OTTAWA August 27th, 1942.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1287.

Examination of Magnesium Alloy Castings
(Jacobs L.6 Engine Crankcase).

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Origin of Material:

In a letter dated July 13th, 1942, File No. 935F-3-5 (AMAE:DAI:IC), Group Captain A. L. Johnson, for Chief of Air Staff, Royal Canadian Air Force, Ottawa, Ontario, requested the examination of a broken Jacobs L.6 engine crankcase cast from a magnesium alloy.

It was requested that this casting be examined to see

(Origin of Material, cont'd) -

if a reason can be found for the failure at the base of the flange, at which point cracks form with the result that eventually a fracture occurs. It was stated that many such failures are being reported.

Later, information was obtained that the casting should conform to the S.A.E. Specification AMS 4434.

Description of Samples:

For the examination, one complete casting with broken flange (casting "A"), and one section of another casting ("B") showing the cracked condition, were submitted.

Figures 1 and 2 show the submitted casting "A" from both sides.

Figures 3 and 4 show the location and character of the fracture of casting "A", as received.

Figure 1. Figure 2.

Casting "A" As Received.
(Approximately 1/5 size).

(Description of Samples, cont'd) -

Figure 3.

Fracture of Casting "A" As Received.
(Approximately 1/5 size).

Figure 4.

Fracture of Casting "A" As Received.
(Approximately 2/5 size).

Figure 5 shows the section of a second casting ("B"), as received, with clearly visible cracks.

Figure 5.

Cracks on Section of Casting "B".
(Approximately 1/3 size).

(Description of Samples, cont'd) -

The fracture of casting "A" (Figures 3 and 4) shows partly a structure associated typically with fatigue (on both ends of the broken piece). The central part of the fracture (which occurred apparently by a sudden break) showed some dark spotted areas.

The submitted section of casting "B" was broken in these laboratories at the location of the crack, to determine the appearance of the freshly fractured surface. This fracture was similar in appearance to the one observed before, showing more clearly dark (discoloured) areas.

X-Ray Examination:

X-ray examination, carried out by W. A. Morrison of the National Research Laboratories, Ottawa, showed no cracks or holes. The radiographs indicated that the castings seem to be very sound, and no microporosity could be found.

Due to the complicated shape of the casting, it is difficult to determine definitely whether or not microporosity exists.

Chemical Analysis:

		As Found	S.A.E. Specification AMS 4434
		- Per cent -	
Aluminium	-	8.59	8.3 - 9.7
Zinc	-	2.14	1.7 - 2.3
Manganese	-	0.15	0.10 min.
Silicon	-	0.10	0.30 max.
Copper	-	0.03	0.05 max.
Iron	-	0.035	-
Nickel	-	None detected.	0.01 max.
Total impurities		-	0.30 max.

The chemical composition of the castings conforms also to the A.S.T.M. Spec. B80-41T, Alloy 17, and corresponds to those of the commercial alloys Dowmetal "C" and "AM 260" (Al. Co. of Am.).

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Mechanical Properties:

Tensile Tests -

The tensile specimens were obtained from various areas, the locations of which are given in Table I.

Due to the complicated shape of the casting, only short test specimens could be obtained. These did not permit the measurement of the yield strength.

The appearance of the fractured areas of the test specimens is given in Table I.

Table I.

Casting	Specimen No.	Location* of the specimen	Size of the specimen, in inches	U.T.S., p.s.i.	Elongation: in 1 inch, per cent	** Fracture
A	1	b	.127 x .500	10,800	-	x
"	2	b	.129 x .492	21,000	-	x
"	3	a	.250 diam.	21,000	1	z
"	4	c	.251 "	28,600	1	x
"	5	c	.251 "	26,600	1	x
B	6	a	.249 "	26,000	1.5	y
"	7	a	.250 "	22,300	1.5	y
"	8	a	.248 "	17,300	1	z
		Average	-	21,700	1	

* Location of the Specimen:

a - adjacent to the fracture,
b - near the fractured part,
c - remote from the fractured part.

