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OTTAWA September 30th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1310.

Examination of a Failed Exhaust Ring
from a Lysander IIIA Aircraft.

(Copy No. 10.)

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 REQUEST AND PURPOSE OF INVESTIGATION:

(This information is supplied, on the next page, by Figure 1, a photostatic copy of the official request letter.)

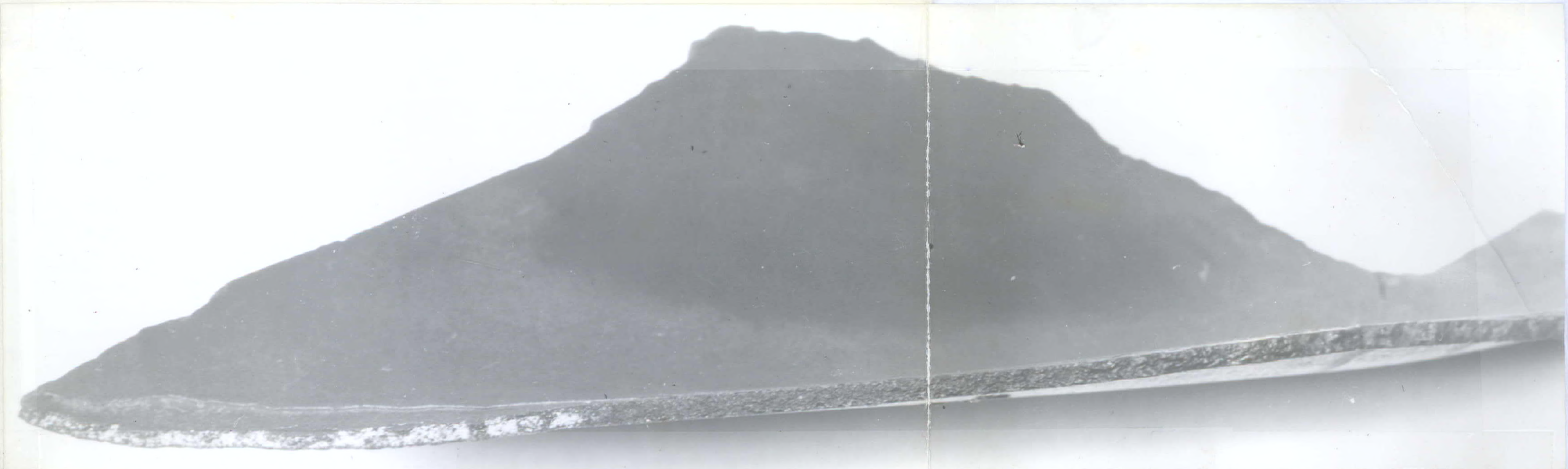
Nature of Sample:

The piece submitted for examination is shown in Figure 1 (placed upon lower left corner of letter). Part of the fracture of the surface seemed of recent origin and part was oxidized. Figure 2 shows a close-up of the fracture.

(Text continued on Page 3)

(Nature of Sample, cont'd) -

Figure 2.



FRACTURED SURFACE OF SPECIMEN.

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Chemical Analysis:

		Sample As Received	Specification S-84
		- Per cent -	
Carbon	-	0.02	0.12 max.
Silicon	-	0.02	0.20 "
Manganese	-	0.33	0.50 "
Phosphorus	-	0.021	0.05 "
Sulphur	-	0.047	0.05 "
Nickel	-		0.30 "

-

Spectrographic Analysis:

Major constituent	-	Fe.
Strong traces	-	Mn, Ni.
Traces	-	Co, Al, Cu.
Faint traces	-	P, Pb, Si, Cr.
Very questionably present	-	Mo.

Physical Tests:

There was not enough sample for physical tests, but it was evident from the microstructure that the material would not have 25 per cent elongation in 2 inches as specified in Specification S-84.

Micro-Examination:

The new fracture showed no oxide coating. The old fracture had a heavy coating of oxide. From this it would seem that considerable time elapsed between the first crack and the final failure.

(Continued on next page)

(Micro-Examination, cont'd) -

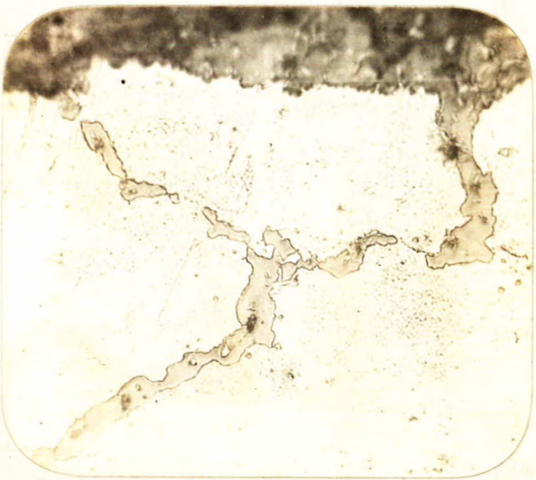
Figure 3.

X100, etched with Keller's reagent.
ALUMINIUM COATING ON SHEET STEEL.

The aluminium coating shown in Figure 3 was found on only one side of the sample submitted.

Penetration of oxide around the grain boundaries is shown in Figure 4. Figure 5 shows either that the aluminium offers some protection against attack, or that this side had no corrosion-erosion attack.

Figure 4.



X500, nital etch.
INTERGRANULAR CORROSION OF STEEL.

Figure 5.

X500, nital etch.
INCLUSIONS IN ALUMINIUM COATING.

