O T T A W A December 4th, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1129.

Examination of a Welded Aluminium Alloy Casting.

(Copy No. 5)

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 Problem:

In a letter dated November 17th, 1941, Mr. K. S. Rawlins, Assistant Chief Inspector (Materials), British Air Commission, Washington, D. C., requested the radiological examination of an aluminium alloy casting which had been rectified by welding. One casting was submitted.

(Origin of Problem, cont'd) -

It was stated that the casting submitted, made in modified 12 per cent silicon alloy, is one of a quantity of 200 which had been machined before the error in the casting was discovered. Inside the casting at the bottom are two saddle bosses which receive the bearing surfaces. These two bosses were out of alignment in the original casting. Consequently the firm who are machining the casting drilled a large hole right through the bottom of the casting, welded in the two bosses in correct alignment, and then closed the outer walls of the casting by welding. Surplus metal was then ground off, as can be seen from visual examination. Before granting permission for the use of this casting it was desired that an X-ray survey of the area should be made, to determine the serviceability of the weld.

The casting is a part of the exactor control. Breakdown of the bosses would merely result in upsetting the calibration of the throttle settings of the engine; it is understood that the pilot would still be able to maintain control of the aircraft. If, however, a piece of the wall of the casting were to fall out in flight the hydraulic fluid which this casting contains would be lost, resulting in loss of control of the engine. The actual pressure exerted on the bosses in service is estimated to be not more than two pounds.

X-Ray Examination:

The X-ray examination, carried out by L. W. Ball (on loan from the National Research Laboratories, Ottawa), (X-Ray Examination, cont'd) -

showed in the original casting many gas cavities, a considerable pinhole porosity, and also, on one side, many inclusions of heavy metals. The section of the casting which was rectified by welding appeared to be satisfactory for the purpose. The joining of the casting and the welded part showed uniformly homogeneous structure. The welded portion is almost completely free from porosity, but there is one area where the metal is thinner than is desirable.

Figures 1 to 4 show some copies (natural size) of the six radiographs that were examined. Due to the difficulty of obtaining a clear photographic reproduction of radiographs of complicated castings, because of large differences in the density of the films, it was necessary to make direct prints.

(Continued on next page)

Figure 1.

RADIOGRAPH OF THE CASTING.

(Note: This is a print of radiograph; consequently, cavities appear as white spots and heavy density areas (such as solder) appear as black spots.)

Figure 2.

RADIOGRAPH OF THE CASTING.

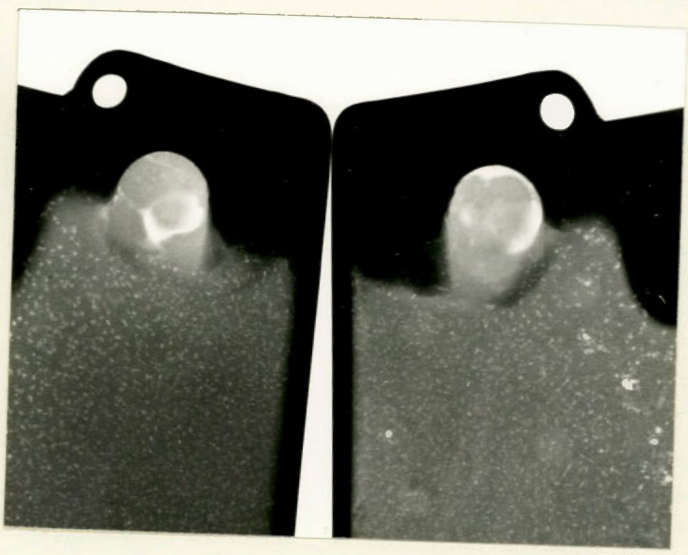
Dark spots - heavy metal inclusions.
White spots - porosity and gas cavities.

Figure 3.

RADIOGRAPH OF THE CROSS-SECTIONED CASTING.

White spots - cavities and porous areas.
Dark spots - heavy density areas.

Figure 4.



RADIOGRAPH OF THE WELDED AREA.
This shows the non-uniformity of the welded metal.

(X-Ray Examination, cont'd) -

X-ray examination made to examine the serviceability of the weld shows that the casting itself would not be considered to be of satisfactory quality, due to porosity, and had been repaired by soldering. This was confirmed by qualitative spectrographic analysis, which demonstrated that the inclusions of heavy metals shown in the radiographs were essentially an alloy of zinc and tin.

From the results of this radiographic examination it was felt that the welding could be considered satisfactory but some doubt was created concerning the casting itself. Accordingly, on November 22nd, 1941, a telegram was immediately dispatched to Mr. K. S. Rawlins in Washington, as follows:

"Re TC/44309 welded aluminium alloy casting radiographic examination shows submitted casting originally very porous which was repaired by soldering stop Questionable in view of importance of this part whether this condition is not more hazardous regardless of any welding as performed stop Thickness of material replaced by welding not uniform also thin but looks to be best part of the casting."

