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OTTAWA July 15th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1448.

Examination of Aluminium Alloy Strips
for Aircraft Sections.

(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

OTTAWA July 15th, 1943.

REPORT

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1448.

Examination of Aluminium Alloy Strips for Aircraft Sections.

Abstract

Examination of the strips of 24ST aluminium alloy revealed no metallurgical reasons for the different behaviour of the lots of material represented, and all specimens conformed to the requirements of Specification D.T.D. 270.

It is suggested that production of the aircraft sections be changed by quenching the 'as received' material from the recommended temperature. It is essential that fabrication should follow this quenching operation immediately, unless ageing is delayed by refrigeration

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Origin of Problem and Object of Investigation:

On June 22nd, 1943, F/L E. R. Cook, for Commanding Officer, No. 11 Technical Detachment, R. C. A. F., Montreal, Quebec, requested verbally the examination of several lots of aluminium alloy strips which were taken from the production of

(Origin of Problem and Object of Investigation) -

aircraft sections at Cresswell-Pomeroy, Montreal, Quebec.

Information given at that time, and further confirmed by a letter (File No. 902-38-19 (AMAE:DAI)) dated July 3rd, 1943, from A/C A. L. Johnson, for Chief of the Air Staff, Department of National Defence for Air, Ottawa, Ontario, stated that trouble has been encountered in rolling these strips in the "as received" (fully aged) condition to form Z-sections, because of cracking along the bent corners in the processing.

It was further stated that these defects were observed only after the production of a considerable quantity of apparently "good" sections.

An investigation was requested to ascertain if any metallurgical reason could be found to explain the erratic performance of the material and also if the different lots of the submitted material conform to the requirements of the British Specification D.T.D. 270.

It was also desired that the properties of the material, after reheating and quenching but before ageing, be investigated.

Description of Material:

Table I lists the submitted material, including identification marks of each lot as well as the lot numbers given in these Laboratories for easier reference in this report:.

(Continued on next page)

(Description of Material, cont'd) -

TABLE I.

Lot No.	Heat Treatment Batch	Drawing No.	Type	Thickness, in.
1	HDEMZ	28 A 5039	Strips	0.065
2	HDAVV	B 8669	"	0.082
3	TWRU	B 9048	"	0.054
4	HDAUZ	B 78 J	"	0.063
5	HDBOE	B 78 P	"	0.063
6	HDAUU	B 9047	Coil	0.063
7	HDAYT	B 9047	Rolled Z-sections	0.065
8	HDAYT	-	Coil	0.069
9	HDAMY	-	Rolled Z-sections	0.065
10	HDAMY	-	Strips	0.065

Lots Nos. 1-6 are representative of material which was said to be unsatisfactory, but no sections rolled from these materials were submitted.

Lot No. 7 consists of good rolled Z-sections, and Lot No. 8 was taken from the same batch before rolling.

Lot No. 9 represents badly-cracked rolled Z-sections, and Lot No. 10 the same material before rolling.

In this investigation the material will be identified by the above lot numbers only.

Besides the above listed material, some pieces of other cracked sections were submitted for general informative purposes but these were not further investigated.

In investigating the design of the rolled Z-sections, the following ratios between bend radius and thickness of material were found:

Good Z-Section (Lot No. 7) -

Outside radius of bend = 3.2 x thickness of section
Inside " " " = 2.3 x " " "

Cracked Z-Section -

Outside radius of bend = 2.6 x thickness of section
Inside " " " = 2.0 x " " "

Cracked Right Angle -

Outside radius of bend = 2.6 x thickness of section
Inside " " " = 1.4 x " " "

Chemical Analysis:

Table II gives the results of chemical analysis of the submitted samples (one for each lot):

TABLE II.

