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DEPARTMENT OF MINES AND RESOURCES

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Ottawa, July 12, 1946.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2076.

Metallurgical Examination of a Defective
Cylinder Head Casting.

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(Copy No. 4.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

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OF
MINES AND RESOURCES

Mines and Geology Branch
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Origin of Material:

On June 5, 1946, Mr. A. E. Cartwright, Metallurgist, Canadian Foundry Supplies and Equipment Limited, Montreal, Quebec, submitted a defective cylinder head casting to these Laboratories for metallurgical examination.

In his letter of July 22, 1946, Mr. Cartwright supplied the following information. The cast iron jacket casting had been made by the Acadia Gas Engines Limited. It had not failed in service but does show leakage after machining, this defect causing a loss of 50 per cent in production. Details regarding their foundry practice, gating, sand, cores, melting, etc., are not known.

Object of Investigation:

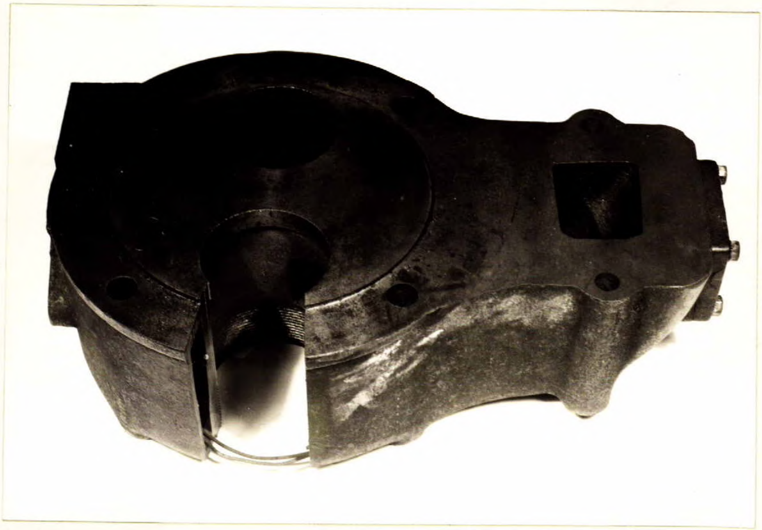
To examine the casting for metallurgical defects and determine their origin.

PROCEDURE:

1. Visual Examination:

The area of the casting which had exhibited leakage had been indicated with blue chalk. Three sections, approximately ½ inch in thickness, were cut from this area. Figure 1 is a photograph of the cylinder head with these sections removed. No visual evidence of any defect was found and hence two additional sections were cut from the casting. Figure 2 is a photograph of the casting with all five sections removed. Figure 3 is a photograph of Sections Nos. 4 and 5. There was definite evidence of porosity in Section No. 5 at the area indicated (see Figure 8 also).

Figure 1.



PHOTOGRAPH OF DEFECTIVE CASTING.

(Sections Nos. 1, 2 and 3 are removed from porous area.)

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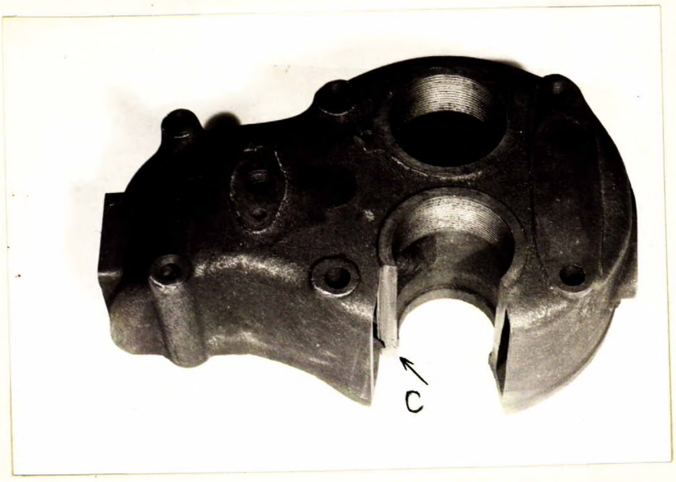
(Procedure, cont'd) -

Figure 2.



