O T T A W A      March 4th, 1942.

<u>R E P O R T</u>

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1171.

Examination of a Cracked Spigot on the Barrel
of a 3-Inch Trench Mortar.

(Copy No. 1 .)

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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Origin of Request and Object of Investigation:

On February 21st, 1942, a 3-in. trench mortar barrel was received from Mr. H. H. Scotland, of The Inspection Board of the United Kingdom and Canada, 58 Lyon Street, Ottawa. The spigot (see Figure 2) was cracked at the base of the threads.

The barrel was accompanied by Analysis Requisition No. O. T. 128, requesting that it should be ascertained whether or not the metal was at fault.

Macro-Examination:

Figure 1 shows the barrel submitted for examination. Figure 2 is a "close-up" of the cracked end, showing the nature and position of the crack.

The spigot end was cut off and slit. One half was etched in 38 per cent HCl, 12 per cent $H_2SO_4$ for 2 hours, to develop the forging pattern. This is shown in Figure 3.

Figure 4 shows a portion of the fractured surface. It would seem that this crack was developing for some time.

Figure 5 is a macrophotograph, taken at 40 diameters, showing a crack developing at the base of a thread. This is taken on the side of the spigot opposite to where the actual failure occurred.

Chemical Analysis:

The chemical analysis of the steel and the chemical specifications are given in Table I:

Table I.

Comparison of Actual and Specified Analyses.

| | OBTAINED (Per cent) | SPECIFIED |
|---|---|---|
| Carbon | 0.49 | 0.3-0.4 |
| Manganese | 0.69 | 0.2-0.85 |
| Silicon | 0.29 | 0.05-0.2 |
| Phosphorus | 0.034 | 0.06 max. |
| Sulphur | 0.044 | 0.06 " |

Physical Examination:

The physical properties of the metal in the forged section of the barrel were determined by means of the tensometer. Tensile test bars were obtained from the shoulder of the forged end. One of these broken bars

(Physical Examination, cont'd) -

is shown in Figure 6. In Table II the values obtained are compared with the specifications:

Table II.

Summary of Physical Test Data.

| | No. 1. | No. 2. | Average | Spec. |
|---|---|---|---|---|
| Ultimate tensile strength, tons/sq.in. | 46.5 | 44.4 | 45.5 | 34-49 |
| Yield strength, tons per sq. in. | 26.5 | 25.9 | 26.2 | 19 minimum |
| Elongation, per cent | 17.9 | 20.0 | 19.0 | 17 " |
| Reduction in area, per cent | 45.0 | 47.3 | 46.6 | ——— |

Vickers hardness values were determined in various portions of the barrel. The results are given in Table III.

Table III.

Vickers Hardness Tests, 10-Kilogram Load.

| | | |
|---|---|---|
| In unforged portion | - | 202 |
| From part where test bar was taken | - | 218 |
| From base of threaded section | - | 227 |

At attempt was made to obtain some sort of impact value for this material. The largest bar that could be obtained was 3/16 inch in diameter. A notch 0.054 inch deep was cut in this bar. A similar bar was prepared from a piece of steel having a known izod impact value of 70 foot pounds on a standard bar 0.45 inch in diameter and

(Physical Examination, cont'd) -

having a notch 0.13 inch deep. The dimensions of the small bar were chosen so that

$$\frac{d}{n} = \frac{D}{N}$$

where d = diameter of small bar,
D = " " large " ,
n = notch depth of small bar, and
N = " " " large " .

The values obtained are as follows:

| | | |
|---|---|---|
| Trench mortar steel | - | 6.5 foot pounds. |
| Standard steel | - | 4 foot pounds. |

Microscopic Examination:

Specimens for microscopic examination were obtained from both the forged and the untreated portions of the barrel. Figure 7 is a photomicrograph of the forged metal at 100 diameters, picral etch, and Figure 8 is one of the untreated metal at 100 diameters, picral etch. Note the similarity of structure.

Discussion of Results:

The crack is the type of failure one would expect from impact, occurring as it does at the root of a thread. It would appear from Figure 4 that the crack developed over a period of time, probably indicating fatigue impact failure. The staining on the cracked surface might be due to some other cause, however.

