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OTTAWA March 17th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1370.

Investigation of Damaged 3-Inch
Trench Mortar Barrel, Mk. II.

(Copy No. 7.)

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 Material and Object of Investigation:

On March 15th, 1943, a damaged Mk. II 3-inch trench mortar barrel was received at these Laboratories for examination. In a letter dated March 15th, File No. H.Q. 130-10-90 (D. of M.M.) MM/AR 9-1-6, signed by Lt.-Col. E. C. Mayhew for Colonel G. M. Grant, Director of Mechanical Maintenance, Department of National Defence (Army), Ottawa, Ontario, it was requested that laboratory tests be carried out to ascertain whether there is evidence of any defects in the steel which may have caused the fracture.

Macro-Examination:

Photographs, Figure 1 at 3/4 actual size and Figure 2 at 1/2 actual size, show the position and manner of failure. From the nature of the fracture it is evident that the failure was instantaneous.

Chemical Analysis:

The steel specified for this part is S-52T. The analysis obtained and that required by the specification are given in Table I.

Table I. - Chemical Analysis.

		Obtained, per cent	Specification S-52T, per cent
Carbon	-	0.47	0.40 - 0.48
Manganese	-	0.66	0.20 - 0.85
Silicon	-	0.22	0.05 - 0.20
Sulphur	-	0.015	0.06 max.
Phosphorus	-	0.008	0.06 max.
Chromium	-	Trace	
Nickel	-	None detected.	

Mechanical Properties:

The mechanical properties obtained and those specified for Steel S-52T are given in Table II.

Table II. - Mechanical Properties.

		Obtained	Specified for S-52T.
Ultimate tensile strength, t.s.i.	-	37	34 - 49
Yield strength, t.s.i.	-	22	19 min.
Elongation in 2 inches, per cent	-	29	17 min.

Metallographic Examination:

A specimen was prepared for the microscope, to determine the cleanliness of the steel. A photomicrograph of this specimen at 100 diameters magnification is presented in Figure 1. The steel is clean.

The structure as revealed by an etch in picric

(Metallographic Examination, cont'd) -

acid is shown in Figure 4 at a magnification of 100 diameters. It is understood that these barrels are annealed at 850° C. (1560° F.). The structure obtained would indicate that the heat treatment was carried out properly.

A specimen from the barrel was normalized at 1560° F. to develop the grain size of the steel at the heat-treating temperature. A photomicrograph of this structure is shown in Figure 5. The grain size is 3 to 4, which is decidedly coarse. Another specimen was normalized at 1700° F., which is the standard temperature for grain size specifications. The grain at this temperature is shown in Figure 6. It is size 2 to 3.

Discussion of Results:

The steel met all the requirements of the specifications for S-52T steel. However, the grain size is decidedly coarse.

For steels of this analysis, the Charpy impact strength may vary from 6 foot-pounds to 12 foot-pounds or more in the annealed condition, depending on the grain size existing at the annealing temperature. If the grain size is 2, which is coarse, the impact strength will be low. If the grain size is 7 to 8, which is fine, the impact strength will be high. This fine grain is usually developed in unalloyed steels by deoxidizing the steel with aluminium. According to the data presented by H. W. Gillett in the publication, IMPACT RESISTANCE AND TENSILE PROPERTIES OF METALS AT SUB-ATMOSPHERIC TEMPERATURES (Project No. 13 of the joint A.S.M.E.-A.S.T.M. Research Committee on Effect of Temperature on the Properties of Metals, published in August, 1941, by the American Society for Testing Materials), fine-grained

(Discussion of Results, cont'd) -

unalloyed steels will retain their impact strength to a greater degree at low temperatures than will coarse-grained steels.

However, C. H. Herty, Jr., and D. L. McBride, in their paper entitled "The Effect of Deoxidation on the Impact Strength of Carbon Steels at Low Temperatures" (Co-Operative Bulletin 67 of the Mining and Metallurgical Advisory Boards and the Carnegie Institute of Technology, Pittsburgh, Pa., 1934), state that in medium carbon steels (0.45 per cent carbon) the difference between aluminium-killed (fine-grained) and the silicon-killed (coarse-grained) steels in their behaviour in impact at low temperatures was not pronounced. The aluminium-killed steel was only slightly more resistant to embrittlement than was silicon-killed steel. In the data they present, the impact strength drops from about 20 foot-pounds at 20° C. (68° F.) to about 8 foot-pounds at -20° C. (-2° F.). However, at 0° C. (32° F.) the aluminium-killed steel still has an impact strength of 17 foot-pounds while the silicon-killed steel has an impact strength of 13 foot-pounds.

From the data presented it is apparent that the impact properties of unalloyed medium carbon steel may be expected to be fairly low even at room temperatures and to deteriorate as the temperature falls. These conditions will be aggravated to some extent by a coarse grain size, but even fine-grained medium carbon unalloyed steels apparently leave much to be desired in impact properties when exposed to sub-freezing temperatures.

The matter of design of the threads on the spigot of these barrels should be given consideration. If the base of a thread is sharp it will act as a notch, creating a concentration of stress that can easily be far in excess of the anticipated

(Discussion of Results, cont'd) -

stresses even when conditions of firing are normal. Sharp threads combined with low temperature could quite easily be the cause of this failure. Unfortunately, the spigot was lost, so the condition of the threads cannot be determined.

