O T T A W A November 12th, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1117.

Examination of a Welded Wing Strut.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

O T T A W A November 12th, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1117.

Examination of a Welded Wing Strut.

Origin of Material and Object of Investigation:

On November 1st, 1941, a welded wing strut was received from G. E. Wallingford, for Chief Aeronautical Engineer, Air Services, Civil Aviation Division, Department of Transport, Ottawa, Ontario. The steel strut, described as "a starboard inner interplane diagonal bracing strut, taken from Fleet Aircraft CF-ANG," had failed in the air, causing collapse of the wing.

Macroscopic Examination:

The entire strut assembly is shown in Figure 1. It consists of an S.A.E. X4130 steel streamlined tube, 0.049 x 0.709 x 1.702 in., as depicted in Figure 2. A U-terminal 0.095 inch thick is welded at each end of the tube and forms an anchorage for a bolt. One of these U-terminals, described as attached to the front starboard mainplane spar fitting, was broken at the weld, as shown in Figure 3. Close examination of this part revealed a crack approximately ½ inch long extending from the side of the terminal into the intermediate zone, i.e., the zone adjacent to the weld seam (see location on Figure 4, magnification X5).

Hardness Tests:

Hardness tests were made at various points along the weld. The Vickers method with a 10-kilogram load was used. (The Vickers hardness numbers in this range of hardness are approximately equivalent to the Brinell numbers.)

		V.H.N.
Strut tube -		
Unwelded metal	-	270
Intermediate zone	-	294
Along weld	-	205-222.
U-terminal -		
Unwelded zone	-	256
Near crack (intermediate zone)	-	281-285
On weld	-	181

..

Magnaflux Tests:

Magnaflux tests were made by Mr. S. Gertsman, of this Department, on the weld that did not fail. Longitudinal and circular magnetizations did not reveal any defect.

Chemical Analysis:

A sample milled from the strut tube analysed as follows:

Carbon	-	0.34	per cent
Manganese	-	0.61	"
Chromium	-	0.92	"
Molybdenum	-	0.2	"

A sample was also taken from the U-terminal and it gave the following results upon analysis:

Carbon	-	0.34	per cent
Manganese	-	0.49	"
Chromium	-	0.89	"
Molybdenum	-	0.2	"

Microscopic Examination:

Specimens cut from the U-terminal which failed and also from the strut tube were given a metallographic polish and examined under the microscope. Examination in the unetched condition showed the material from both the tube and the terminal to be made of clean steel. The specimens were etched in a 2 per cent solution of nitric acid in alcohol. Figure 4 (magnification X5) shows a section of the welded parts taken ¼ inch from the side, the thicker portion bent near the weld (which appears lighter in shade) being the U-terminal. A very irregular crack is clearly visible (even at this low magnification) and extends across the entire thickness in the intermediate zone of the weld adjacent to the weld seam which is in dark

(Microscopic Examination, cont'd) -

contrast with the rest of the base material. The minimum thickness of the material at the weld measures approximately 0.03 inch. A large bright spot and several small ones are visible on the weld of the U-terminal and seem to form a chain extending up to the point where the weld has failed. These spots are blowholes, as is evidenced in Figure 5 (magnification, X40) and Figure 6 (magnification, X100), which give enlarged pictures of these blowholes.

Figure 7, magnification X100, shows the crack at the base of the weld, in the intermediate zone, while Figure 8, magnification X100, shows a portion of the same crack at higher magnification. As is seen in this last photomicrograph, the crack follows the grain boundaries and is therefore very irregular in appearance. The grain structure appears coarser at this intermediate zone of the U-terminal and the pearlite appears to be finer in some areas. Figure 9 (magnification X250) was taken from the U-terminal at the zone where the weld and base metal are in contact. The white constituent present in much larger amount in the weld portion is ferrite and the darker constituent is pearlite, the eutectoid of iron and iron carbide. Figure 10 (magnification X250) also shows the zone of fusion between the weld and base metal on a section of the weld on the strut tube. The two large dark areas are blowholes.

