3 Ex.

FILE COPY

O T T A W A March 19, 1945.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1817.

Metallurgical Examination of Pin from
Aircraft Aileron Control System.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

O T T A W A March 19, 1945.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1817.

Metallurgical Examination of Pin from Aircraft Aileron Control System.

Origin of Material and Object of Investigation:

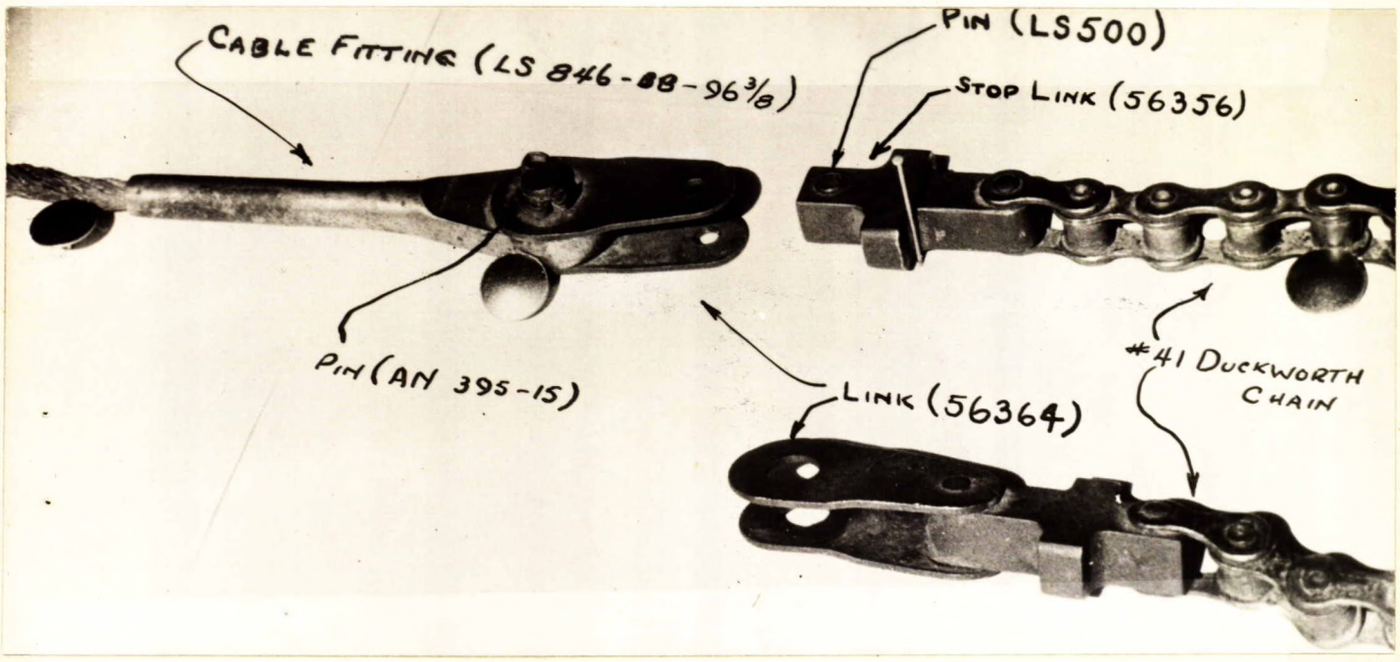
On March 13, 1945, a control column chain, taken from the Aileron control system of Trans-Canada Air Lines Aircraft No. 28 (CF-TCF) which had crashed at Moncton, N.B. on February 27, 1945, was received from the Department of Transport. Mr. P. E. Lamoureux, Materials and Process Engineer of Trans-Canada Air Lines, Stevenson Field, Winnipeg, Manitoba, who witnessed all tests performed at the laboratories, supplied a new chain assembly and spare parts whose properties were compared with those of the failed parts.

The pin (LS500) connecting the stop link (Lockheed Part 56356) and the links (Lockheed Part 56364) had failed in double shear, both heads being lost. These parts with their corresponding identification numbers are shown in Figure 1.

(Continued on next page)

(Origin of Material and Object of Investigation, cont'd) -

Figure 1.



