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OTTAWA April 2nd, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1380.

Examination of a Cylinder Barrel
from a Cheetah Aircraft Engine.

(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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from a Cheetah Aircraft Engine.

Origin of Sample:

A Ford cylinder barrel from a Cheetah aircraft engine was submitted on March 24th, 1943, by Air Commodore A. L. Johnson, for Chief of Air Staff, Department of National Defence for Air, Ottawa, Ontario. The barrel had developed a circumferential crack through its finned portion. This part, marked HS 4140-6-15, was reported to have been centrifugally cast.

Object of Study:

Request was made (letter dated March 24th, File No. 902-38-1(AMAE DAI)) for an examination of this barrel in order to determine, if possible, the cause of failure.

Chemical Analysis:

Drillings from this casting were chemically analysed. The results are as follows:

		Per cent
Carbon	-	0.53
Manganese	-	0.93
Silicon	-	0.30
Sulphur	-	0.032
Phosphorus	-	0.066
Nickel	-	0.13
Chromium	-	1.00
Molybdenum	-	0.20
Copper	-	0.22

Macro-Examination:

Magnaflux examination of the barrel revealed that the crack, about 3½ inches long, traversed the fifth and sixth fin from the finned end of this part. This crack, which went through the barrel wall, did not, however, progress as far as the outer edge of either of these fins. This crack (indicated by letters) is shown in Figures 1 and 2.

A section containing the crack was then removed and broken. The crack was seen to be of the fatigue type with its nucleous (point E, Figure 3) between the fifth and sixth fins. That the outer edge of the nucleous was rough may be seen from Figures 3 and 4.

This barrel had a Vickers hardness number of about 345.

Microstructure:

A specimen for the microscope was removed from the rough nucleus of the failure, mounted in bakelite, and polished on a face approximately perpendicular to the direction of cracking.

It was found that the rough nucleus of the failure was actually a shrinkage-type defect. This is pictured, at

(Microstructure, cont'd) -

100 diameters, in Figure 5. Figure 6 is a photomicrograph of another shrinkage defect found in this same region.

After an etch of 2 per cent nitric acid in alcohol was applied to this specimen, it was seen that the part was composed of fine pearlite (commonly termed sorbite). This structure is shown, at a magnification of X1000, in Figure 7.

The steel in this barrel is fairly clean.

Discussion of Results:

The composition of this part does not follow the specification for SAE 4140 steel. Phosphorus is higher than would be expected in quality steel, being 0.026 per cent over specification. The carbon content is markedly different from the specified amount, so much so that the steel is actually SAE 4150 rather than SAE 4140. This might be dangerous if heat treatment procedure were held to that recommended for SAE 4140 steel. In the event of any welding being done (as is quite unlikely), the higher carbon content is, of course, quite dangerous. The nickel and copper present in this barrel are probably tramp elements.

Macro and micro examinations definitely show that the crack, of a fatigue type, originated at a shrinkage-type defect (caused by faulty casting technique) on the machined surface between two fins.

The heat treatment accorded this cylinder barrel seems to be satisfactory. In view of its hardness and structure it was probably quenched from around 1500° F. and drawn at about 1100° F.

From all of the foregoing it would seem that the failure of this part was brought about by a concentration of

(Discussion of Results, cont'd) -

stress caused by a shrinkage-type defect on the machined surface of this cylinder barrel.

It is understood that this part has been machined from a centrifugally cast sleeve that is radiographed before the machining operation. Such inspection practice is, of course, desirable because it eliminates the machining of bad castings. It might well not, however, show up defects which in relation to the thickness of the casting are quite minor. However, these defects, if present in the finished machined sleeve, would then, in relation to the total thickness of the finished article, be quite large. An X-ray of the machined sleeve, therefore, would be expected to reveal defects of the type responsible for this failure. It is quite possible that a magnafluxing of the finished article would also have uncovered the defect. It is not unlikely, however, that such a small defect would pass magnaflux examination, especially if an inexperienced operator were examining a number of sleeves. As the X-ray method gives a permanent record, when it is used there is much less chance that defects will escape detection.

