O T T A W A July 21st, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1055.

Examination of a Rudder Pedal Leg.

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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REPORT

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Origin of Material:

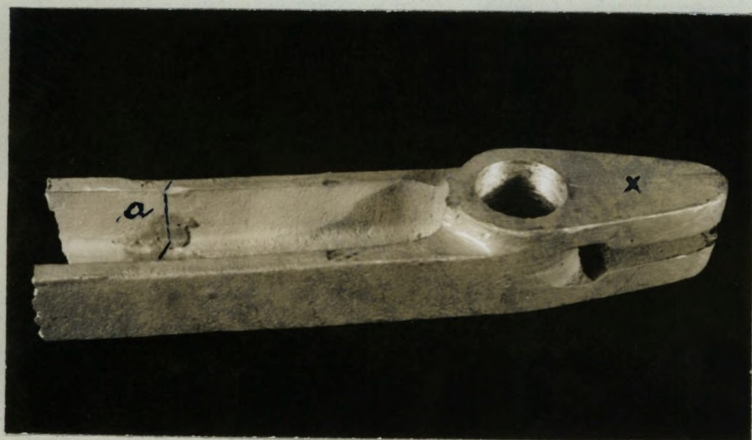
In a letter dated June 30th, 1941, Group Captain A. L. Johnson, Air Service Branch, Department of National Defence, Ottawa, Ontario, requested the examination of a broken piece of a rudder pedal leg, Dwg. 82320 (Federal Aircraft Limited, Montreal).

The broken piece of the casting was received on June 30th, 1941.

Nature of Casting:

Figure 1 shows the broken piece of the casting as received. Figure 2 shows the character of the fractured surface. There were numerous yellowish particles scattered across the complete surface.

Figure 1.



Sample as received.
Approximately ½ size.

Figure 2.

Fracture.
(As received)
Approximately ¾ size.

X-Ray Examination:

The X-ray examination carried out by L. W. Ball (on loan from the National Research Council, Ottawa) showed cavities in two places. The location of these cavities is shown in Figures 3 and 4 by marks "a" and "b".

(See radiographs on
next page)

(X-Ray Examination, cont'd) -

Figure 3.