SAME AS FIGURE I.

(Sections Nos. 1, 2, 3, 4 and 5 removed.)

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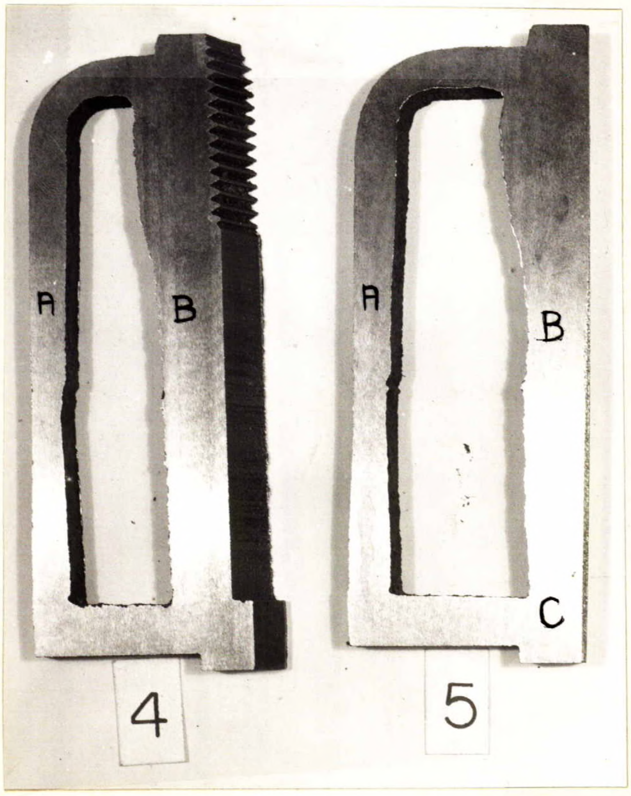
Figure 3.



PHOTOGRAPH OF SECTIONS NOS. 4 and 5,
SHOWING LOCATION OF MICRO SAMPLES.

(Compare with radiographic print, Figure 8)

-

(Procedure, cont'd) -

2. Chemical Analysis:

Drillings from Section No. 1 were taken for chemical analysis, the results of which are listed below. For comparison purposes only, a typical analysis for a nickel-chromium auto cylinder casting (A.S.M. Handbook, 1939) is included.

		Results, per cent	Typical Analysis, per cent
Total carbon	-	3.11	3.25
Combined carbon	-	0.64	
Graphite carbon	-	2.47	
Manganese	-	0.64	0.65
Silicon	-	2.10	2.25
Sulphur	-	0.114	0.10
Phosphorus	-	0.56	0.15
Nickel	-	0.73	0.75
Chromium	-	0.10	0.30
Molybdenum	-	Trace.	-

3. Radiographic Inspection:

Sections Nos. 2, 3, 4 and 5 were submitted for sectional radiographic inspection. The report of the inspection was as follows:-

Sections Nos. 2 and 3. "The resultant plate reveals a fair amount of evenly distributed microporosity present, which may possibly be a little more severe at the flat end of the core. No other radiographic evidence of defects was noted in this examination."

Sections Nos. 4 and 5. "Porosity: some, more than can be expected for sound metal - particularly throughout relatively thin section bounding the core. Shrinkage: in toothed side near core surface about the centre of one specimen (Section No. 5). Piping: (Section No. 4) on the same side running from the square corner for ½ inch - quite severe, penetrating this wall completely in several places - apparently originated in the core side."

(Radiographic Inspection, cont'd) -

Fine detail ordinarily visible in a radiograph against the light is generally lost in printing. For this reason, the fine microporosity in Sections Nos. 2 and 3 is lost in printing, and hence no radiographic print of these sections is included. Figure 8 is a print of the radiograph of Sections Nos. 4 and 5 in which defects are clearly evident.

