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O T T A W A November 15th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1746.

Metallurgical Examination of a 3.7 Steel Shell Forging.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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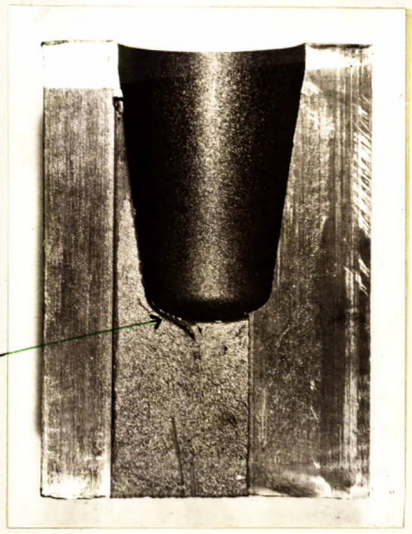
Source of Material and Object of Investigation:

In a letter dated October 24th, 1944 (File No. 12/4/1, Requisition O.T. 4294), Mr. R. C. McGee, I. C. M., for Inspector of Materials, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, requested a metallurgical examination of a 3.7 steel shell forging being submitted, in order to determine the cause of the "blisters" at the base of the forging cavity and the significance of certain lines on the fractured surface of the shell.

Macro-Examination:

Figure 1 is a photograph showing a section of a 3.7-inch steel shell with a small blister at the base of the forged cavity, at "A". The steel had a coarse-grained fracture.

Figure 1.



3.7-INCH STEEL SHELL FORGING.

(Approximately 1/3 size).

Chemical Analysis:

	Specified - Per Cent -	Found - Per Cent -
Carbon -	0.40-0.55	0.49
Manganese -	0.70-1.0	0.80
Silicon -	0.35 max.	0.22
Phosphorus -	0.06	0.012
Sulphur -	0.06	0.026
Chromium -		N.D.
Nickel -		N.D.
Molybdenum -		Trace.

N.D. - None detected.

Mechanical Tests:

Tensile and Izod impact test bars machined from the forging had the following properties:

(Continued on next page)

(Mechanical Tests, cont'd) -

	As Found	Specified
Ultimate stress, p.s.i. -	100,300	85,120-112,000
Yield stress, p.s.i. -	53,300	47,040
Percentage reduction of area -	40.5	--
Elongation, per cent in 2 inches -	23.0	15.0
Brinell (3,000-kg. load) -	170	--
Izod impact, foot-pounds -	18	--

Microscopic Examination:

A cross-sectional specimen cut through the blister at the base of the forged cavity was mounted in bakelite, polished, and examined under the microscope in the unetched condition. The steel was found to be fairly clean. However, several small porous areas were observed adjacent to the blistered section of the forging. Figure 2 is a photomicrograph, at X100 magnification, of the unetched steel, showing one of these porous areas. Small amounts of oxides, chiefly iron oxides, were observed in and around this porous area.

Figure 2.

X100, unetched.