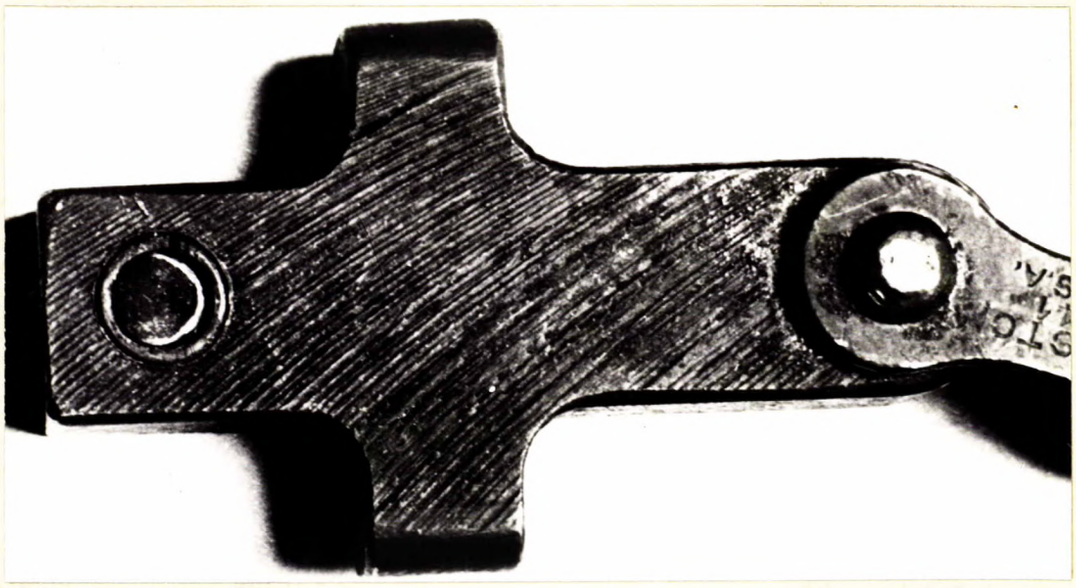
VIEW OF CONTROL COLUMN CHAIN
AS RECEIVED AT PMRL.

(Approximately $\frac{3}{4}$ full size).

Figures 2 and 3 show both sides of the stop link with the broken pin still in place.

(Continued on next page)

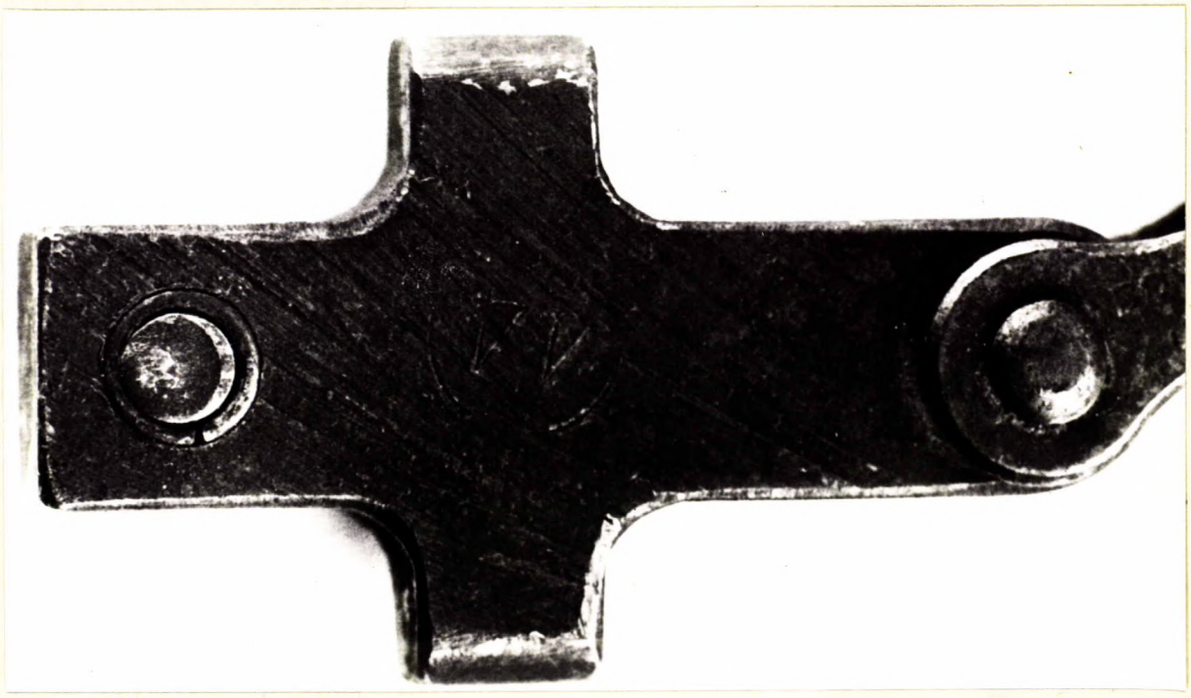
Figure 2.



