'd) -

Figure 6 gives the microstructure at 1000 diameters one inch below the surface. Compare with Figure 4.

A McQuaid - Ehn test was conducted to determine the austenitic grain size at 1700° F. The result is shown in Figure 7. The grain size is mixed, 30 per cent No. 3 and 70 per cent No. 6.

Discussion of Results:

It will be noted that the steel in the block under examination complies with both the chemical and physical specifications as outlined in Specification S40 for "D" steel. However, the steel is quite soft and there is a large amount of ferrite present. The steel in this condition was probably not strong enough in bearing to resist the compressive forces transmitted to it through the bushing insert. This could be remedied by increasing the bearing area between the bushing and the block, if possible.

The heat treatment tests outlined above were conducted in an effort to determine whether or not it would be possible to suppress the formation of ferrite. It will be noted, in the first test on the $1\frac{1}{2}$" x $1\frac{1}{2}$" piece, that the formation of ferrite was almost entirely suppressed. The cooling rate at 1300° F. in this piece was estimated to be 28 fahrenheit degrees per second. This would indicate that a cooling rate of this order would be necessary.

On the subsequent heat treatment of the block, by quenching from 1500° F. to 800° F. in water and from then on in oil, a cooling rate of 50 fahrenheit degrees per second was obtained $\frac{1}{2}$ inch below the surface. The microstructure at

(Discussion of Results, cont'd) -

a distance of one inch below the surface (Figure 6) shows that even at this point the cooling has been rapid enough to suppress most of the ferrite.

Given this quenching treatment followed by a suitable drawing temperature, for example 1200° F., the compressive strength of this steel should be greatly improved over the compressive strength it possessed in the condition in which it was received. This should enable it to better support the firing pin bushing in service.

In explanation of the reasoning behind this heat treatment, ferrite will be formed if the austenite is allowed to transform at a temperature in the neighbourhood of 1000° F. The greater the length of time the steel takes to cool through this range, the more ferrite is formed. The ideal condition would be to cool from the quenching temperature to below the temperature range in which ferrite is formed, rapidly enough that no ferrite will have a chance to form.

In a relatively massive piece such as the breech block in question, it was evident that oil quenching did not provide a sufficiently rapid cooling rate. Therefore, water quenching was indicated, but this increased the hazard from quenching cracks. These quenching cracks are formed in the temperature range below 800° F. So a combination water quench to 800° F., followed by an oil quench from 800° F. down, would appear to be the answer. No cracks were found in the block so treated and an improved structure was developed.

It took about 25 seconds for the block to reach 800° F. in the water quench. From the cooling curve, Figure 5, a practical quenching cycle would be 25 seconds in water, then transfer to oil and hold in the oil for about 3½ minutes.

Conclusions:

1. The steel met all requirements of Specification S40, "D" steel, in the condition in which it was received at these laboratories.

2. The bushing appeared to be a good fit.

3. The compressive strength of the steel was not sufficient to support the firing pin bushing in firing.

Recommendations:

The compressive strength of the steel could be improved by adopting the following heat treatment:

(a) Heat to 1550° F.

(b) Quench in water to below 800° F. (requires from 25 to 30 seconds).

(c) Transfer immediately to oil and hold until temperature has reached 250° - 300° F. (requires about three and a half minutes).

(d) Draw at a suitable temperature to produce desirable impact and tensile properties (say 1200° F.).

This heat treatment would lose much of its effectiveness if it were carried out on the solid forging from which the breech block were machined. The forging should be normalized after forging, the machining operations nearly completed, and then the heat treatment performed. Otherwise, the mass of metal in the rough forging would slow up the cooling rate in the quench and permit the formation of more ferrite.

These recommendations presuppose that it is not possible or practical to change the material specification or to change the design.

The trouble could be eliminated by increasing the bearing area between the bushing and block, thereby distributing the compressive stresses over a larger area, if such a

(Recommendations, cont'd) -

change in design is possible.