(Figure 8 appears on Page 10)
(at end of report.)

4. Hardness Test.

Three hardness readings were taken on the machined surface of one section with a Brinell Hardness Tester (10-mm. ball, 3,000-kg. load for 30 seconds). Brinell hardness numbers ranged between 183 and 192.

5. Microscopic Examination.

Three representative samples, "A", "B" and "C", were cut from Section No. 5 (see Figure 3), mounted, polished, and etched in 2 per cent nital for microscopic examination. The following table lists the photomicrographs appearing in this report (at end):

Figure 4. - Sample "A", unetched, X100, showing size and distribution of graphite flakes. Pattern corresponds to A.S.T.M. Classification Size 6, Type A.

Figure 5. - Sample "B", unetched, X100, showing size and distribution of the graphite flakes. Pattern corresponds to A.S.T.M. Classification Size 4, Types A and B.

Figure 6. - Sample "A", nital etch, X500, normal structure of graphite, ferrite, pearlite and steadite (phosphide eutectic).

Figure 7. - Sample "B", nital etch, X500, normal structure of graphite, pearlite and steadite (phosphide eutectic).

Figure 9. - Photograph of the porous area "C" from Section No. 5. Approximately X9.

(Radiographic Inspection, cont'd) -

Figures 10 and 11. - Sample "C", nital etch, X100, photomicrographs of porosity and shrinkage cavities.

Discussion:

The chemical analysis and hardness test are normal for a grey iron cylinder casting and are considered satisfactory.

The chromium content could possibly be raised to 0.15-0.20 per cent with beneficial results. Chromium is essentially a carbide former and the effect of raising the chromium content on the microstructure would be to form less ferrite and finer graphite and pearlite. Additional hardness and wear resistance would result from this slight change in structure. (It is believed that the tendency to eliminate porosity would be increased also.)

The microscopic examination, with the exception of the defects noted, revealed a normal pearlite grey iron structure (see Figures 6 and 7). The presence of ferrite in the outer web of the section examined is indicative of a slower cooling rate in that part of the casting. The size and distribution of the graphite flakes (see Figures 5 and 6) correspond to A.S.T.M. Classification Size 4-6, Types A-B, and are considered normal.

The most serious defects noticed were the porosity and shrinkage revealed by the sectional radiographic examination of Sections Nos. 4 and 5 (see Figure 8). Figures 9, 10 and 11 are photomicrographs of the porous area "C".

Without knowledge of the foundry conditions, gating, moulding, pouring, temperatures and core properties, it is

(Discussion, cont'd) -

difficult to say what part these important variables had in causing shrinkage cavities and porosity. Careful check should be kept continuously on such variables as:

Pouring temperature.	Core hardness.
Pouring time.	Permeability of mould and core metal runout.
Mould temperature.	Shrinkage property of the iron.
Mould hardness.	

The tendency of cast iron to form shrinkage cavities can be measured by the "K" casting, a sketch of which is shown as Figure 12 herein.

It is well known that thin sections draw molten metal away from thick sections, resulting in porosity and voids in the latter unless precautions are taken. Chilling would overcome this but, more important, proper gating and feeding are necessary to arrive at the desired directional solidification of the casting.

If the amount of gas generated by the core is not already known, it is suggested that tests be made to measure this important factor. Core gas measurements, taken daily, provide a useful check upon core mixing and baking. Under-baked cores may generate as much as three times the amount of gas that will ordinarily arise from properly baked cores.

Conclusions:

1. The hardness values and chemical analysis are normal for a cylinder head casting and are considered satisfactory.

2. Increasing the chromium content to 0.15-0.20 per cent would (a) refine the structure,
(b) improve hardness and wear resistance,
(c) decrease any tendency to show porosity.

3. The microstructure, with the exception of the defects noted, is typical and satisfactory for a pearlitic grey cast iron.

