O T T A W A   August 14th, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1061.

An Examination of
Zinc-Alloy Die Castings.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

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CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Origin of Material:

Two die-cast tire pump crankcases were submitted by the Motor Transport Section of the Inspection Board of the United Kingdom and Canada to the National Research Laboratories at Ottawa, Ontario, in July, 1941. Following X-ray inspection (N. R. L. Report PX-79, July 23rd, 1941) they were submitted to the Metallic Minerals Division of the Bureau of Mines, at Ottawa, for chemical analysis, metallographic examination, and interpretation of the fabrication process.

The castings were received on July 23rd, 1941.

Nature of Castings:

Figure 1 shows the die castings as received. The casting identified as "new" (left) is designated "No. 1" and the "old" casting (right) is designated "No. 2".

Figure 1.

CASTINGS AS RECEIVED.

Casting No. 1 - left.
Casting No. 2 - right.

Examination of the surfaces revealed holes and shrinkage cracks on both castings.

Figures 2, 3 and 4 show the character of these defects. The photographs are about 2/3 actual size.

(Continued on next page)

(Nature of Castings, cont'd) -

Figure 2.

Photograph, approximately 2/3 actual size, showing large cavities and cracks on Casting No. 1.

Figure 3.

Photograph, approximately 2/3 size, showing a large hole in Casting No. 2.

(Nature of Castings, cont'd) -

Figure 4.

Photograph, approximately 2/3 size, showing shrinkages, cold-shut and cracks on Casting No. 2.

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X-Ray Examination:

The X-ray examination carried out by the National Research Laboratories at Ottawa (see Report PX-79) showed a large number of cavities and microcavities in both castings.

Chemical Analysis:[@]

	Casting No. 1.	Casting No. 2.
Aluminium, per cent	4.33	4.52
Copper, "	2.33	2.45
Magnesium, "	0.06	0.06

[@] Note: The difference between above analysis and that made for the National Research Laboratories (Report PX-79) is explained in the "Discussion of Results" of the present report.

<u>Physical Tests:</u>

<u>Hardness</u> -

Casting No. 1	-	90-100 V. H. N.
Casting No. 2	-	100-110 V. H. N.

<u>Microstructure:</u>

Figures 5 and 6 show α-primary crystals and ternary eutectic $\alpha + \gamma + \varepsilon$ (89 per cent zinc, 7 per cent aluminium, 4 per cent copper).

<u>Figure 5.</u>

X200, etched.⊛

<u>CASTING NO. 1.</u>

<u>Figure 6.</u>

X200, etched.⊛

<u>CASTING NO. 2.</u>

⊛ Etch as given in METALS HANDBOOK, 1939 Edition, pp. 1768-9. (Solutions Nos. 4, 5, and 2).

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Specification for Die Casting Zinc Alloy S.A.E. No. 921 and A.S.T.M. B 86 - 38 T, Alloy XXI: (Covers alloys known generally as "Zamak 2" or "Mazak 2").

Chemical Analysis:

		Per cent
Aluminium	-	3.5-4.5
Copper	-	2.5-3.5
Magnesium	-	0.02-0.10
Iron, maximum	-	0.10
Lead, "	-	0.007
Cadmium, "	-	0.005
Tin, "	-	0.005

The zinc used in the production of this alloy shall be special high grade (99.99+ per cent) pure zinc.

Physical Tests:

Ultimate tensile strength, minimum - 44,000 p.s.i.

Elongation in 2 inches, minimum - 2 per cent.

Charpy impact strength, minimum - 6 ft. lb.

General Information:

This alloy, because it is subject to loss of impact strength and to dimensional changes upon ageing, is rapidly being replaced by the more permanent alloys S.A.E. No. 903 and S.A.E. No. 925.®
Lately its use has been generally restricted to the few parts requiring its superior hardness.

®The specifications for these alloys are:

		S.A.E. No. 903	S.A.E. No. 925
Chemical Analysis:		(Per cent)	
Aluminium,	-	3.5-4.3	3.5-4.3
Copper,	-	0.10 max.	0.75-1.25
Magnesium,	-	0.03-0.08	0.02-0.08
Iron, max.	-	0.10	0.10
Lead, max.	-	0.007	0.007
Cadmium, max.	-	0.005	0.005
Tin, max.	-	0.005	0.002
Physical Tests:			
Ultimate tensile strength, min.		35,000 p.s.i.	40,000 p.s.i.
Elongation in 2 inches, minimum		3 per cent.	2 per cent.
Charpy impact strength, minimum		12 ft. lb.	12 ft. lb.

DIE-CASTING TECHNIQUE:

1. Influence of the Chemical Composition.

The higher copper alloys are stronger but are also liable to brittleness due to the precipitation which occurs as a result of room-temperature ageing. Higher copper content also increases the tendency to hot-shortness of the casting.