It is evident, from Figure 5, that cracks have commenced to develop all around the circumference of the spigot, since this area is opposite the visible failure. This condition could be caused by tensile impact stresses which could originate in the firing of the gun.

The tensile tests show that the material complies

(Discussion of Results, cont'd) -

with the physical specifications for "T" steel. The carbon and silicon are a little high but should not be a source of trouble.

Reference is here made to a paper by D. S. Clark and G. Datwyler, of the California Institute of Technology, entitled "Stress Strain Relations under Tension Impact Loading" and published in the Symposium on Impact Testing presented at the 41st Annual Meeting of the American Society for Testing Materials, June 28th, 1938. On page 105, in item 2, under Summary, the following appears:

> "The dynamic force-elongation diagrams for several materials have been determined and compared with static diagrams of the same materials. In most cases, it has been found that the yield and maximum forces are higher with dynamic loading than with static loading."

This would indicate that the steel in the trench mortar barrel under investigation should be expected to have a yield strength of at least 26.2 tons per square inch and an ultimate tensile strength of 45.5 tons per square inch under dynamic loading.

Should the chamber pressure on firing generate stresses approaching the static yield strength of the metal in the spigot it would be only natural for this metal to fail after relatively few rounds had been fired. For safe operation with this type of steel, a designing strength well below the yield strength of the material should be used, to enable the part to stand up under repeated stresses.

The macro etching indicates good forging practice. This is also confirmed by both the microscopic examination and the physical tests.

It is rather difficult to say just what significance, (Discussion of Results, cont'd) -

if any, should be attached to the transverse impact tests. Standard specimens were not used. On Page 318 of "Mechanical Testing", Vol. 1, by R. G. Batson and J. H. Hyde of the National Physical Laboratory, Teddington, England, it is stated that there is no fixed relationship between the impact values obtained on large and small bars. This book is published by Chapman & Hall, Ltd., London, England. Qualitatively speaking, these tests would indicate that the steel is tough and not unduly notch-sensitive when subjected to transverse stresses. It should be borne in mind, that the stresses in the case at hand are tensile, not transverse.

It should also be pointed out that it was not possible to make any of these tests, except hardness and microscopic, in the actual location of failure. The metal was slightly harder at the base of the spigot than where the tensile bar was obtained (227 Vickers vs. 218 Vickers). There was a wider spread in hardness between this and the transverse impact test (227 Vickers vs. 208 Vickers). However, in hardnesses of this order such variations are not significant.

Conclusions:

1. The metal meets physical specifications for "T" steel.

2. The carbon and silicon contents are off specification.

3. The forging practice is good.

4. The crack could have been caused by repeated

(Conclusions, cont'd) -

tensile impact stresses from firing.

5. The steel does not appear to be unduly brittle or notch-sensitive.

Recommendations:

1. The intensity of stresses generated in the spigot metal by firing should be determined. If these stresses approach the minimum specified yield strength they are too high and the barrel should be redesigned.

2. Care should be taken that the base of the thread be not absolutely sharp. It should have a slight radius. This point is fully as important as is proper design, since sharp angles or notches can cause a concentration of stresses that may cause an otherwise properly designed section to fail.

3. Should the concentration of stresses be too high and redesigning not practical, a stronger material would be indicated.

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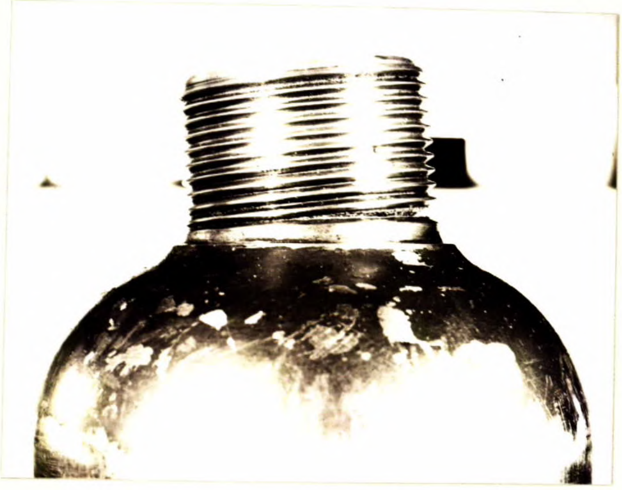
Figure 1.