Due to the service which this part is to perform, as stated in the letter of request, a complete examination of this casting was considered advisable.

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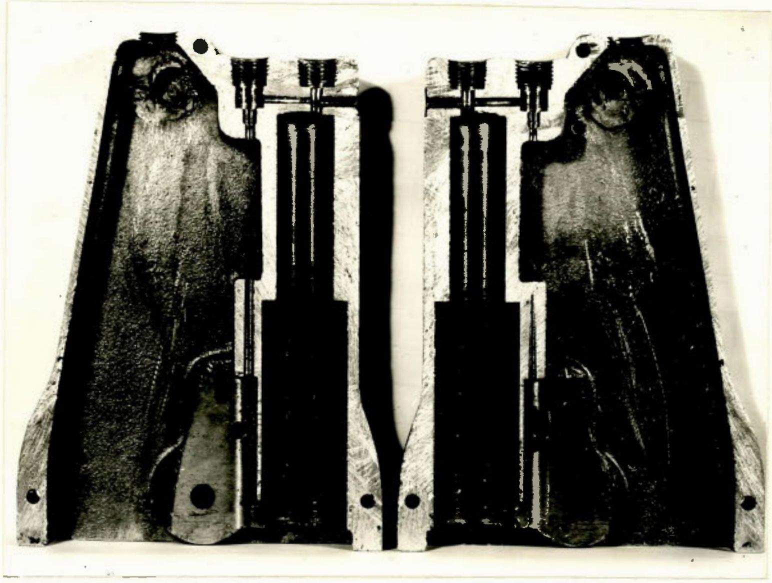
Appearance of the Casting:

The cross-section of the casting is shown in Figure 5.

Figure 5.



CROSS-SECTION OF THE CASTING.
(Approximately 1/3 size).

Upon visual examination of the casting after cross-sectioning, the gas cavities were very clearly shown on the machined surfaces and in the sawed section surface.

Considering the conditions under which the welding had to be done, it is reasonably satisfactory.

Some very loosely attached flux was knocked off during the sawing operation.

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Chemical Analysis:

		Per cent	
Silicon	-	4.90-5.01	(5 determinations)
Copper	-	1.23-1.31	(7 determinations)
Iron	-	0.70	
Manganese	-	0.10	
Magnesium	-	0.14	
Nickel	-	0.01	
Titanium	-	0.02	

Physical Tests:

Tensile Test -

A specimen for the tensile test was cut from the casting, the wide surfaces being left in the "as cast" condition.

The following results were obtained:

Ultimate tensile stress	-	12,700 p.s.i.
Elongation in 1 inch	-	1 per cent.

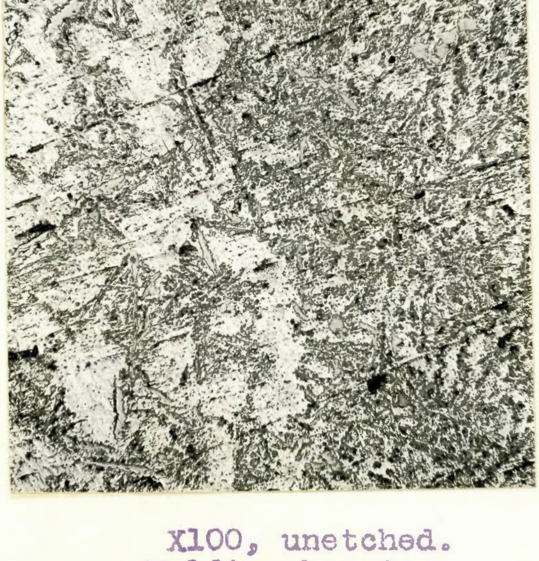
The fractured surface shows holes and non-metallic inclusions.

Hardness Test -

Original casting	-	60-70 V.H.N.
Welded section	-	48-53 V.H.N.

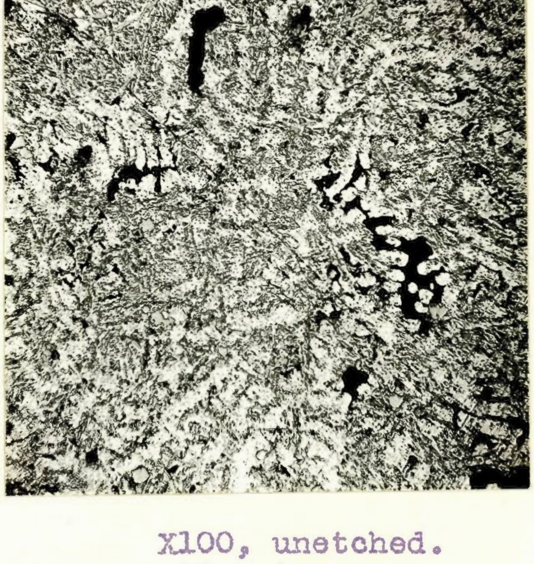
Microstructure:

Figure 6.