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Conclusions:

1. The steel is clean.
2. The steel meets chemical and mechanical requirements for S-52T steel.
3. The grain size is coarse at the annealing temperature specified, indicating a possibility of poor impact properties.
4. All medium carbon unalloyed steels in their annealed condition have relatively low impact properties at normal temperatures and lose their toughness as the temperature decreases. This loss in toughness may become serious even at 10° F. Since the material under investigation failed in a brittle manner, this characteristic of medium carbon steels should receive close attention.

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RECOMMENDATIONS:

1. The steel used for these barrels should be required to meet an impact specification that would ensure a fine-grained steel.
2. If cold-temperature performance is deemed important, consideration should be given to an alloy steel better suited to this service.
3. Attention should be paid to the design of the threads on the spigot. Sharp threads could easily be the cause of a failure of this nature.

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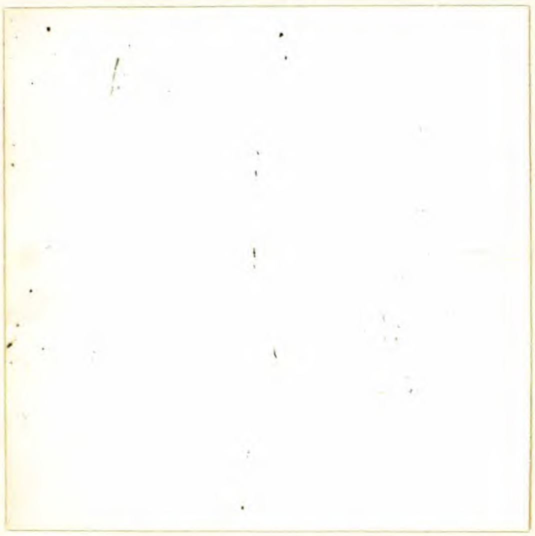
Figure 1.

Photograph, at $\frac{3}{4}$ actual size, of fractured surface.

Figure 2.

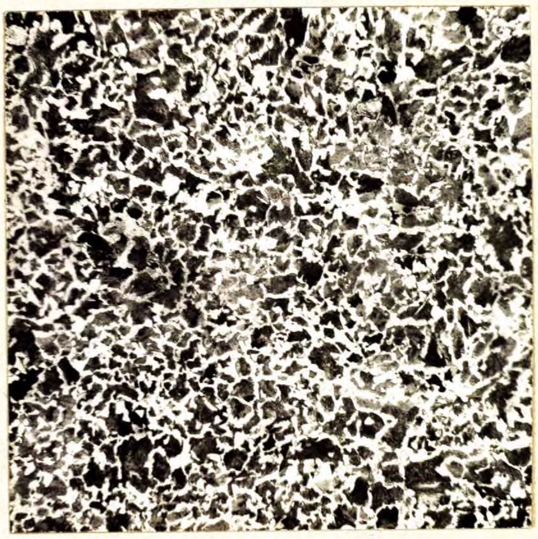
Photograph, at $\frac{1}{2}$ actual size, showing position of fracture.

Figure 3.



X100, as polished.
Photomicrograph showing inclusions in steel. Clean steel is indicated.

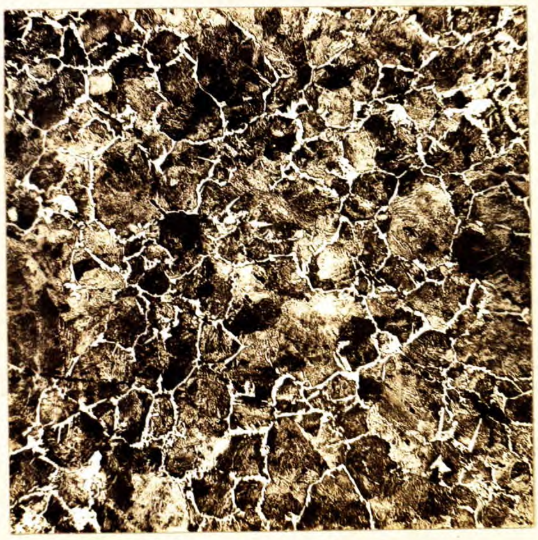
Figure 4.



X100, picral etch.

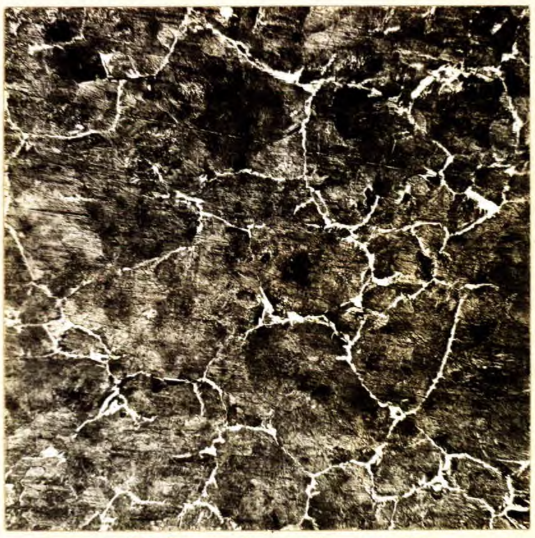
Photomicrograph of structure of steel as received. Proper heat treatment is indicated.

Figure 5.



X100, picral etch.
Structure after normalizing at 1560° C. to show grain size at heat-treating temperature.
Grain size, 3 to 4.

Figure 6.



X100, picral etch.
Structure after normalizing at 1700° C. to show standard McQuaid-Ehn grain size.
Grain size, 2 to 3.