O T T A W A January 10th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1145.

Examination of Material in Spar Member
and Elevator Hinge from Cessna-Crane
Aircraft 7664.

(Copy No. 8 .)

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 Material:

On December 15th, 1941, two metallic specimens that had fractured in service were received from Mr. A. C. Halferdahl, of the National Research Council, Ottawa, Ontario, for examination. One of the samples was from a steel tubing that had functioned as a spar member on Cessna-Crane Aircraft 7664. The other was from a magnesium-alloy hinge

(Origin of Material, cont'd) -

that had been fastened to the elevator of the same aircraft. This aircraft had failed in service.

The Problem:

The complete elevator mechanism had been sent to the National Research Council, Ottawa, by Wing Commander A. F. Britton, of the Department of National Defence (Air Services), Ottawa. The spar from which the steel specimen had been taken ran the length of the two elevators. The elevators had been supported by a centrally located steel hinge and four magnesium-alloy hinges, two at the outside and two at the centre of each of the two elevators. The magnesium-alloy specimen had been cut from one of these hinges.

Both steel spar and magnesium alloy hinges were broken, the former almost in the centre, the latter in the curved portion just removed from the base. The problem was to determine which member failed first. The shape of the spar, one half of which was straight and the other bent, indicated that failure had occurred first in the hinge, as one would expect that a failure in the centre of the spar would bow it about the point of failure in the event that failure was accompanied by plastic deformation. The evidence, however, is not too conclusive, as the bending may have been produced when the spar hit the ground after the accident.

These laboratories had previously examined a section of a spar from a Cessna-Crane aircraft which had failed in a similar fashion. The examination (Report of

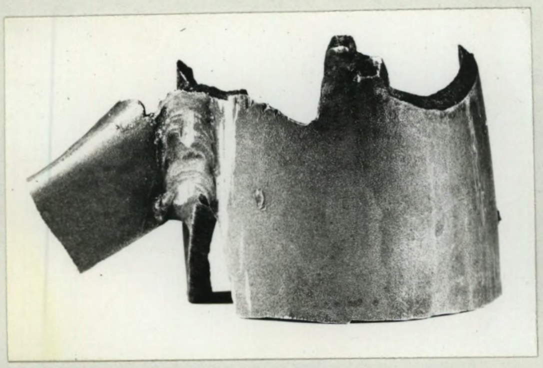
Investigation No. 1106, October 9th, 1941) indicated that the steel was in good condition and that it was unlikely that the failure had been caused by alternating stresses.

The Cessna-Crane aircraft that had crashed were only two out of five hundred that were in service. As the remaining aircraft are still flying the problem is one of some moment.

Macroscopic Examination:

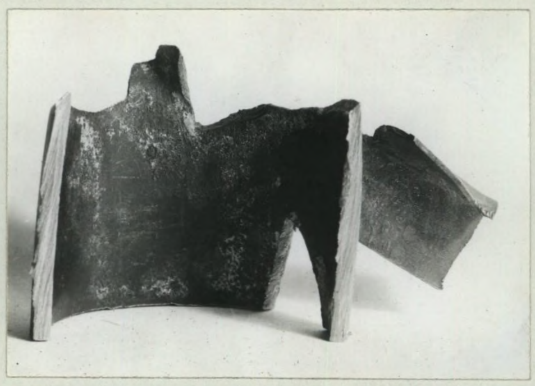
Figures 1 and 2 show the nature of the steel specimens received, the photographs being approximately to size:

Figure 1.



Spar fracture.

Figure 2.



Spar fracture.

In a letter dated December 15th, 1941, Mr. Halferdahl indicated that he had made a thorough study of the fracture exhibited in these photographs. Consequently, no further examination was made.

The hinge fracture is shown, approximately to

(Macroscopic Examination, cont'd) -

size, in Figures 3 and 4:

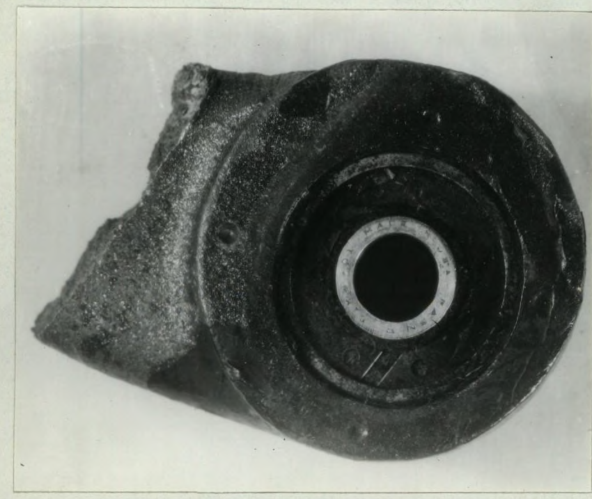


Figure 3.