Addition of magnesium, necessary to prevent inter-granular corrosion, unfortunately also causes hot-shortness and lower fluidity.

It is essential that the zinc used be of high purity. Castings made of less pure zinc tend to deteriorate and grow because of intercrystalline corrosion.

2. Casting Conditions.

Accurate control of all casting conditions is important. The temperature of the metal and the die and the speed of operation must be determined and kept constant. The regulation of the temperatures should be automatic.

The most favourable casting temperature is 395-410°C. (740-770°F.). Care should be taken not to overheat the metal at any stage in the operation. Higher temperature decreases the life of the die and die-casting machine, and facilitates the oxidation of the molten metal (a possible cause of inclusions of the insoluble zinc oxide in the casting). Higher melting temperature also causes holes and hot-shortness in the die casting, lower mechanical properties, and coarser grain size.

Pressure die castings (cold chamber type) are frequently cast at too low a melting temperature; such a casting is more brittle and the microstructure shows large primary crystal inclusions.

Too low temperature of the die causes poorer surface

(Die-Casting Technique, cont'd) -

(surface cracks) and increases the tendency to corrosion. The best die temperature should be 180-220°C. (355-425°F.). For very complicated castings, however, the die temperature should be lower (in spite of the fact that this will have an unfavourable effect on the surface appearance); if the die temperature is allowed to exceed 220°C. (425°F.) the casting will be brittle.

Pressure on the piston is best about 1,000 p.s.i. (1,000 to 1,700 p.s.i.). Too low a pressure causes lower mechanical properties and porosity of the casting.

Speed of the piston is not so important; average speed should be about 1.2 in./sec. Low speed causes perfect surface but lower mechanical properties; higher speed causes poorer surface and inclination to surface cracks.

For the production of sound die-castings, dimensions of the sprue and the size of the vents which allow for the escape of gases from the die chamber must be carefully controlled. These dimensions are dependent upon the type of the die-casting and of the die-casting machine and must be very carefully calculated.

3. Ageing Effects.

Because of the drastic chilling involved in the die-casting and the fact that the solid solubilities of both aluminium and copper in zinc change with temperature, these alloys are subject to some ageing effects, such as dimensional changes, hardening, drop in impact strength, etc. By using alloys without copper content (e.g. S.A.E. No. 903, Zamak 3) it is possible to prevent further changes by a stabilizing

(Die-Casting Technique, cont'd) -

anneal.

Unannealed copper-containing alloys, however, first show a shrinkage due to the aluminium content, and then an expansion due to the copper content. Annealing will only take care of the former shrinkage.

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Discussion of Results:

The surface inspection and the X-ray examination show that both die-castings have many shrinkage holes, surface cracks and microcavities, which probably originate from bad casting conditions. These defects possibly might have been reduced if a lower copper, lower magnesium alloy had been cast.

Cavities and porosity are caused above all by too high melting temperature and too low pressure on the piston. Other causes are unbalanced dimensions of the sprue (e.g., too small) or of the vents in the die for gases (e.g., too large).

Cold-shuts (Figure 4) on the surface are caused usually by too low a die temperature and too low a pressure on the piston.

Hot-shortness (brittleness in metal when hot), which caused the smaller surface cracks shown in Figure 4, increases with the temperature of the molten metal, also with the copper content and with the addition of magnesium.

Higher copper content and addition of magnesium also decreases the fluidity of the alloy.

The chemical composition compares closely to that specified in American Specifications S.A.E. No. 921 and

(Discussion of Results, cont'd) -

A.S.T.M. B 86 - 38 T, Alloy XXI. The variation in the chemical analysis of the aluminium content determined for the National Research Laboratories (N. R. L. Report PX-79) is probably due to contamination of the sample with other drillings high in aluminium content. The present analyses were obtained from a very carefully prepared sample and were doubly checked.

The hardness should be satisfactory but shows that the cooling rate of the castings was rather high (too low temperature of the die).

The microphotographs show a normal structure for this type of die-cast alloy. Casting No. 1 shows coarser grain size (higher temperature of the molten alloy) than does Casting No. 2 (higher cooling rate).

Conclusions:

The defects in these two die-castings could possibly be caused by any or all of the following:

1. Overheating of the molten metal.
2. Too low a temperature of the die.
3. Insufficient pressure on the piston.
4. Excessive magnesium content.
5. Improper dimensions of the sprue or of the vents in the die for air and gases.

It would be advisable to check each of the above possible causes in determining the correct casting conditions. It would be better to hold the magnesium content lower, e.g. to 0.03 per cent.

Superior hardness of the alloy under investigation

(Conclusions, cont'd) -

is not required in such applications as for pump crankcases. Consideration should be given to the use of a more suitable alloy with less or no copper in its composition.

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