CONCLUSIONS:

1. The Lysander IIIA exhaust ring submitted cracked because severe oxidation had made it extremely brittle.

2. Chemically, the material conformed to Specification S-84, with a coating of aluminium.

3. One side of the specimen was found to be aluminium-coated. It is probable that the other side had also been coated but the corrosive-erosive action of exhaust gases had removed this coating.

4. The first crack occurred a considerable time before final failure. In the interim, exhaust gases passed through the crack, oxidizing its surfaces.

5. Aluminium-coated ingot iron is not generally recommended for severe heat and corrosion service in exhaust gases. Its life under these conditions would be limited. Carbon monoxide gas would soon leak out as cracks began to form.

6. Both titanium-bearing 18-8 stainless steel and columbium-bearing 18-8 stainless steel are recommended for exhaust pipes.

(AIRCRAFT EXHAUST MATERIALS ARE)
(DISCUSSED AT GREATER LENGTH)
(IN THE ATTACHED APPENDIX.)

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APPENDIX.

Aircraft Exhaust Systems.

STEEL[1] points out that ordinary steel cannot stand up under conditions of excessive heat and the corrosive and erosive actions of exhaust gases. Stainless steel, however, gives satisfactory service.

Oberhoffer[2] gives the following composition for exhaust pipes on automobiles:

	Per cent
Carbon	0.05 - 0.15
Manganese	0.03 - 0.06
Phosphorus	0.045
Sulphur	0.045

Automobile exhaust pipes are subject to much lower temperatures than are aircraft exhausts. R. T. Rolfe[3] states, "For use at high temperature, where severe scaling may occur, carbon steels are useless."

Plain carbon steel coated with pure aluminium has its heat corrosion resistance greatly improved. Cyanide pots, salt baths, furnace trays and other fittings are coated either by metal spray or by a process known as Calorizing. A diffusion heat treatment after the aluminium coating has been applied is used to enhance the heat-resisting properties.

(Continued on next page)

(1) Stainless Steel in the Hot Spot, STEEL, April 21st, 1942.

(2) Das Technishe Eisen, p. 482.

(3) "Steels for the User."

(Aircraft Exhaust Systems, cont'd) -

LIGHT METALS[4] reports the composition of aluminium wire for spraying as being:

		Per cent
Silicon	-	0.23
Iron	-	0.37
Manganese	-	Traces
Copper	-	Nil

ENGINEERING ALLOYS[5] refers to aluminium-coated steel being used in exhaust systems.

Pure aluminium melts at about 1220° F. but when heated in contact with steel it will dissolve iron, and as its iron content increases, its melting point is raised. At 20 per cent iron content the melting point is about 1800° F.[6] Since exhaust gases exceed 1400° F.,[7] it is evident that aluminium-coated steel should serve to resist heat corrosion for a limited time.

Vibration and movement between engine and manifold can cause considerable stresses to be developed in the exhaust ring. The universal joint exhaust manifold is now used extensively in advanced type military and commercial aircraft.[8] Flexible joints reduce the possibility of brittleness failure similar to the one described in this report.

(Continued on next page)

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(4) May, 1942, issue.

(5) American Society for Metals publication.

(6) Metallography of Aluminium and Its Alloys, V. Fuss. (Translated from German by R. J. Anderson.)

(7) AERO DIGEST, April, 1940, Custom-Built Manifolds on a Production Basis.

(8) AERO DIGEST, June, 1941, Exhaust Manifolds, Ralph Haver.

(Aircraft Exhaust Systems, cont'd) -

Acid content of fuels is recorded as a cause of corrosion in exhaust systems.[9] Corrosion and pitting due to exhaust gases are a common maintenance problem in exhaust systems.[9]

In 1931[10] the life of ordinary steel manifolds was five or six months, with frequent overhauls and repairs. The introduction of stainless steel resulted in an increase of over 300 per cent in manifold life.

ENGINEERING ALLOYS[11] refers to the following as suitable for exhaust manifolds:

Carbon	Chromium	Nickel
	- P e r c e n t -	
0.30	20	
0.15 max.	11 - 15	70
0.12	18	8 + titanium

Haver[12] reports that columbium stabilized 18-10 stainless steel is used throughout on Ryan manifolds.

H. A. Campbell[13] says, "Exhaust manifold systems are made usually from chromium-nickel steels within types 321 (titanium-bearing 18-8) and 347 (columbium-bearing 18-8) analyses, and also from high-nickel-base materials such as 79-80% Ni, 13% Cr, 6.5% Fe. No conclusive evidence of superiority of any one of these materials over the others has appeared."

(Continued on next page)

(9) AVIATION, June 1942, Service Problem of Aircraft Engine Exhaust Systems.

(10) Custom-Built Manifolds on a Production Basis, AERO DIGEST, April 1940.

(11) Publication of the American Society for Metals.

(12) Exhaust Manifolds, AERO DIGEST, June 1941.

(13) METALS AND ALLOYS, January 1942.

(Aircraft Exhaust Systems, cont'd) -

G. F. Titterton,[14] assistant chief engineer of the Grumman Aircraft Engineering Corporation, mentions the use of stainless 18-8 for exhaust collectors.

There are many other references to the use of 18-8 and similar stainless steels for exhaust service. Bain, Aborn and Rutherford, in "The Book of Stainless Steel,"[15] describe the method of stabilizing 18-8 stainless steel by heat treatment, and also explain the beneficial effects of titanium and columbium.

Whether plain steel, aluminium-coated steel, or stainless steel is used depends upon the service life required. The aluminium-coated steel described in this report had reached the end of its useful life. Stainless could be used in its place to obtain far greater and safer life in service. Stainless steel, of course, contains large quantities of strategic alloys.

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(14) In METALS AND ALLOYS, January 1942.

(15) Publication of the American Society for Metals.