(Conclusions, cont'd) -

4. Serious defects, such as porosity and shrinkage cavities, were detected.

5. The porosity observed in Figures 8, 9, 10, 11 and 12 is probably due to metal shrinkage. Lacking details of gating, pouring, etc., it is not possible to state what remedial measurements should be taken, other than close attention to operational details.

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(Figures 4 to 12 follow,)
(on Pages 9 to 11.)

Figure 4.

X100, unetched.

SIZE AND DISTRIBUTION OF GRAPHITE FLAKES IN SAMPLE "A".

Pattern corresponds to A.S.T.M. Classification Size 6, Type A.

-

Figure 5.

X100, unetched.

SIZE AND DISTRIBUTION OF GRAPHITE FLAKES IN SAMPLE "B".

Pattern corresponds to A.S.T.M. Classification Size 4, Types **A and B.**

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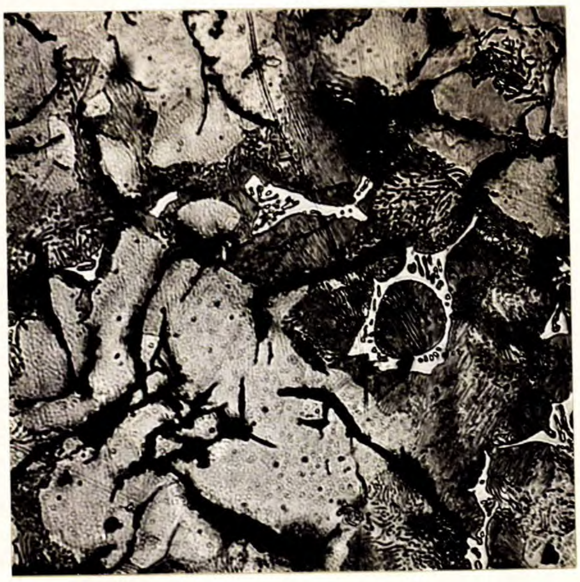
Figure 6.



X500, nital etch

NORMAL STRUCTURE, SAMPLE "A".

Graphite, ferrite, pearlite and steadite (phosphide eutectic).

-

Figure 7.

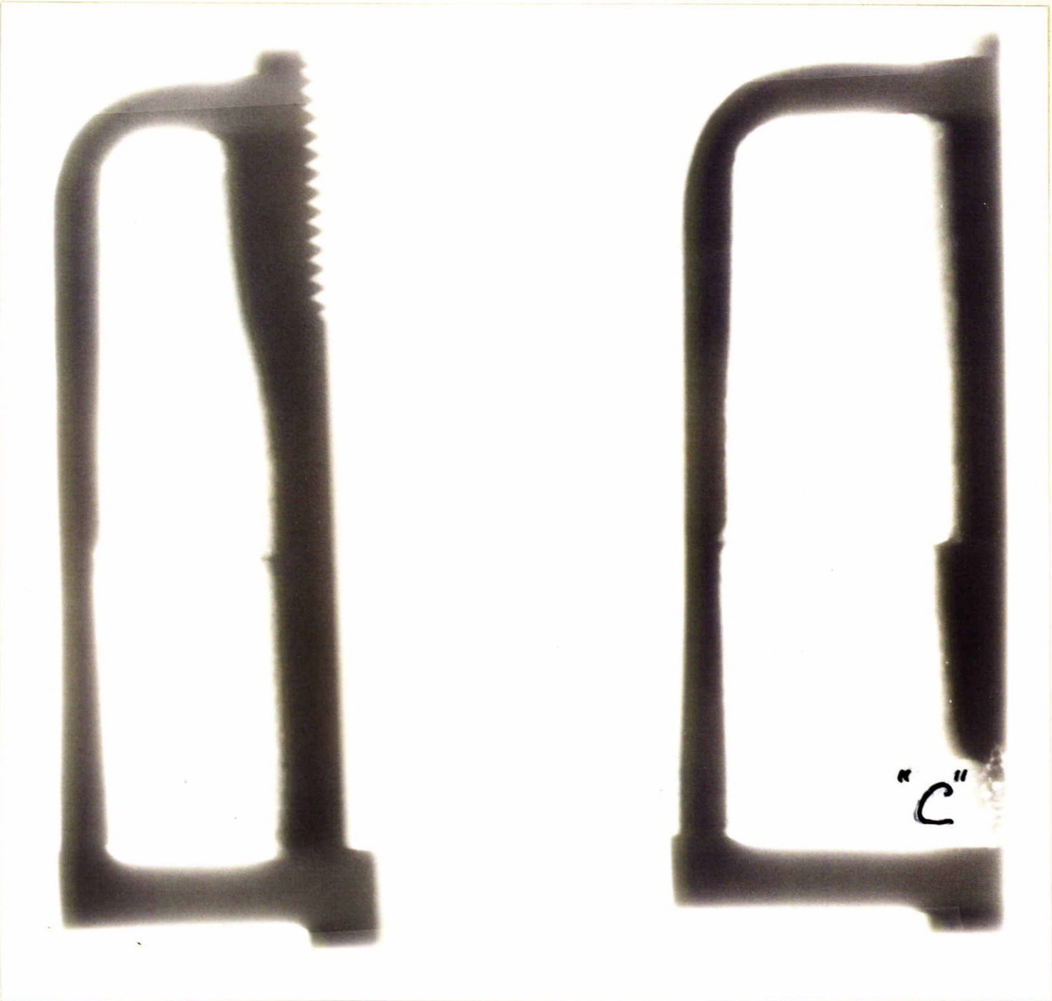
X500, nital etch.