Lot No.		Copper	Magnesium	Manganese	Iron	Silicon
		- P e r		c e n t -		
1	-	4.65	1.50	0.59	0.32	0.21
2	-	4.74	1.37	0.63	0.31	0.27
3	-	4.56	1.34	0.62	0.32	0.23
4	-	4.63	1.49	0.60	0.37	0.23
5	-	4.50	1.44	0.59	0.35	0.21
6	-	4.52	1.31	0.59	0.40	0.27
7	-	4.68	1.35	0.59	0.37	0.23
8	-	4.41	1.47	0.60	0.35	0.30
9	-	4.41	1.35	0.60	0.40	0.30

British Specification D.T.D. 270 requires the following composition limits:

		Per cent
Copper	-	3.5-4.8
Magnesium	-	0.8-1.8
Manganese	-	0.3-1.5
Iron	-	0.5 max.
Silicon	-	0.4 max.

MECHANICAL PROPERTIES:

Tensile Tests -

Table III shows the results of tensile tests on samples "as received". The tensile test specimens (0.5-inch wide) were cut longitudinally from the examined samples.

TABLE III.

Lot No.	0.1% Proof Stress, p.s.i.	Ultimate Tensile Stress, p.s.i.	Elongation, per cent In 2 in.	In 1 in.
1	55,600	65,600	16.5	18
2	53,750	71,700	17	24
3	56,200	73,850	15.5	17
4	55,500	71,000	15.5	22
5	54,500	71,500	18.5	20
6	54,850	71,600	17	20
7	54,700	72,500	16	20
8	53,600	72,350	18	23
9a⊕	51,200	68,100	12.5	19
9b⊕	49,050	70,600	17	18
10a	51,250	71,250	19	22
10b	51,250	69,350	18	21

⊕ Cracked Z-sections.

The requirements of Specification D.T.D. 270 are as follows:

0.1% proof stress	-	min., 39,200 p.s.i.
Ultimate tensile stress	-	min., 62,720 p.s.i.
Elongation in 2 inches	-	min., 15 per cent.

Table IV shows the results of tensile tests which were carried out 30 minutes after reheat-treatment of the samples.⊕⊕

(Continued on next page)

⊕⊕ 15 minutes in salt bath at 495° C., and immediately quenched in cold water.

(Mechanical Properties, cont'd) -

Tensile Tests, cont'd -

TABLE IV.

Lot No.	0.1% Proof Stress, p.s.i.	Ultimate Tensile Stress, p.s.i.	Elongation, per cent In 2 in.	In 1 in.
1	24,500	62,200	20.5	28
2	26,900	61,000	20.5	26
3	26,150	58,100	19.5	22
4	27,400	61,900	18	20
5	25,750	61,250	20	26
6	23,100	55,300	20.5	28
7	24,500	58,000	20.5	26
8	25,900	57,900	19	22
9	25,800	63,200	18.5	24
10	23,150	56,100	20.5	25

90° Reverse Bend Tests -

The 90° reverse bend tests were carried out in accordance with B.S.S. 485, Para. 9b. The specimens (1/2-inch wide) were taken transversely to the main axis of the strips.

Table V gives the average results calculated from at least three reverse bend tests.

TABLE V.

Lot No.	Thickness, inch	Number of 90° bends (excluding the first 90° bend) As received	Quenched@	Annealed@@	Radius of bend, inch
1	0.065	5	9	10	0.250
2	0.082	5	7	10	0.312
3	0.054	11	15	36	0.250
4	0.063	5	7	10	0.250
6	0.063	7	11	14	0.250
8	0.065	5	9	15	0.250
10	0.065	7	10	20	0.250

@ 15-minute heating in salt bath at 495° C., and immediate quenching in cold water. Tests carried out 30 minutes after quenching.

@@ Annealed for 15 minutes at 350° C., and cooled slowly with the furnace. Tested 2 days after annealing.

The requirements of British Specification D.T.D. 270 are as follows:

Thickness, in inches -	0.064-0.056	0.080-0.072
Radius of bend, inch -	0.252	0.320
Number of 90° bends, min., -	1	1

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(Mechanical Properties, cont'd) -

Hardness Tests -

The hardness was determined by the Vickers method, using a 10-kilogram load.

The hardness tests were carried out on longitudinal and transverse sections of the samples. Table VI gives the limits of hardness numbers determined on particular samples.