** Appearance of the Fracture:

x - "sound" (light colour without any spots),
y - dark spots on part of the fractured area,
z - whole fractured area dark (discoloured).

(Continued on next page)

(Mechanical Properties, cont'd) -

Tensile Tests, cont'd -

Figure 6 shows the fracture of Test Specimen No. 7 with visible dark spots.

Figure 6.

Fracture of Test Specimen No. 7.

(Approximately three times actual size).

Specification AMS 4434 requires the following minimum values:

	U.T.S., p.s.i.	Elongation in 2 inches, per cent	Brinell hardness
For separately cast test bars -	34,000	1	70
For test bars cut out from castings (average from 4, preferably 10 specimens) -	25,500	-	70

Clause 6 of this specification states that the castings must be homogeneous and that when broken for fracture test they must show a uniform colour of the fractured area.

Hardness Tests -

Hardness was determined by the Vickers method, using a 10-kg. load, with the following results:

85 - 90 V.H.N.

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Micro-Examination:

Micro-examination revealed a great amount of micro-cavities (interdendritic porosity), as shown in Figures 7 and 8.

Figure 8 shows the microstructure normal for a solution-heat-treated and subsequently aged (precipitated) magnesium alloy of this type.

The grain size of the examined samples was rather coarse.

Figure 7. Figure 8.

X100, unetched. X100, etched in 2% nital.

The examination of sections taken adjacent to the fractures of the test specimens confirmed that the dark spots (Figure 6) on the fractured area were caused by interdendritic cavities (microporosity).

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Discussion of Results:

X-ray examination showed sound material. However, due to the complicated shape of the casting this is no guarantee for the absence of some microporosity.

Chemical analysis of the casting conforms closely to the requirements of S.A.E. Specification AMS 4434. This type

(Discussion of Results, cont'd) -

of magnesium alloy is used particularly when maximum pressure tightness is required.

The fractures of both castings, and also some of the fractured test specimens (Figure 6), showed dark spotted areas. Such marked discoloration is typical for areas of microporosity (interdendritic cavities). The discoloration varies in intensity with the degree of porosity present. Mechanical tests taken from such areas show a reduction in properties varying with the intensity of discoloration.*

The results of the tensile tests are generally lower than the minimum values given in Specification AMS 4434. Especially poor results showed the specimen with discoloured fractures (Table I). This agrees also with other recent investigations ** which revealed that the mechanical properties (also the fatigue resistance) of this type of magnesium alloy (i.e., Dowmetal C) are very sensitive to microporosity, especially in the fully heat-treated condition.

The micro-examination revealed a great amount of microporosity (Figures 7 and 8) and confirmed that the discolored areas visible on the fractures are due to microcavities.

Microporosity is normally caused by imperfect casting conditions and occurs at the grain boundaries due to the wide solidification range of magnesium alloys containing aluminium and zinc.

Similar defects might be due to overheating during the heat treatment. Temperature control is extremely important as if temperatures in excess of the eutectic melting point are

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* L. G. Day and H. G. Warrington - Light Metals, Vol. 1 (1938), No. 8, p. 271.

** R. S. Busk - American Society for Testing Materials, 1942 Preprint, 8 pp.

(Discussion of Results, cont'd) -

reached before complete solution is attained, there arises the risk of cracking, distortion, and the reduction of mechanical properties.

It might be thought that the presence of eutectic indicates faulty heat treatment, as this constituent, if equilibrium conditions are established, should all be in solution. In point of fact, however, as much as three days may be required to establish equilibrium in these alloys; so a satisfactory commercial heat treatment may well leave some eutectic out of solution. The presence of eutectic may also be caused as a result of overheating, and German investigators* claim that this formation may be associated with microcavities. As both lack of casting soundness and overheating could account for the facts observed, it is difficult to be dogmatic as to the cause of the defects and it can only be stated to be due to one or the other, or both, of the possible causes.

<u>Conclusions:</u>

The failure of the examined castings was caused by too low mechanical properties and is due to microporosity of the castings.

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* A. Beck - "The Technology of Magnesium and Its Alloys," - translated London 1940, p.50.