NORMAL STRUCTURE, SAMPLE "B".

Graphite, pearlite and steadite (phosphide eutectic).

-

Figure 8.

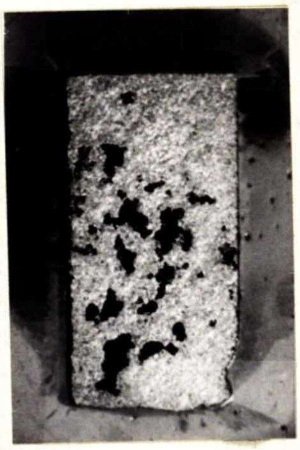


RADIOGRAPHIC PRINT OF SECTIONS NOS. 4 and 5.
(COMPARE WITH FIGURE 3.)

Note shrinkage cavities at area "C".

(Actual size).

Figure 9.



PHOTOGRAPH OF MOUNTED SAMPLE, AREA C,
SHOWING POROSITY.

(Approximately 9 times actual size).

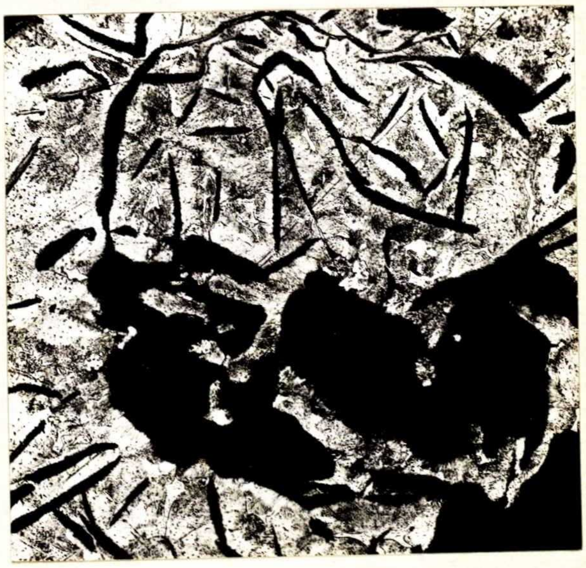
Figure 10.

X100, nital etch.

SHOWING NATURE OF THE CAVITIES
OF AREA "C".

Note the small round cavity,
evidence of gas porosity.

Figure 11.