STOP LINK WITH SHEARED PIN IN PLACE.

(Approximately 3 times full size).

Figure 3.



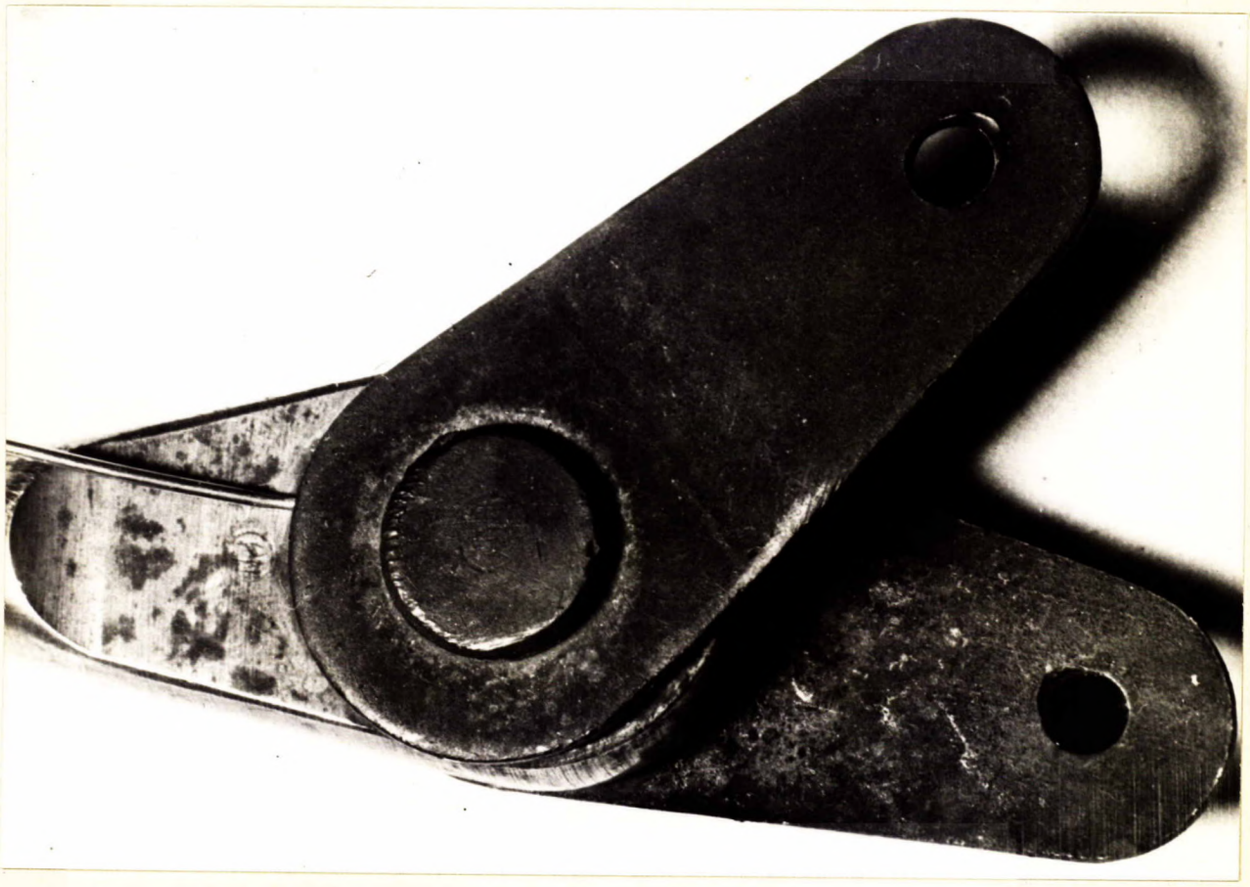
OPPOSITE SIDE OF STOP LINK.