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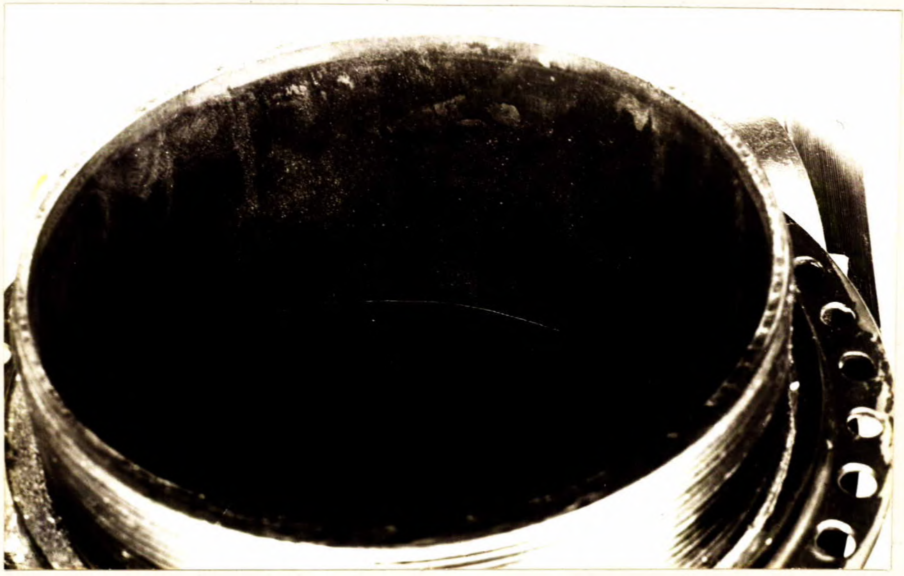
Figure 1.

CRACK OUTLINED BY MAGNAFLUX POWDER.

(Approximately to size).

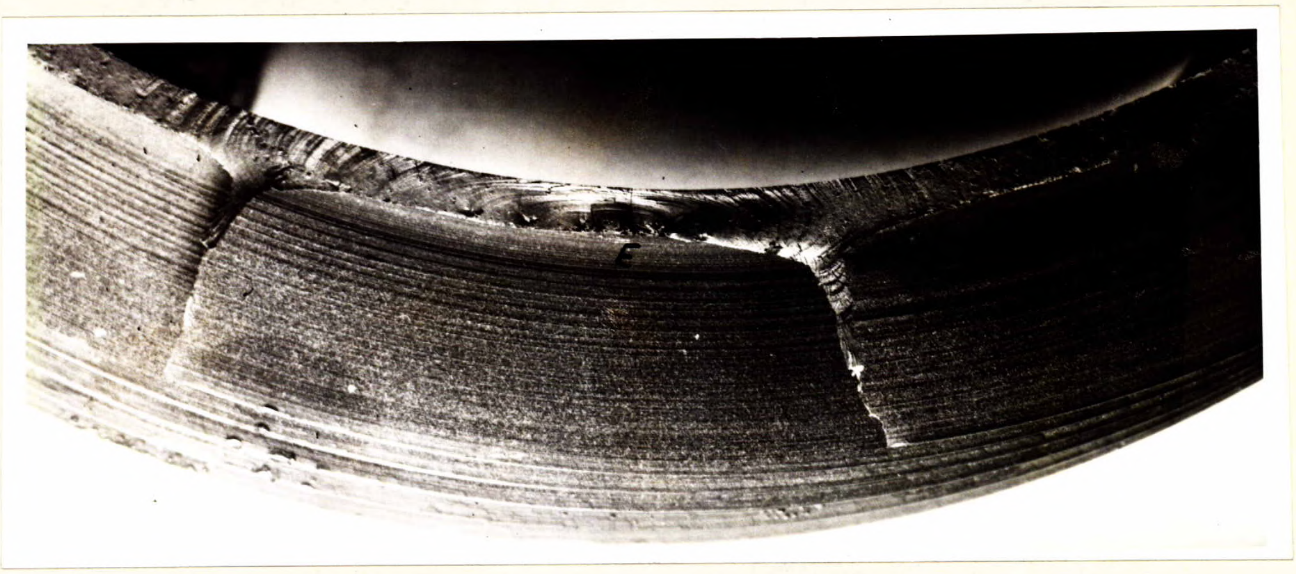
Figure 2.