If this change of design is not practical and it is not desired to change the heat treatment cycle now employed, it will be necessary to employ a deeper hardening steel, such as SAE 4335.

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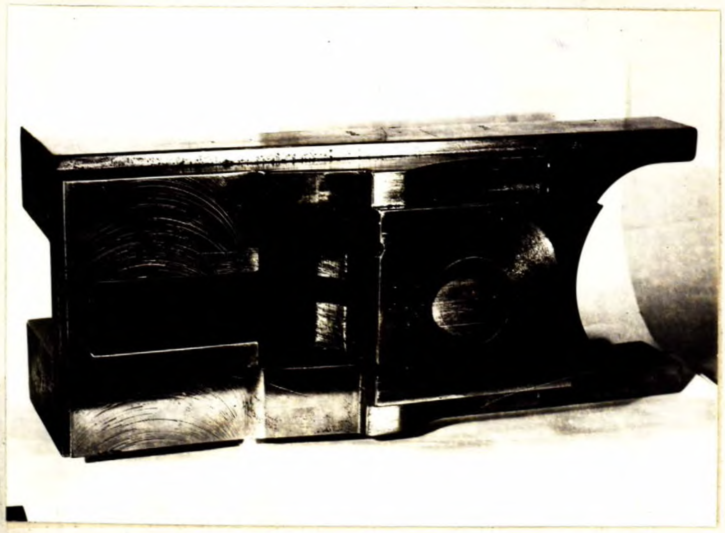
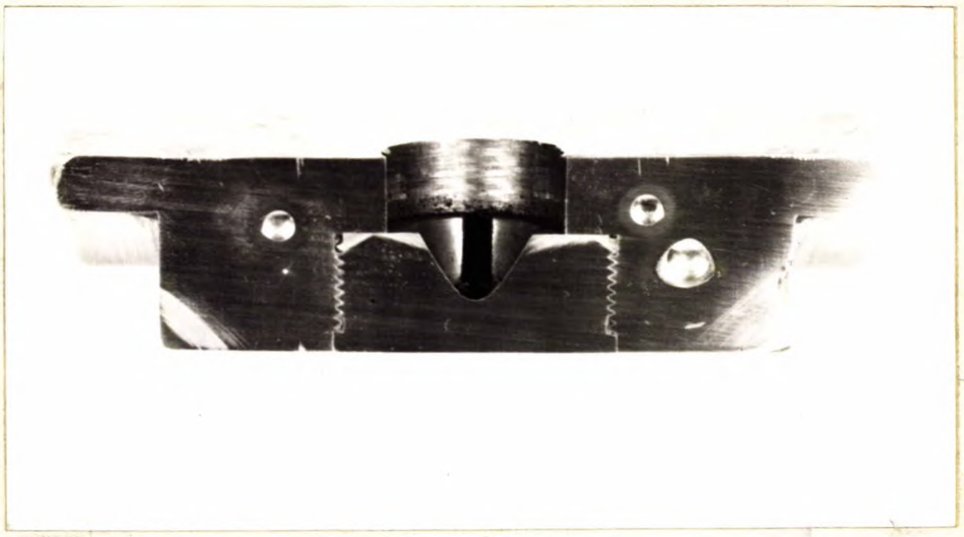
HVK:GHB.

Figure 1.



Photograph of Breech Block.
(About ½ actual size).

Figure 2.



Section cut to show fitting of bushing.
(Photograph at actual size).

Figure 3.

Photomicrograph, X1000.
Electro polish, picral etch.

STRUCTURE OF STEEL AS RECEIVED.