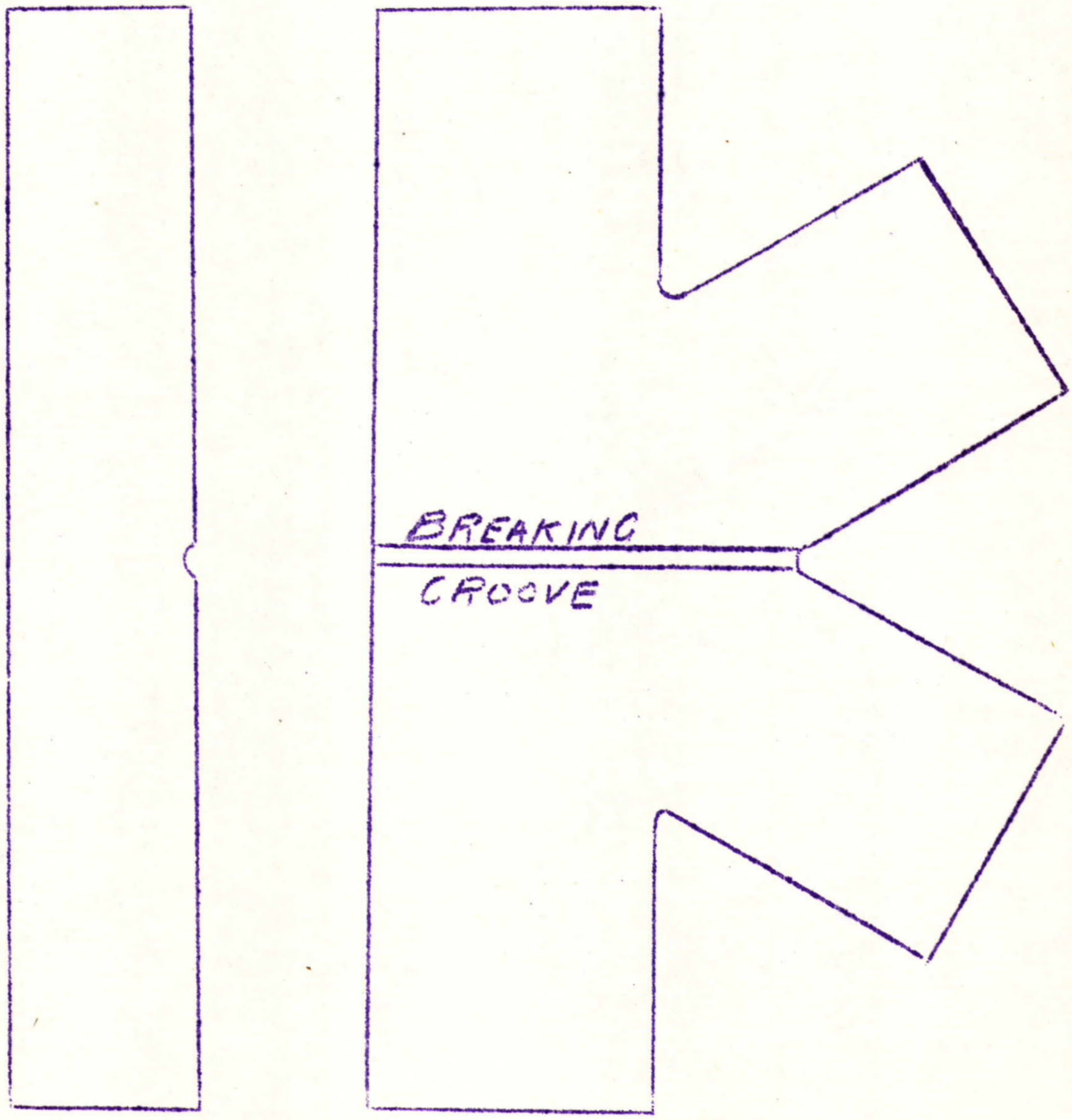


X100, nital etch.

SAME AS FIGURE 10.

Cavities believed to be
due to shrinkage.

Figure 12.



SHRINKAGE TEST CASTING.

(Actual size).

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