Discussion of Results:

Macroscopic examination indicates that a crack was starting in the intermediate zone adjacent to the weld seam of the U-terminal. Such a condition is often observed in the metal adjacent to a weld and is recognized as very harmful, since it is sufficient to determine a fatigue failure under high vibratory stress. However, in the present case, failure actually took place in the weld and not in the intermediate zone.

According to some results published by Whittemore and Brueggeman (Technical Publication 348, pp. 323-359, 1930 U. S. Nat. Advisory Committee for Aeronautics), the hardness number on welded S.A.E. X4130 tubing averaged 240 for the unwelded material tested, 275 for the zone adjacent to the weld seam, and 175 for the weld metal. Hardness results observed here are conforming with these averages.

The S.A.E. specifications call for the following chemical composition for X4130 steel:

		Per cent
Carbon	-	0.25-0.35
Manganese	-	0.40-0.60
Chromium	-	0.80-1.10
Molybdenum	-	0.15-0.25

The straight S.A.E. 4130 steel differs from the S.A.E. X4130 in that it has a higher manganese content. The analyses of samples milled from the strut tube and from the U-terminal conform respectively to the requirements of specifications of the S.A.E. X4130 and 4130 steels.

Fusion is fairly good between the weld and the base material (Figures 9 and 10). The weld metal contains

(Discussion of Results, cont'd) -

less carbon than the base metal, as can be seen by the lower amount of pearlite (grey constituent) present in the weld. (Figures 9 and 10).

Such blowholes as shown in Figures 5 and 6 are sufficient to considerably reduce the endurance limit of the weld and to contribute in bringing fatigue failure under high repeated stress. The lack of homogeneity in the welded material may come from some of the following: unsuitable fluxing, moisture on the weld, or improper welding technique such as hesitating before breaking the arc, backing up over the previously deposited metal, etc. These flaws can be detected by X-ray examination.

Summary:

Examination of a welded strut assembly which failed in service showed that:

1. The steel used in the strut tube and U-terminal is of good quality and conforms with the specification requirements.
2. A fatigue failure occurred in the weld.
3. The fatigue fracture progressed from some blowholes in the weld and under repeated high stress finished by sudden tearing.
4. A detectable crack was slowly progressing in the intermediate zone and would have been sufficient to determine a fatigue failure if the weld had resisted longer.

Conclusion and Recommendations:

In the present case, the internal stress concentration due to blowholes in the weld has contributed to the failure of the parts under examination.

The following are recommended:

1. Welding with a crater eliminator.(*)

2. X-ray examination of the weld seam, to detect flaws after welding.

3. Periodic magnafluxing of the welded areas to detect fatigue cracks.

0000000000000
0000000
000

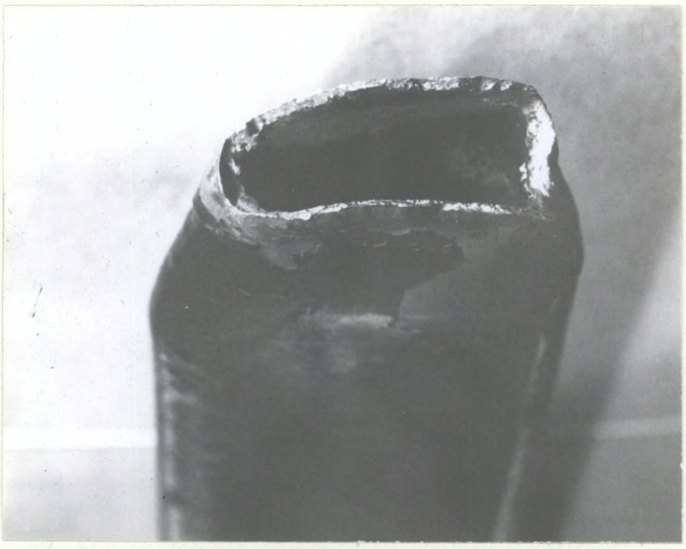
RP:PES.

(*) The crater eliminator slowly extinguishes the arc (by decreasing gradually the current) in order to allow the gas included in the weld to escape before solidification of the metal. (See "Arc Welding S.A.E. X4130," STEEL, Nov. 3, 1941.).

Figure 1.

Strut assembly, approximately $\frac{1}{4}$ size.

Figure 2.



S.A.E. X4130 steel streamlined tube, approximately natural size.