(Approximately 3 times full size).

(Origin of Material and Object of Investigation, cont'd) -

Figure 4 is a view of the links which connected the stop link to the cable fitting. It will be noted that some distortion had taken place on the outside of one link and on the inside of the other.

Figure 4.



LINKS (LOCKHEED PART 56364).

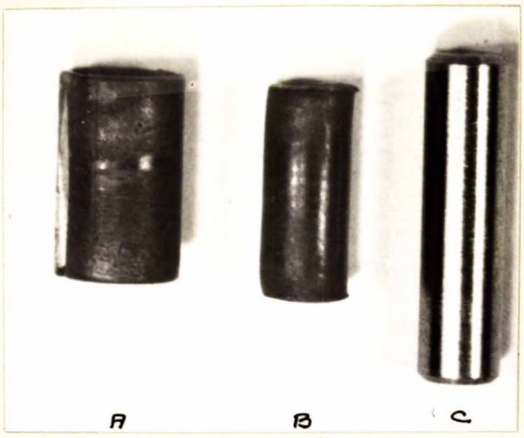
(Approximately 4 times full size).

A view of the sheared pin is shown at B in Figure 5. A is the bushing removed from the broken pin while C is an unused pin.

(Continued on next page)

(Origin of Material and Object of Investigation, cont'd) -

Figure 5.



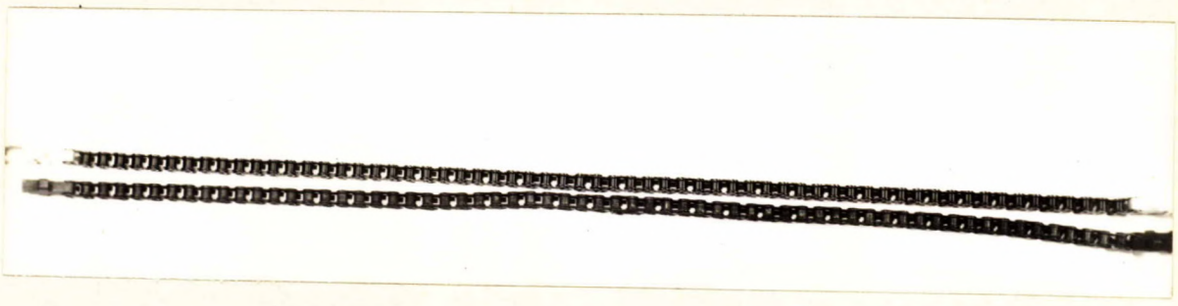
A. - Bushing from sheared pin.
B. - Sheared pin.
C. - New pin.

(Approximately 3 times full size).

-

The chain (#41 Duckworth) also had been distorted. Maximum distortion in the links had occurred at a point 14 inches from the sheared LS500 pin. When placed against a full-scale drawing, this point was found to fall on the control wheel sprocket. A view of the chain alongside an unused chain is shown in Figure 6.

Figure 6.



DISTORTION IN CHAIN.

(Approximately ¼ full size).

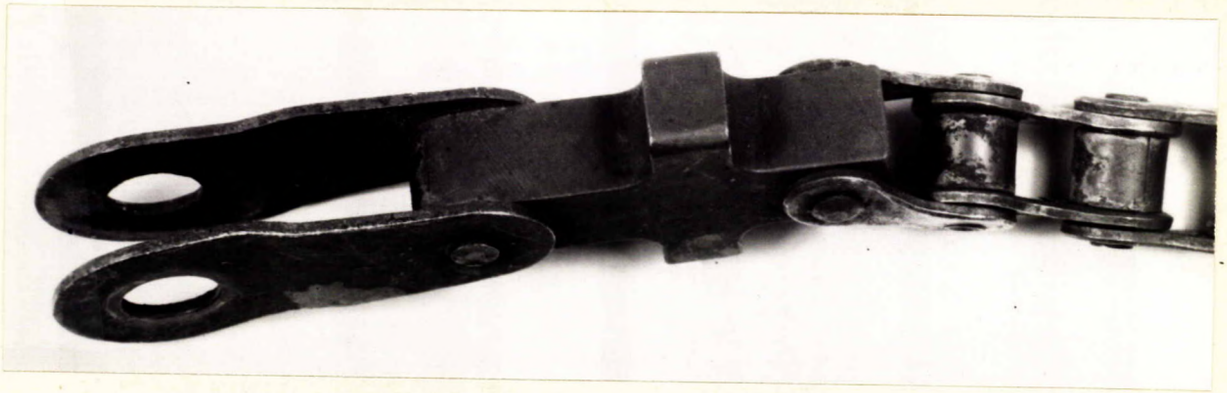
-

A certain amount of twisting had also taken place. This was, for the most part, at the end of the chain furthest