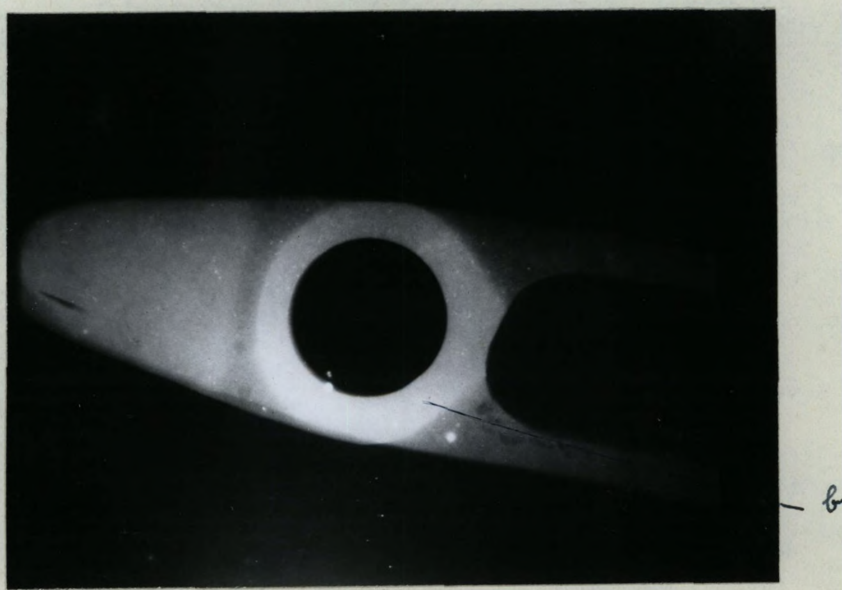
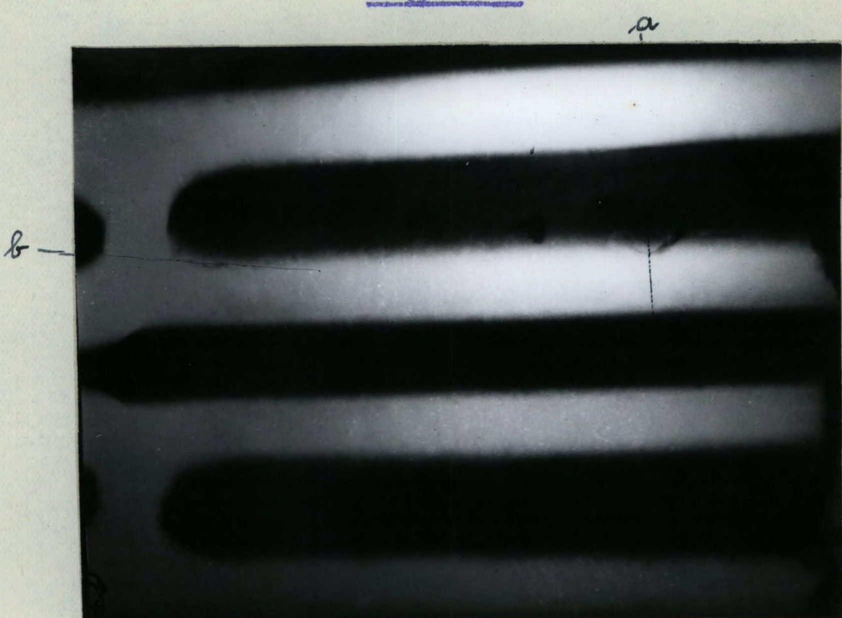


Figure 4.



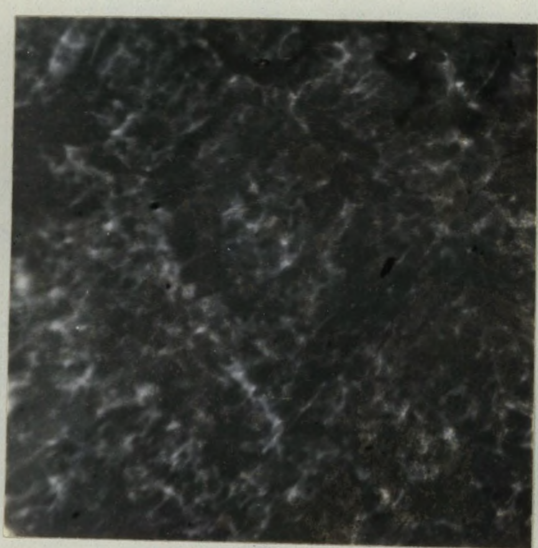
Radiographs.

Thin sections of the metal near the break were examined by the new method of microradiography. Segregation of $CuAl_2$ and very small cavities similar to those seen by

(X-Ray Examination, cont'd) -

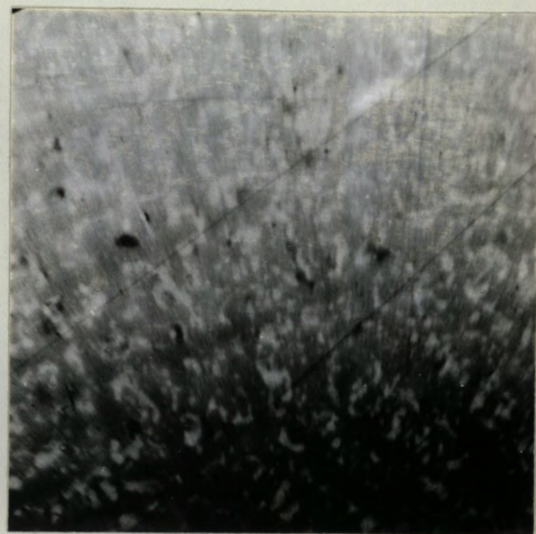
the microscope were shown. Figures 5 and 6 are reproductions of microradiographs made by L. W. Ball.