Hinge fracture.

Figure 4.

Hinge fracture.

(Approximately to size)

Figure 3 shows the location of the break, while Figure 4 shows that the fracture, apart from a small bruise at one end, has a uniform appearance.

Chemical Analysis:

The following table gives the analyses of the steel and magnesium alloy, as well as the composition of various comparative materials:

(Continued on next page)

(Chemical Analysis, cont'd) -

Steels

	Carbon, per cent	Manganese, per cent	Molybdenum, per cent	Chromium, per cent
Spar -	0.31	0.55	0.18	1.10
S.A.E. X4130 -	0.25-0.35	0.40-0.60	0.15-0.25	0.80-1.10

Magnesium Alloys

	Aluminium, per cent	Zinc, per cent	Manganese, per cent	Silicon, per cent
Hinge	6.28		0.15	0.54
Dow Metal H	6	3	0.2	
A.S.T.M. B80-41T Alloy 4	5.3-6.7	2.5-3.5	0.15 min.	0.30 max.
D.T.D. 289	8.5 max.	3.5 max.	0.5 max.	

Hardness Tests:

Mr. Halferdahl had made a survey of the hardness of the welded steel section and reported Vickers hardnesses of 203 in the weld and 270 in the intermediate zone. The magnesium alloy was found to have a hardness of 70, as determined by the Vickers method, using a 10-kilogram load.

Microscopic Examination:

In Figure 5 the steel structure is shown at X1000 magnification. The structure is finely pearlitic and contains some ferrite.

(See Figure 5 on next page)

(Microscopic Examination, cont'd) -

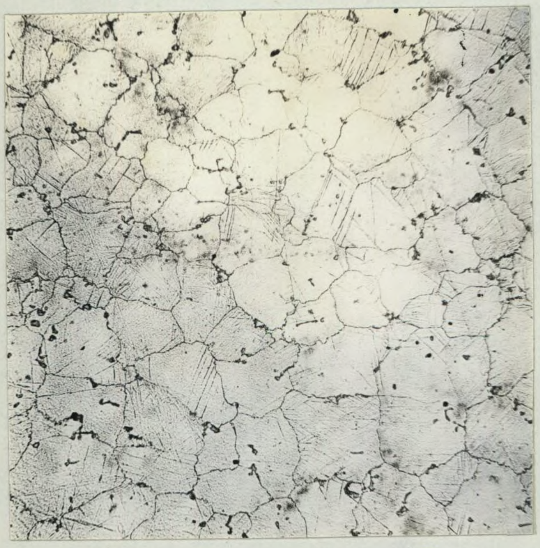
Figure 5.

X1000, etched in
2 per cent nital.

STEEL STRUCTURE.

Figures 6 and 7, at X100 and X250 magnification respectively, show the structure of the magnesium alloy.

Figure 6.



X100, etched.⊕

Figure 7.

X250, etched.⊕

MAGNESIUM ALLOY.

⊕ ETCHANT:	Diethylene glycol	-	75 per cent
	Nitric acid	-	1 "
	Distilled water	-	24 "

These figures show that the alloy is a single phase,

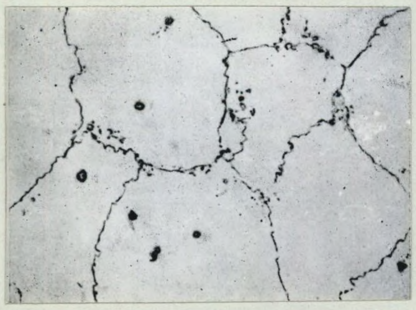
(Continued on next page)

(Microscopic Examination, cont'd) -

all constituents being in solution.