(Origin of Material and Object of Investigation, cont'd) -

from the break. This is illustrated in Figures 7 and 8.

Figure 7.



TWIST IN LAST LINK OF CHAIN.

(Approximately twice full size).

-

Figure 8.

SIDE VIEW OF CHAIN SHOWING TWIST.
(Approximately twice full size).

-

The examination of the failed assembly was carried out with the object of:

1. Determining whether the failed pin complied with specifications.

2. Determining whether the failed pin had been subjected

(Origin of Material and Object of Investigation, cont'd) -

to its breaking stress.

3. Determining whether the pin failed before or after the crash.

Procedure:

A new control chain assembly which had been certified airworthy by Lockheed Aircraft Corporation, Burbank, California, was tested for strength. One-half of the chain was first pulled slowly. A Duckworth #41 pin in the chain failed under a load of 2,060 pounds.

A view of this fractured portion is shown in Figure 9.

Figure 9.

FRACTURE IN CHAIN (Breaking load - 2,060 lb.)

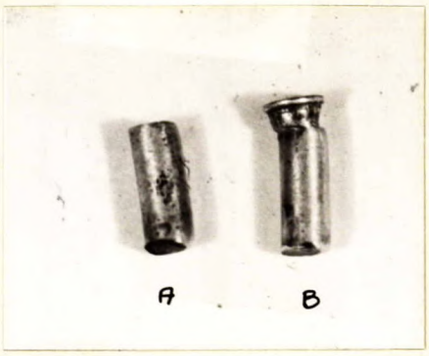
(Approximately twice full size).

The remaining portion of this half was then retested and the LS500 pin failed at one end only under a load of 2,200 pounds (see B in Figure 10). The second half of the chain was then tested using a more rapid application of loading. In this test the LS500 pin broke in double shear under a load of 2,100 pounds. This pin is shown at A in Figure 10.

(Continued on next page)

(Procedure, cont'd) -

Figure 10.



LS500 Pins

A. - Failed in double shear.
B. - Failed in single shear.

(Approximately twice full size).

This latter pin failed in the same way as had the pin in the failed control assembly and the fractures presented the same appearance.

The properties of these two pins were then studied with the object of comparing the properties of the LS500 pin from the crashed aircraft with those of the pin from the new chain which had proved satisfactory during the tests.

Hardness readings were taken using the Vickers hardness tester with a 5-kilogram load. The average hardness of the failed pin was 175, while that of the pin from the tested chain was slightly harder, being 226. These values were then checked using a 100-gram load on the Tukon hardness tester.

The diameters of the two pins were also measured. The averages of three readings on each were taken. The pin which failed in service was 0.1480 inches in diameter while the pin which failed under test measured 0.1445 inches. Specification calls for a diameter of 0.140 inches before

(Procedure, cont'd) -

peening.

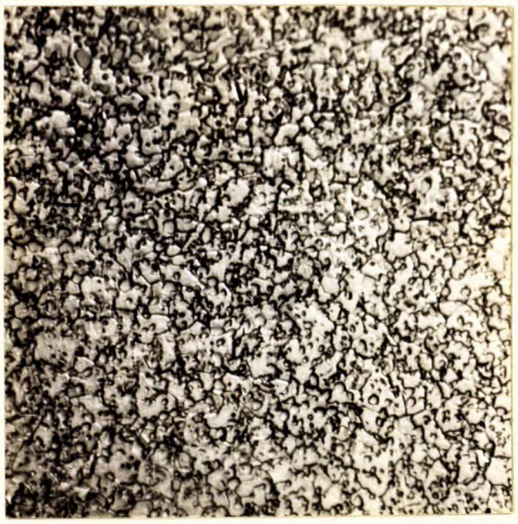
Spectrographic analyses were also carried out since the samples were too small for ordinary chemical analysis. The spectrograph is unable to determine carbon, sulphur and phosphorus but can determine accurately the similarity of two steels. This test showed the steel in the two pins to be very nearly identical.