Figure 5.



X100, approx.

Figure 6.



X100, approx.

Microradiographs.

Chemical Analysis:

		Per cent
Copper	-	4.15
Iron	-	0.82
Silicon	-	0.79
Manganese	-	0.06
Magnesium	-	Nil
Titanium	-	0.16
Zinc	-	Trace only.
Nickel	-	Nil

Physical Tests:

Hardness -

Four different locations in this part were tested

(Physical Tests, cont'd) -

Hardness, cont'd -

for hardness, namely:

(1) In Figure 1, location marked "X":

V.H.N. - 70 to 85.

Hardness taken on cross-section of this part shown in Figure 1 at "a", with locations shown in Figure 7 by marks "c", "d", and "w".

(2) Location "c":

V.H.N. - 60.

(3) Location "d" (near the welded area):

V.H.N. - 70 to 85.

(4) Location "w" (on welded area):

V.H.N. - 100.

Tensile Test -

A specimen for the tensile test was cut from the piece of the casting as received and machined. The specimen so obtained was not of sufficient length for a proof-stress test. The following results were obtained:

Ultimate tensile stress, p.s.i.	-	28,600
Elongation in 2 inches,	-	2 per cent
Elongation in 1 inch,	-	4 "

The appearance of the fractured surface of the test specimen also showed yellow particles.

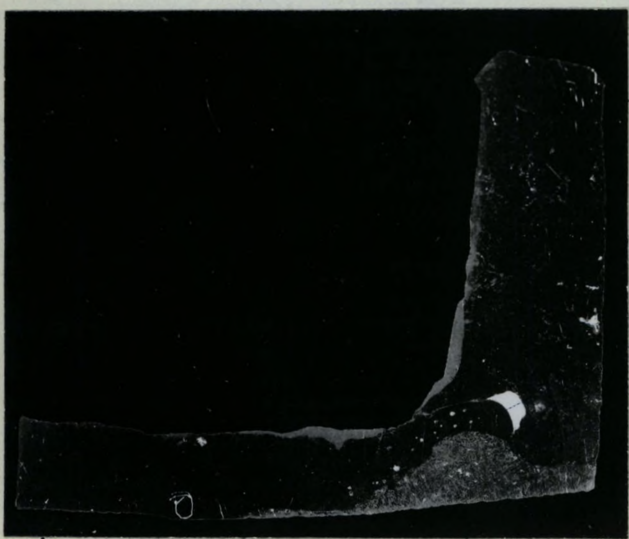
Microstructure:

The characters of the cavities as located by the X-ray are shown in Figure 7 (section shown in Figure 4, marked "a") and Figure 8 (section shown in Figures 3 and 4, marked "b").

(See Figures 7 and 8 on next page)

(Microstructure, cont'd) -

Figure 7.



c d w

X3, polished,
unetched.

Figure 8.

X1.5, rough.

Figure 7 shows that this part was welded on both sides. Probably due to the porosity of this casting, welding was done in order to salvage this particular part.

Figure 8 shows shrinkage cavities.

Figures 9 and 10 show the nature of the welded part. The material used for the welding includes silicon. This was determined by a chemical spot test (as given in "Light Metals" - Vol. 1, 1938, page 355) as well as by the difference in microstructure.

(See Figures 9 and 10
on next page)

(Microstructure, cont'd) -

Figure 9.

X15, unetched.

Figure 10.

X15, unetched.

Figure 11.

X100, unetched.

Section in weld area.

Figure 12.

X100, unetched.

Welding boundary.

(Continued on next page)

(Microstructure, cont'd) -

Figure 13.

X100, unetched.

Material as cast, near the welded area.

Figure 14.

X100, unetched.

Material as cast, remote from welded area.

