OTTAWA September 2nd, 1942.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1288.

(Subsequent to Investigation No. 1274, dated July 27th, 1942.)

Some Experimental Heat Treatments of 6-Pdr. Breech Block Forgings.

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Origin of Material and Object of Investigation:

Subsequent to our Report of Investigation No. 1274 (July, 1942), on the examination of a defective 6-Pdr. Mark III breech block No. 457, nine (9) tensile test bars were submitted to this laboratory by the Inspection Board of the United Kingdom and Canada, 70 Lyon Street, Ottawa, Ontario, for tensile tests and microscopic examination. These bars were accompanied by letter, file No. 4/4/344/CDLV-283/6-c.c. 4/6/0/1, dated August 27th, 1942, and signed by Mr. M. W. Hollands, for Inspector General. This letter is

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

quoted below and the chart accompanying it is reproduced in Figure 1. The work requested was covered by Analysis Requisition No. O.T. 3191.

"Gentlemen:

re: Experimental Heat Treatment,
6 Pdr. Breech Blocks

Further to our telephone conversation of this morning, I have sent under separate cover nine test pieces provided by Dominion Bridge Co. and taken from experimentally heat-treated 6 Pdr. Breech Blocks being produced in their plant.

It is requested, please, that you pull these test pieces to determine the tensile properties of the steel. In addition I would like to have a section cut from one end of each of the test specimens and a micrographic examination of the structure made. The sections should be cut from those ends of the specimens which bear the stamping and identification numbers inasmuch as these ends are farthest removed from the original outside surface of the heat-treated forgings.

Specimens Nos. 1 to 8 inclusive have been double-quenched from the temperatures indicated on the attached information sheet. Specimen No. 9 will probably have different properties and structure than the other eight samples, for the block from which it was taken was given a regular single quench treatment and was heat-treated after parting off from the forging string.

It will probably be necessary to carry out further machining on several of the test specimens inasmuch as there is some heavy scoring and also several visible surface defects in the test length of the specimens.

It is requested that this work be rushed as much as possible, please, and I would appreciate receiving your telephoned advice at the earliest possible moment.

Yours faithfully,

(Signed) M. W. Hollands
for Inspector-General."

(Continued on next page)

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

Figure 1.

Photograph of chart accompanying the request letter.

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Physical Tests:

All bars received were first turned down to 0.505" diam. and threaded to fit the grip of the tensile machine. The bars as received were 0.564" diam. but some had rather deep tool marks and it was considered advisable to remove them. Furthermore, the original test bar used for Report No. 1274 was 0.505" diameter. The results of these tests are given below:

(Continued on next page)

(Physical Tests, cont'd) -

Summary of Tensile Test Results.

Bar No.	Ultimate tensile strength, p.s.i.	0.1 per cent proof stress, p.s.i.	Elongation in 2 inches, per cent	Reduction in area, per cent	Heat treatment (Degrees Fahrenheit)		
					1st Quench	2nd Quench	Draw
1	103,600	78,380*	14	39.7	1540		1000
2	110,100	84,800	22	51.3	1540		1000
3	114,000	87,600	11	21.7	1540		1000
4	112,600	89,800	7	9.3	1540		1000
5	105,800	78,700	19	36.5	1650	1540	1100
6	113,300	83,700	20	41.7	1650	1540	1100
7	113,350	83,900	19	45.0	1650	1540	1100
8	116,600	88,900	18	39.4	1650	1540	1100
9**	117,050	89,750	18	40.5	1540		1000

* Drop of beam.

** Single block parted from string before heat treatment.

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Microscopic Examination:

Specimens for the microscope were cut from the end of each test bar. Photomicrographs were taken of the structure of the metal in Bars Nos. 3, 6 and 9 at a magnification of 1000 diameters. The specimens were etched in 4 per cent picral. These photomicrographs are shown in Figures 3, 4 and 5, respectively, and are characteristic of the structure of the metal in all these bars. Figure 2 is a photomicrograph of the structure in the original breech block examined in Report of Investigation No. 1274, also taken at 1000 diameters.

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Discussion of Results:

It will be noted that the double quenching treatment did improve the ductility of the metal. However, this is not the desired result in this case, for, as is pointed out in our Investigation Report No. 1274, it is desirable to increase the support given the firing pin bushing by the breech block. This can be done either by increasing the bearing area between the bushing and the block or by increasing the compressive strength of the metal.