X100, unetched.
Welding boundary.

Figure 7.



X100, unetched.
Section in weld area.

(Microstructure, cont'd) -

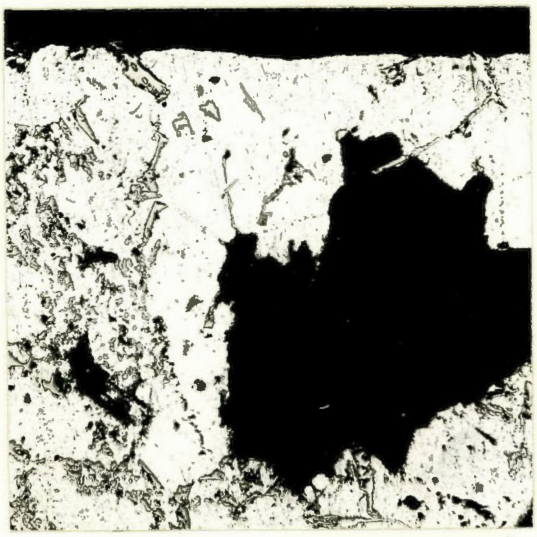
Figure 6 shows that the welding joint is satisfactory. Figure 7 shows some porosity in the welded section and the microstructure indicates that a high-silicon aluminium alloy welding rod was used.

Figure 8.

X100, unetched.

Section of the original casting (remote from the welded area).

Figure 9.



X100, unetched.

Material as cast, near the soldered locations.

Figures 8 and 9 show the microstructure normal for a low-silicon aluminium alloy with copper content. Figure 9 shows considerable porosity and gas cavities, similar to those repaired by soldering.

British Specifications for Aluminium Alloys D.T.D.272 and D.T.D.276:

Chemical Analysis:

		Per cent
Silicon	-	4.5-5.5
Copper	-	1.0-1.5
Magnesium	-	0.4-0.6
Iron	-	0.6 max.
Titanium	-	0.25 max.

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(British Specifications for Aluminium Alloys D.T.D.272 and D.T.D.276, cont'd) -

Tensile Tests:

		Ultimate tensile stress, p.s.i.	Elongation in 2 inches, per cent
D.T.D.272	- Sand cast --	24,640	2
	- Chill cast --	29,120	-
D.T.D.276	- Sand cast --	33,500	-
	- Chill cast --	38,500	-

This specification is similar to the following U. S. specifications: Federal QQ - A-601; A.S.T.M. B 26-37T Alloy N; S.A.E. 322; Alcoa 355; etc.

Discussion of Results:

Radiographic and visual examinations show that the casting is very poor.

Chemical analysis shows that the casting was not made from modified 12 per cent silicon alloy, as stated in the letter, but from a heat-treatable low-silicon aluminium alloy. This alloy is considered suitable for leak-proof castings for aircraft and automotive parts. The analysis conforms to the specification with the exception of magnesium.

The specimens for tensile tests taken by cutting from castings show lower physical properties than regular cast test specimens. In this case, however, porosity of the casting was undoubtedly responsible for the low physicals. The presence of an exceptional number of non-metallic inclusions would also aggravate this condition.

The hardness of the casting, as determined with the Vickers hardness tester, is normal for this type of alloy.

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(Discussion of Results, cont'd) -

The micro-examination shows that the welded area and the joining possess satisfactory structures. The microstructure of the casting (Figure 9) shows porosity cavities and larger gas cavities.

Hardness tests and micro-examination show that the welding was done with a high-silicon aluminium alloy.

Conclusions:

1. The considerable pinhole porosity and many gas cavities in a casting intended for a part the failure of which would cause loss of control of the engine should be sufficient reason for its rejection.

2. The chemical composition used for this part is considered satisfactory, but regardless of composition a proper foundry practice is necessary.

3. The appendix following describes a method which could be used in a 100 per cent inspection for porosity defects of aluminium alloy castings. This method has been obtained from the literature and has not yet been checked in these laboratories.

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APPENDIX.

"Non-Destructive Testing of Light Metal Castings."

(Abstract from METAL INDUSTRY, London, England - vol. 59, No. 19, November 7, 1941, p. 296.)

Recommended Procedure:

(1) Treatment of the casting in a solution of 2 per cent ammonium acetate, 15 per cent potassium dichromate and 83 per cent water, for half an hour at 70 to 80 degrees C.;

(2) Rinsing in running cold water;

(3) Dipping in hot water to expedite drying; and

(4) Examination of any spots after 1 to 4 hours in daylight.

The etching solution is contained in a 5- to 7-mm.-thick pure aluminium container, or an earthenware container may be used. The rinsing tank should likewise be of aluminium or earthenware, as iron is attacked by ammonium acetate.

The test will show up micro-porosity, cracks and surface pores, as well as cold-shuts, by the formation of yellow dichromate spots.

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