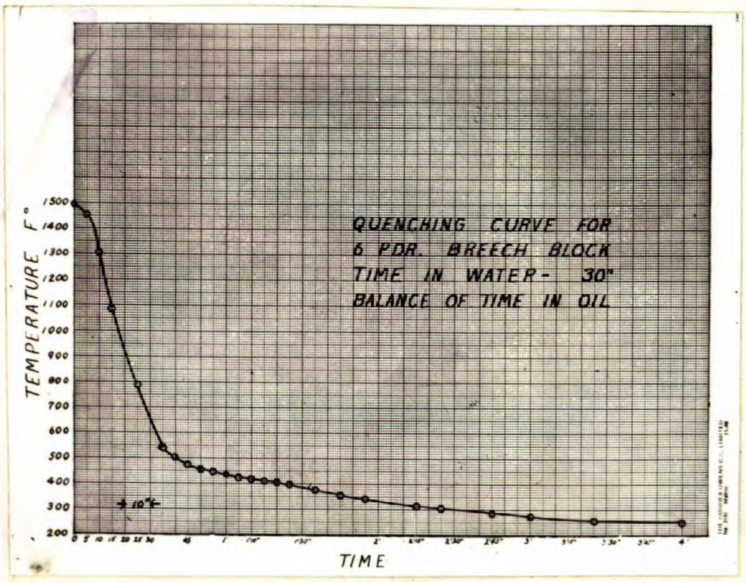
Note large amount of ferrite.

Figure 4.

Photomicrograph, X1000.
Electro polish, picral etch.

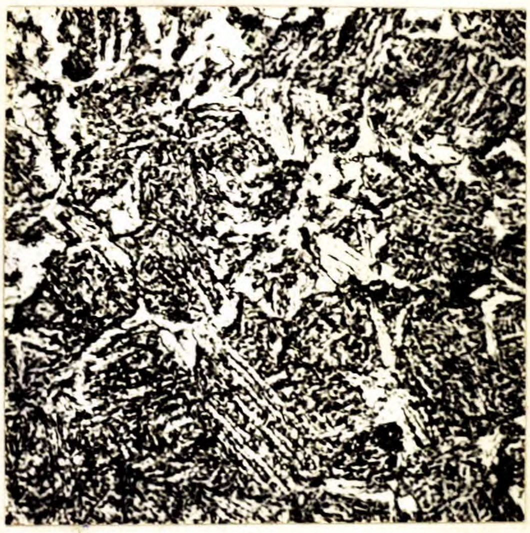
Structure in section $1\frac{3}{4}''$ x $1\frac{1}{2}''$ after oil quench from 1550° F. and draw from 1200° F.

Figure 5.



Cooling curve of metal, $\frac{1}{2}$ inch below surface of breech block during controlled quench in water and oil.

Figure 6.

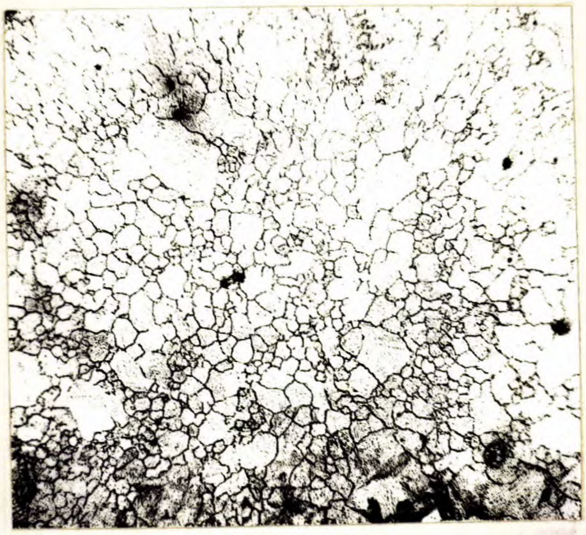


Photomicrograph, X1000.
Electro polish, picral etch.

Structure 1 inch below surface, resulting from controlled quench from 1500° F. and draw at 800° F.

Note small amount of ferrite present. Compare with Figure 4.

Figure 7.



Photomicrograph, X1000.
Electro polish and relief etch.

MCQUAID-EHN GRAIN SIZE.

30% No. 3 and 70% No. 6.

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HVK:GHB.