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OTTAWA April 19th, 1944.

# REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1622.

## Examination of a Fractured 4-Inch Mark XIX Twin Cradle.

(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 March 28th, 1944, Commander (E) H. Greenwood, of the British Admiralty Technical Mission, 58 Lyon Street, Ottawa, Ontario, submitted, for examination, a portion of a 4-inch Mark XIX Twin Cradle steel casting.

In a letter (File No. 11-11-5-1) accompanying the casting, the following information was given:

"This cradle has been used in a Twin Mounting at Longueuil for proving guns for some weeks, the total number of rounds fired being 126 (approximately 60 each side of which 40 were 15-20 per cent over load)."

It was requested that the chemical composition and physical properties of the steel be checked.

Macroscopic Examination:

The outer and inner surfaces of the casting were covered with a heavy scale of iron oxide. The fracture was of the non-duplex type. There was no evidence of any deformation at the point of fracture. The coarse, non-duplex nature of the fracture is illustrated in Figure 1.

Figure 1.

PHOTOGRAPH SHOWING FRACTURE OF CASTING
(Approximately 1/3 actual size).

Chemical Analysis:

Drillings taken from the casting were analysed and the following results were obtained:

| | | Reputed Analysis - Per cent - | Found |
|---|---|---|---|
| Carbon | - | 0.22-0.28 | 0.24 |
| Manganese | - | 0.60-0.81 | 0.83 |
| Silicon | - | 0.39-0.40 | 0.48 |
| Phosphorus | - | 0.013-0.028 | 0.017 |
| Sulphur | - | 0.027-0.037 | 0.040 |

Physical Tests:

Tensile, impact and bend tests were carried out on specimens machined from the casting. The following results were obtained:

(Continued on next page)

(Physical Tests, cont'd) -

Mechanical Properties.

| TENSILE TESTS | | Reported Range of Physical Properties | FOUND Test No. 1* | Test No. 2 |
|---|---|---|---|---|
| Ultimate stress, p.s.i. | - | 72,160-77,280 | 69,500 | 74,400 |
| Yield stress, p.s.i. | - | 34,640-38,360 | 39,300 | 42,500 |
| Elongation, per cent in 2 inches | - | 28.5-32.0 | 9.0 | 31.5 |
| Reduction in area, per cent | - | 52-58 | 9.0 | 49.5 |
| Brinell hardness | - | --- | 131 | 131 |

* Test No. 1 considered non-representative, due to shrinkage cavity in fracture.

Impact Tests:

| Temperature | Izod | Charpy |
|---|---|---|
| 70° F. | 15-18 ft-lb. | 13 ft-lb. |
| 0° F. | 6 " | 2 " |
| -30° F. | 4 | 2 " |

Note: All fractures of impact specimens, coarse.

Bend Tests:

| Dimensions of test piece, inches | Width of presser, inches | Aperture between rollers, inches | Angle of bend, degrees |
|---|---|---|---|
| 3 x 0.5 x 0.25 | 1.0 | 1.6 | 180° |

The specimen bent through an angle of 180° without cracking.

Microscopic Examination:

A specimen of the steel adjacent to the surface of the fracture was given a metallographic polish and then examined under the microscope in the unetched condition. A fairly large number of globular sulphide inclusions were observed in the steel. These are illustrated in Figure 2, a photomicrograph at X100 magnification. The nital-etched structure of the steel is shown in Figure 3. The dark etching material is pearlite (the iron-iron carbide constituent) and the white etching material is ferrite (the iron content). It was noted that the steel was fairly fine-grained.

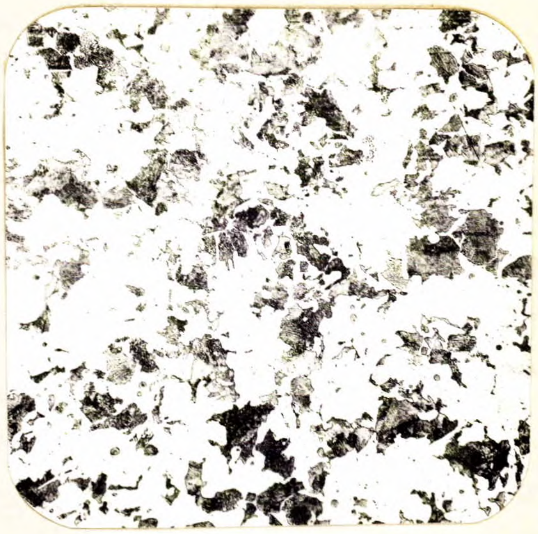
(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 2.

X250, unetched.

Figure 3.



X100, etched in
2 per cent nital.

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Discussion of Results:

The fairly heavy scale observed on the casting indicated that the casting had not been heat-treated in a neutral atmosphere. The composition of the steel conforms to the analysis given in Commander Greenwood's letter except for the sulphur content which is a bit high. In preparing specimens for tensile tests, areas containing slag and small shrinkage cavities were encountered. The latter defect was quite noticeable in Tensile Test No. 1. This test specimen also had checks in the gauge length just below the fracture. Such checks are generally associated with inclusions. The elastic properties of this bar were poor. The physical properties obtained in Tensile Test No. 2, however, were fairly satisfactory. The bend tests showed the steel to have good ductility but the impact test results were low especially at zero and sub-zero temperature conditions.

The lamellar pearlite and the large ferrite areas revealed by the microscopic examination indicated that the

(Discussion of Results, cont'd) -

steel had been cooled fairly slowly through the critical range. Although the inclusion content is high, the globular nature of the inclusions minimizes their effect on the properties of the steel. As a consequence, the steel is ductile although low in impact strength.

The sudden breaking of this casting after firing 126 rounds is due either to a progressive failure or to a very severe blow at the time of fracture or immediately prior to it. The non-duplex nature of the fracture shows that the former is not the case, i.e. the progressive failure can be ruled out. The lack of distortion shows that the casting was broken in impact and not in tension. Inasmuch as it resisted over 100 shots it would seem that these impact stresses at or just previous to the time of failure must have been greater than the part was normally encountering. It is also quite probable that failure may have been due to carrying out firing tests under low temperature conditions.

To improve the factor of safety, the impact strength should be increased. Three things govern this and must be controlled; namely, steel making, composition, and heat treatment.

1) Steel Making. In this connection it might be advisable to keep the sulphur as low as possible, i.e. 0.030 per cent maximum, and also that the deoxidation of the steel be the subject of careful study.

2) Composition. The carbon content should be kept as low as possible without interfering with the plant operation or strength requirements. The range now being used should prove satisfactory.

3) Heat Treatment. The steel castings should have a single or, preferably, a double normalizing heat treatment. For the latter, heat treatment temperatures of 1750° F. and 1500° F. are suggested.

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