CRACK OUTLINED BY MAGNAFLUX POWDER.

(Approximately 2/3 size).

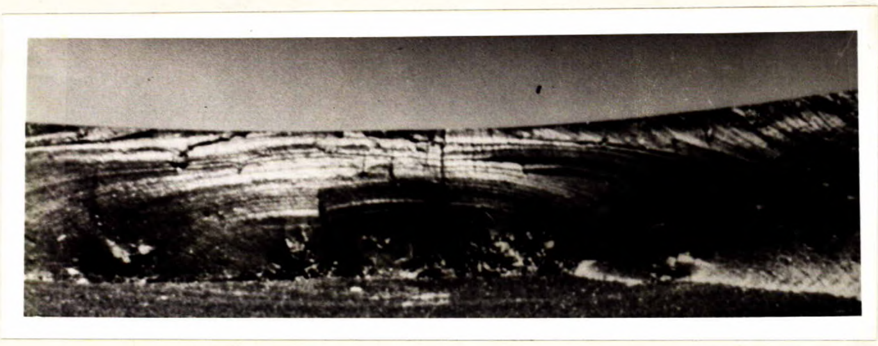
Figure 3.



Note nucleus at E.

(Approximately twice actual size).

Figure 4.



Note roughness at nucleus of failure.

(Approximately 8 times actual size).

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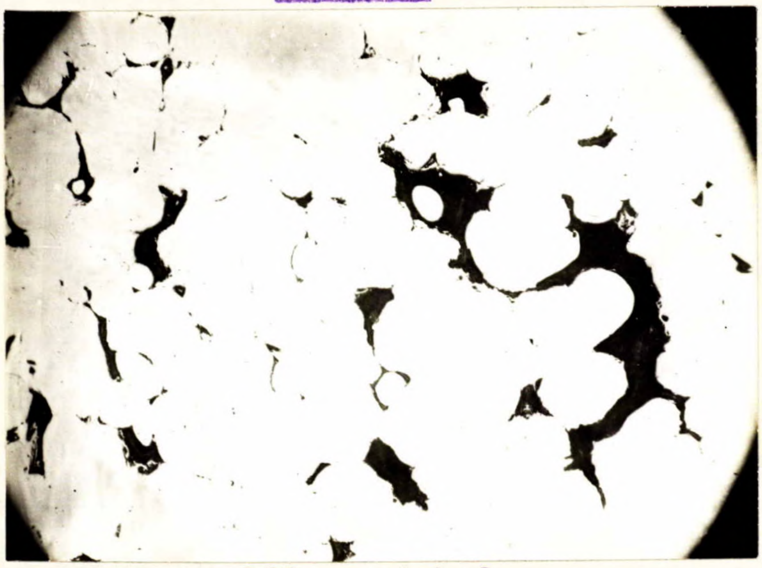
Figure 5.

X100, unetched.
Horizontal surface is fillet between fifth and sixth fins. Sloping surface (lower left of picture) is the fractured surface. Note shrinkage-type defects at start of fracture.

Figure 6.



X100, unetched.
Shrinkage-type defects present in the region of the fracture.

Figure 7.

X1000, nital etch.
MICROSTRUCTURE OF THE STEEL.

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