Figure 15.

X200, etched with Keller's reagent.*

Welding boundary.

Figure 16.

X200, etched with Keller's reagent.*

Material as cast, near the welded area.

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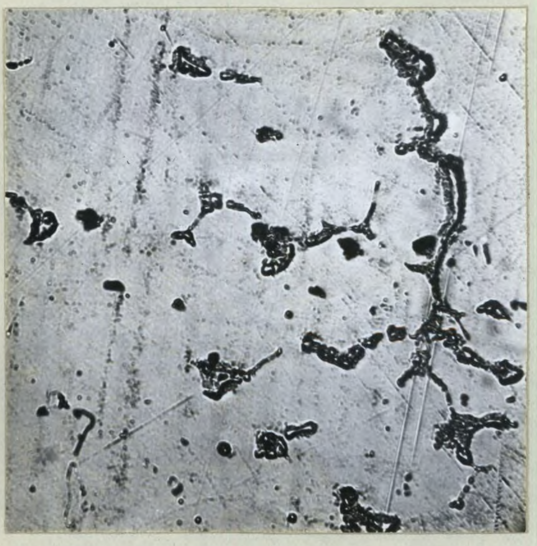
* Keller's reagent: HF, 1 per cent; HCl, 1.5 per cent; HNO_3, 2.5 per cent; and H_2O, 95 per cent.

(Continued on next page)

(Microstructure, cont'd) -

Figure 17.	Figure 18.
	
X200, unetched.	X200, etched with Keller's reagent.*

Section adjacent to the fractured surface, as received.

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* Keller's reagent: HF, 1 per cent; HCl, 1.5 per cent; HNO_3, 2.5 per cent; and H_2O, 95 per cent.

British and American Specifications for Alloys of This Type:

(a) - British Specification D.T.D. 298.
(b) - Specifications S.A.E. 38, A.S.T.M. B 26-37T (Alloy G), and Alcoa 195-T4.

Chemical Analysis:	Per cent (a)	Per cent (b)
Copper	4.0-5.0	4.0-5.0
Iron	0.7 max.	1.0 max.
Silicon	0.9 max.	1.2 max.
Manganese	*	0.05 max.
Magnesium	*	0.03 max.
Titanium	0.25 max.	0.20 max.
Zinc	*	0.05 max.
Other impurities.	0.20 max.	0.05 max. each.

* Included in "other impurities".

(Continued on next page)

(British and American Specifications for Alloys of This Type, cont'd) -

Tensile Test:

	(a)	(b)
Ultimate tensile stress, p.s.i.	31,000 min.	29,000 min.
Elongation in 2 inches,	Minimum, 7.0 per cent.	Minimum, 6.0 per cent.

DISCUSSION OF RESULTS:

The X-ray examination shows many cavities and the porosity of the whole part. Microradiographs show also the segregation of the $CuAl_2$.

The chemical composition compares closely to that specified in British Specification D.T.D. 298 and in the following American specifications: S.A.E. 38; A.S.T.M. B 26-37T, Alloy G; and Alcoa 195-T4.

The tensile test specimen, being taken from a section of the casting itself rather than a standard test bar, would yield lower results both in strength and elongation. The rather unsatisfactory elongation would possibly also be affected by the porosity of the casting.

The variations of the hardness shows that the metal has been affected by the heating during the welding operation and the different rate of cooling afterward.

The segregation of copper particles shown in the fractures may possibly have been caused also by the welding operation.

The micro-examination shows that considerable

(Discussion of Results, cont'd) -

porosity existed in the casting and also shows the character of the welding. The welding material included silicon (determined by chemical spot test) and copper (indicated by hardness tests). The microstructure adjacent to the fractured surface shows pronounced segregation of $CuAl_2$.

Conclusion:

Heat-treated aluminium-alloy castings intended for use in aircraft construction should not be repaired by welding. In cases where this might be necessary, extreme care should be taken to prevent any change in the structure.

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