Figures 8 and 9 show respectively the heat-treated and heat-treated-and-aged structures for an alloy of approximately the same composition as the metal in the hinge, these photomicrographs being taken from A. Beck's THE TECHNOLOGY OF MAGNESIUM AND ITS ALLOYS (London, 1940) - Figures 57 and 60, on Pages 50 and 51.

Figure 8.



X200, etched.

SOLUTION HEAT-TREATED.

Figure 9.

X200, etched.

SOLUTION HEAT-TREATED AND AGED.

. .

Discussion of Results:

Macroscopic Examination -

In so far as the steel is concerned the failure does not appear to have been caused by alternating stresses, as there was a fair amount of plastic deformation at the point of failure. This also was true of the steel specimen that had been taken from the spar of the other wrecked Cessna-Crane aircraft. The lack of distortion in the magnesium-alloy hinge failure is consistent with the assumption that it failed in fatigue. One would, however, expect that a fracture produced by alternating stresses

(Discussion of Results, cont'd) -

would not be of such uniform appearance.

Chemical Analysis -

Chemical analysis confirmed that the materials were of the type reported, namely, S.A.E. X4130 steel and Dow Alloy H.

Hardness Tests -

Hardnesses reported for the steel are those that would be expected in welded S.A.E. X4130 steel. This steel would be expected to have the following physical properties:

Tensile, p.s.i.	Yield, p.s.i.	Elongation, per cent
95,000	72,000	7 per cent.

The hardness of the magnesium alloy is that which is obtained after a heat-treatment and ageing. The microscopic examination, however, would indicate that the hinge had only been given a solution heat-treatment. It is probable, then, that the hardness of the part has been increased somewhat by the cold working that accompanied failure. The following table lists physical properties for this alloy as given by the A.S.T.M. and the Dow Chemical Company, as well as the details of the heat treatments that confer these properties:

	HEAT TREATED ⊕		HEAT TREATED AND AGED ⊕⊕	
	Dow values	A.S.T.M. values	Dow values	A.S.T.M. values
Tensile, p.s.i. -	38,000	32,000	38,000	34,000
0.2% Proof, p.s.i. -	12,000	11,000	19,000	16,000
Elongation, per cent	11	7	5	3
Brinell hardness -	55		70	
Endurance limit, p.s.i. -	10,000		10,000	

⊕ Heated at 435°C. for approximately 16 hours and cooled rapidly.
⊕⊕ " " " " " " " ", cooled rapidly, and then reheated at approximately 210°C. for 8 hours.

(Discussion of Results, cont'd) -

Microstructure -

The structure of the steel is normal for X4130 steel. This also applied to the welded areas examined. The magnesium-alloy structure is that produced by a solution heat-treatment. Inasmuch as this treatment confers better ductility than the solution-and-ageing treatment without lowering the fatigue strength perceptibly, it would seem that the hinge material has received the best possible heat treatment. The single-phase material would also be expected to have a better corrosion resistance.

Summary:

No defect was found in the steel tubing.

From a metallographic standpoint, the magnesium alloy appeared to be in a satisfactory condition. National Research Council work, however, revealed what may have been a fatigue crack in this metal and showed also that the metal had opened up at locations near the point of fracture.

Stress analysis results reported at the conference held at the National Research Council in Ottawa on January 8th, 1941, would show that the spar design meets the airworthiness requirements while the hinge does not, if consideration be given to certain severe loads that are liable to be applied momentarily.

Summarizing, then, the following factors indicate that the magnesium-alloy hinge failed before the steel spar:

1. There was no defect found in the steel, and defects in steel are usually easily recognizable.
2. There was some evidence of minor defects in the

(Summary, cont'd) -

magnesium-alloy hinge.

3. Stress analysis figures showed that the steel spar had a much larger factor of safety and there is no reason to assume that this spar would be submitted to an extraordinary stress that the hinges would escape.

4. The bend in the spar member is the type that would be produced if the hinge had failed first.

Although it has not been definitely proven, it is concluded, then, that a magnesium-alloy hinge failure (which most probably was produced as a result of heavy alternating stresses or a stress suddenly applied) was responsible for the crash. It may be wondered why more failures have not been encountered in other Cessna-Crane aircraft. It may be that the castings in the two wrecked aircraft were the only defective ones produced. It is more probable, however, that the broken castings were submitted to an unusually severe service.

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