Complete chemical analyses of the pins was impossible, due to the small size of the pins, but carbon dertemination was made. The pin that failed in service contained 0.84 per cent carbon while the one which failed in test contained 0.78 per cent carbon.

Micro-Examination:

The microstructures of the two samples were also compared. They proved to be practically identical, consisting of spheroidized carbides in a matrix of ferrite--the accepted structure of spheroidized carbon drill rod. The microstructures are shown in Figures 11 and 12.

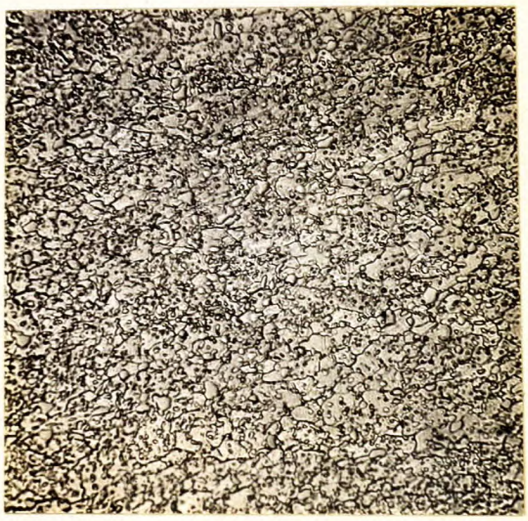
Figure 11.



X500, nital etch.

MICROSTRUCTURE OF LS500
PIN FROM CRASHED AIRCRAFT.

Figure 12.



X500, nital etch.

MICROSTRUCTURE OF LS500
PIN BROKEN IN TEST.

(Micro-Examination, cont'd) -

From these two photomicrographs it can be seen that the spheroidized structure of the pin which failed under test was finer than that of the pin taken from the crashed aircraft. This agrees with the hardness results which showed the tested pin to be slightly harder.

..

One pin was taken from the chain which had failed in service and examined. No shear was observed, although the pin was taken from the most distorted part of the chain. No shear was found in the LS500 pin taken from the opposite end of the failed chain.

Discussion:

The equivalent tensile strength figures for the two pins were as follows:

	V.P.N.	p.s.i.
Pin which failed in service -	175	88,000
Pin which failed in test -	225	114,000

The figures for tensile strength were obtained by multiplying the equivalent Brinell hardness number by 500. The shear strengths would be approximately three-quarters of this or 66,000 p.s.i. and 85,500 p.s.i. respectively. This gives strengths of 122,000 and 171,000 p.s.i. in double shear. Multiplying by the area of the pins gives dead loads of approximately 2,100 pounds and 2,800 pounds respectively. Both these values are above the specified design load of 1,222 pounds (Lockheed Report No. 910).

The fact that no shear was observed in the LS500 pin taken from the other end of the chain that had failed in service would seem to indicate that the stop link at that end of the chain had been against the stops, i.e., the wheel was "hard over" and that the LS500 pin at that end had not been subjected

(Discussion, cont'd) -

to the stress which had broken the pin at the other end of the chain.

The similarity of the method of failure and of the faactures between the pin which had failed in service and that which had failed under rapid application of loading in the tensile test would seem to indicate that failure of the chain in service had occurred in much the same way.

Although no definite conclusions can be drawn as to why maximum distortion in the chain occurred at a point on the control wheel sprocket, it is likely that there was some violent wrenching action at this point.

Lack of decarburization on the sheared ends of the LS500 pin does not constitute definite proof that failure of the pin occurred after the fire which consumed the aircraft. Temperatures high enough to cause decarburization may not have been attained.

Conclusion:

Conclusive proof that the pin failed either before or after the crash is lacking. It can be said, however, that the pin complied with specifications and that consequently the pin must have been subjected to a stress greater than the designed breaking stress, and that this stress was rapidly applied. If, in the opinion of aeronautical engineers, these designed stresses could not have been exceeded while the plane was in the air then failure must have occurred at the time of the crash.

oooooooooooo
ooooo
o

TCH:GHB.