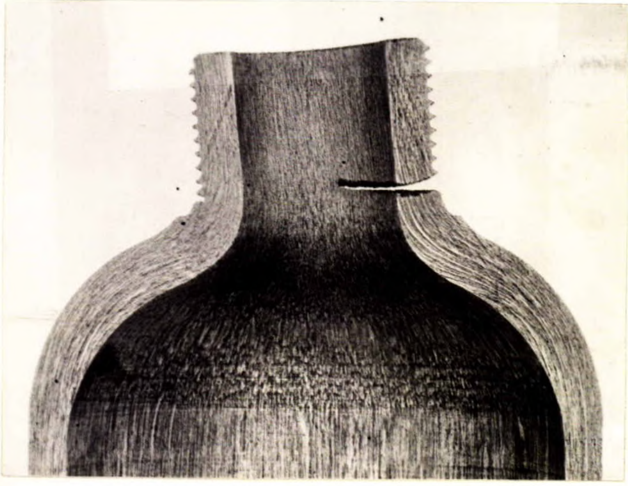
3-in. Trench Mortar Barrel, 1/10 size.

Figure 2.



Photograph showing crack in spigot. Natural size.

Figure 3.

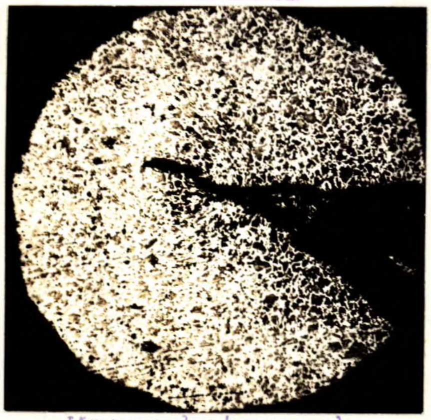


Macro etch of forged end, showing lines of flow. Natural size.

Figure 4.

Photograph of surface of fracture.

Figure 5.

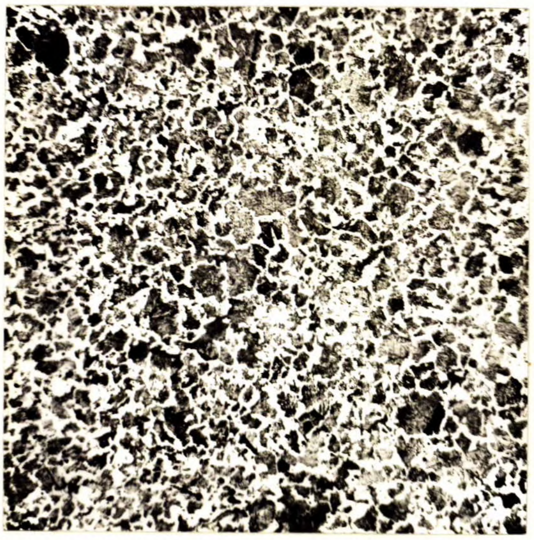


Macrophotograph showing crack starting at base of thread. X40, picral etch.

Figure 6.

Photograph of tensile tests used. Natural size.

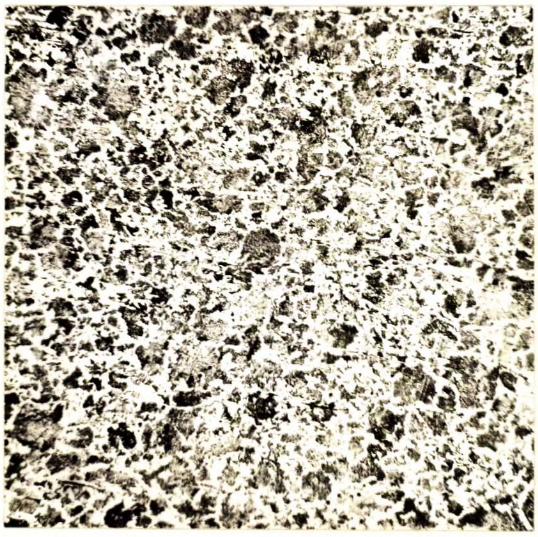
Figure 7.



X100, Picral etch.

MICROSTRUCTURE OF FORGED METAL.

Figure 8.



X100, Picral etch.

MICROSTRUCTURE OF UNFORGED METAL.

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