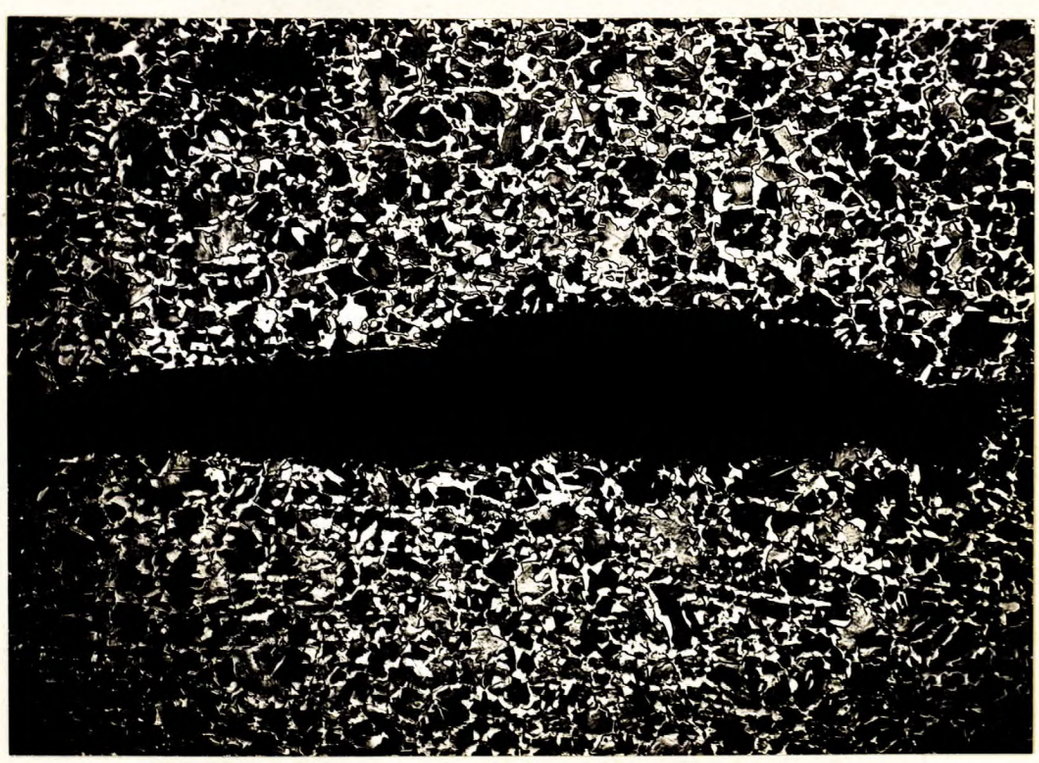
SHOWING POROUS AREA ADJACENT TO BLISTER.

(Continued on next page)

(Microscopic Examination, cont'd) -

The steel was then etched in a solution of 2 per cent nitric acid in alcohol and re-examined. Figures 3 and 4 show the nital-etched structure of the material, at 60 and 100 magnifications respectively. In Figure 3 is also shown a cavity which was not quite closed in the forging operation. The structure is typical of that of normalized medium-carbon steel and consists of pearlite (the iron-iron-carbide constituent, the dark etching material) and ferrite (the iron constituent, the white etching material).

Figure 3.

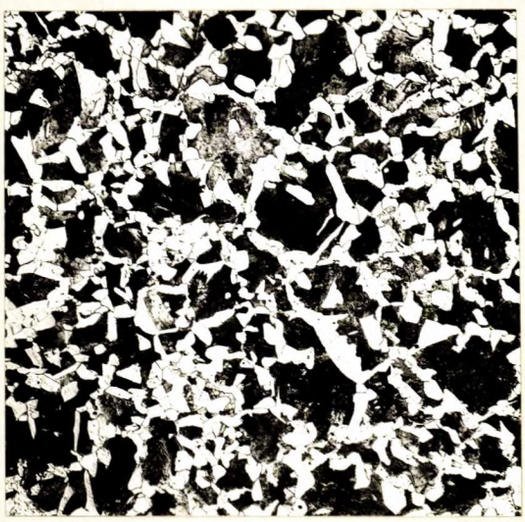


X60.

SHOWING NITAL-ETCHED STRUCTURE AND ELONGATED POROUS CAVITY.

(Microscopic Examination, cont'd) -

Figure 4.



X100, etched in
2 per cent nital.

SHOWING PEARLITE (DARK AREAS)
AND FERRITE (WHITE AREAS).

The steel is in the normalized condition.

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Discussion of Results:

The chemical composition was within the range specified for shell steel. The steel also had the specified mechanical properties. The areas of unsound metal at the base of the forged cavity are due to the presence of possibly trapped gases or a small amount of secondary pipe. Forging apparently was not enough to close these cavities. The defects indicate either faulty cropping practice or deoxidation. In view of the silicon in the steel the former is almost certainly the cause of the trouble. Steel containing such cavities should not be used in shells, for while such cavities do not greatly weaken the shell there is no guarantee that more serious defects are not present. Moreover, the surface of the shell cavity may

(Discussion of Results, cont'd) -

be seriously marred.

No significance could be attached to the lines in the coarse-grained fracture of the shell.

Conclusions and Recommendations:

1. The steel was properly made and heat treated to the specified mechanical properties.

2. The porous condition observed either was caused by entrapped gases in the ingot or resulted from a secondary pipe which was not closed in the forging operation, with the latter being the more probable explanation.

3. Steel showing such defects should not be used in shells.

4. The manufacturer of the ingots should be informed of these defects and steps taken by him to eliminate this condition.

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