The compressive strength of the metal would naturally be increased if the formation of ferrite on quenching were to be suppressed. This could be accomplished, as explained on Pages 6 and 7 of Investigation No. 1274, by increasing the cooling rate in the neighbourhood of 1000° F. Whether ferrite will form or not depends on the relationship between the cooling rate and the rate of transformation. If the cooling rate is slower than the transformation rate in the neighbourhood of 1000° F., ferrite will form. If the cooling rate is faster than the transformation rate in the neighbourhood of 1000° F., no ferrite will form.

The transformation rate of any given steel cooling from any given temperature above its critical range is a constant characteristic of that steel and cannot be altered by multiple quenching.

The problem, therefore, resolves itself into one of getting rid of heat as rapidly as possible.

It is understood that the present practice is to forge a billet or stringer of such size and shape that four breech blocks can be made from it. This stringer is then fully heat treated previous to any machining operations. This heat treatment consists of an oil quench from 1540° F., followed by a draw at from 1000° F. to 1200° F.

(Continued on next page)

(Discussion of Results, cont'd) -

Such a stringer would probably weigh about 375 pounds and would be about 18" x 12" x 6" in size. From the point of view of heat dissipation, the quenching should be four times as effective if the stringer has been quartered before heat treatment. Provided a good grade of quenching oil were used and proper quenching practice employed, this would be expected to give an improvement in results. The fact that it did not (see Test Bar No. 9 and Figure 5) would mean one or more of the following:

(a) The hardenability of the steel is too low to respond to this slightly faster cooling rate.

(b) That the quality of the quenching oil is poor.

(c) That the quenching practice could be improved.

A good quenching oil should be quite fluid even at room temperature, and should not thicken upon use. If it becomes heavy and viscous it will not circulate properly and therefore will not carry the heat away from the metal being quenched. It is also necessary that the volume of oil, the means of cooling, and the means of circulation or agitation, all be such that there is always an adequate volume of cool oil flowing past the metal being quenched to effectively remove its heat. The oil temperature should not rise above about 150° - 170° F.

A second alternative improvement to aid in the dissipation of heat would be to quarter each stringer and do all the rough machine work on each breech block either as forged or normalized. Each finished breech block weighs about 40 pounds. A roughly machined block might weigh 45 or 50 pounds. Here we have several advantages:

(Continued on next page)

(Discussion of Results, cont'd) -

1. The machinability in the forged or normalized condition is better than in the heat-treated condition.

2. The amount of heat used in heat treating the breech blocks is cut in half, since about half of the metal in the original stringer has been cut away.

3. In quenching one semi-finished breech block, only 1/8 of the amount of heat contained in a full stringer has to be dissipated. This means that the quenching is eight times as effective.

Again, the full advantage of this method will not be realized if the quenching oil is heavy and viscous, if the oil is not kept cool, and if suitable agitation or circulation is not provided.

If the improvement in structure to be realized by this method is not adequate there are two other alternatives. There is available an oil that forms an emulsion with water. It is claimed that this emulsion will give a quenching rate equivalent to that of water in the upper temperature range and a slow cooling rate in the low temperature range. Quenching the semi-finished breech blocks in such an emulsion should yield improved results. Alternatively, the quenching technique outlined in our Report of Investigation No. 1274 could be considered. This consists of quenching into water and transferring into oil when the temperature has dropped to 800° F. This last method, while effective, is rather complicated and should only be considered as a last resort.

It has been brought to the writer's attention that the direction of the forging lines could also have an influence on the ability of the breech block to support the firing pin bushing. At present it is understood that the forging lines are perpendicular to the face in which this bushing is set. The thread supporting the bushing would be strengthened somewhat if the direction of forging were parallel to this face.

Conclusions:

The tests, carried out at the request of the Inspection Board of the United Kingdom and Canada, have demonstrated that the multiple quenching treatment, such as was used in this case, will not alter the rate of transformation from the final quenching temperature.

It is therefore evident that the suppression of the formation of ferrite can not be effected by such an angle of attack.

The only method of attack is to increase the cooling rate, and several suggested methods of accomplishing this are outlined in the above discussion.

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Figure 2.

Photomicrograph, X1000, electro polish, picral etch.

STRUCTURE OF STEEL IN ORIGINAL BLOCK REPORTED ON IN REPORT OF INVESTIGATION NO. 1274.

Figure 3.

Photomicrograph, X1000, electro polish, picral etch.

STRUCTURE OF STEEL IN TEST NO. 3.

Figure 4.

Photomicrograph, X1000, electro polish, picral etch.

STRUCTURE OF STEEL IN TEST NO. 6.

Figure 5.

Photomicrograph, X1000, electro polish, picral etch.

STRUCTURE OF STEEL IN TEST NO. 9.

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