Figure 3.

U-terminal, showing failure at weld. (Approximately to size).

Figure 4.

X5 magnification,
nital etch.

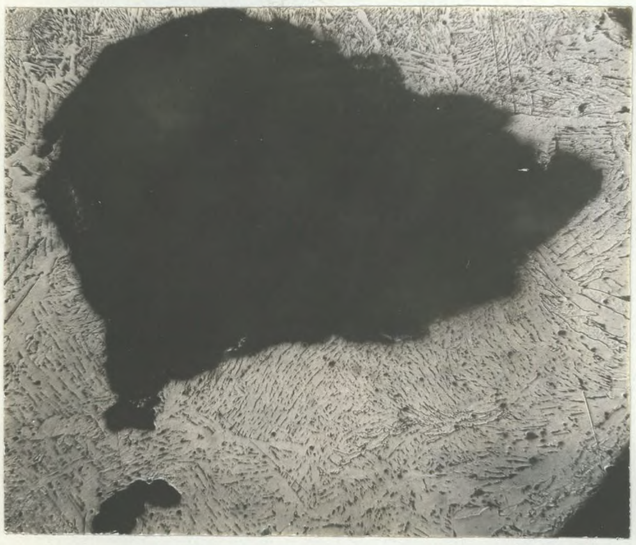
Section of the welded parts.

Figure 5.

X40, nital etch.

Blowholes in U-terminal weld.

Figure 6.



X100, nital etch.

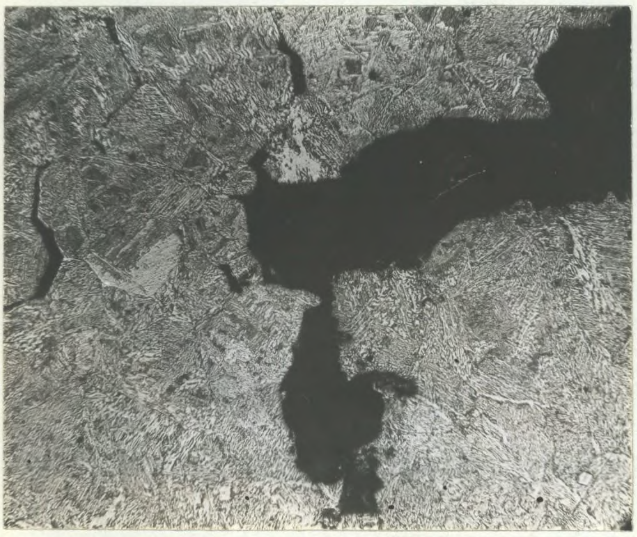
Large blowhole in U-terminal.

Figure 7.

X40, nital etch.

Crack in the intermediate zone.

Figure 8.



X100, nital etch.

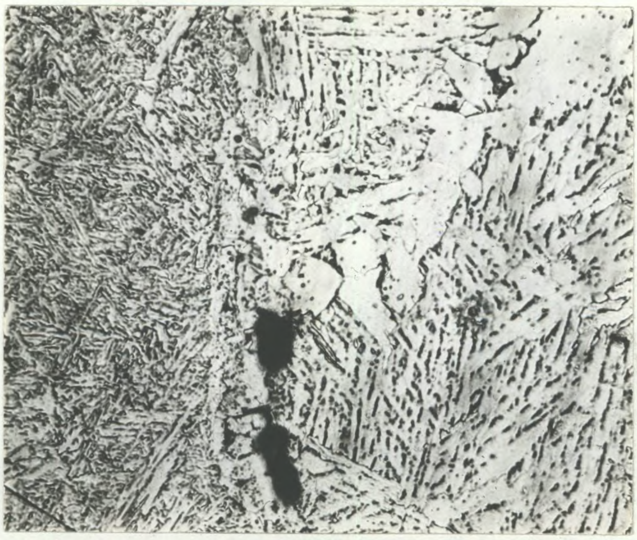
Portion of crack in intermediate zone.

Figure 9.

X250, nital etch.

Zone of fusion between weld and base metal on U-terminal.

Figure 10.



X250, nital etch.

Zone of fusion between weld and base metal on strut tube.

RP:PES.