TABLE VI.

Lot No.	Hardness, V.H.N.	Lot No.	Hardness, V.H.N.
1	136-141	6	140-142
2	136-142	7*	146-164
3	144-150	8	140-142
4	139-142	9*	149-162
5	140-145	10	136-138

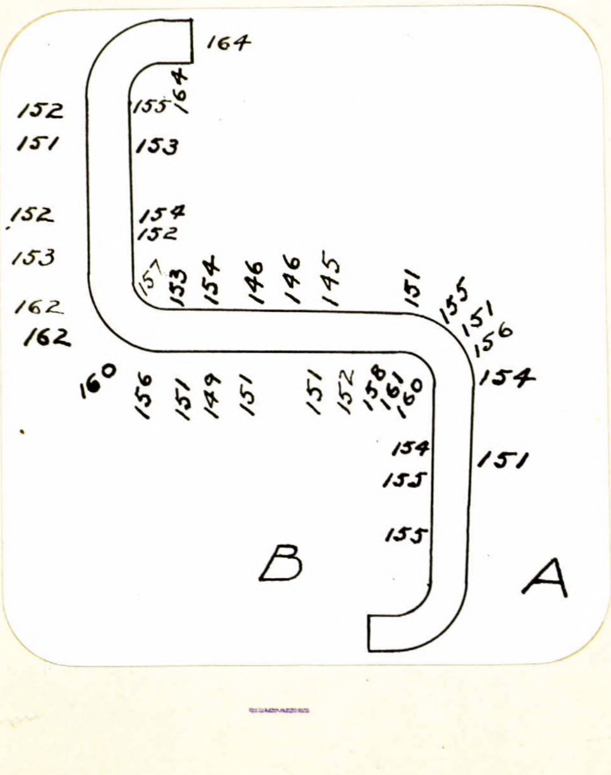
* After rolling to sections.

Figure 1 shows the distribution of hardness on cross-sections of rolled shapes.

A - Good section (Lot No. 7)

B - Cracked section (Lot No. 9)

Figure 1.



Microscopic Examination:

Microscopic examination carried out on samples taken from each lot of the submitted material showed no defects and practically no differences in the microstructures.

Figures 2 and 3 show the average microstructure.

Figure 2.

X100, Keller's etch.
LONGITUDINAL SECTION.

Figure 3.

X100, Keller's etch.
TRANSVERSE SECTION.

Figures 4 and 5 show the structure of the cracked bend of a rolled Z-section (Lot No. 9).

Figure 4.

X100, Keller's etch.
LONGITUDINAL SECTION.

Figure 5.

X100, Keller's etch.
TRANSVERSE SECTION.

DISCUSSION OF RESULTS:

The results of chemical, mechanical and metallographic examinations show that all submitted samples contain no material defects and exhibit practically no difference in properties of both 'good' and 'unsatisfactory' lots. All conform to the requirements of Specification D.T.D. 270.

The shaping of the sheet metal in aircraft sections may be performed with the material in three different conditions (heat-treating tempers):

A. "As received," which normally means the forming in the aged condition.

B. "As quenched," which means that the material is formed immediately after reheating to approximately 490° C. and quenching, before or in the first stage of ageing.

C. "As annealed," which means that the material is formed after fully annealing at 350-400° C. and slow cooling. After the formation of the section, in order to regain the optimum mechanical properties it must again be reheated, quenched, and straightened.

The selection of the proper temper of the material depends upon the complexity of the shape and severity of the forming operation (type of forming method, e.g. drawing, rolling, etc.; amount of forming operations in which the shape is obtained, gradually or rapidly, etc.; the kind of forming lubricant used; the design and condition of tools; etc.).

The most important factor is the ratio of the bending radius to the thickness of the sheet. Normally recommended[@] minimum working radii for 24ST--sheet of comparable

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@ "Forming Aluminum" - published by the Aluminum Company of America, Pittsburgh, Pa., 1941, pp. 43-45.

(Discussion of Results, cont'd) -

thickness to that submitted--are 3 to 5 times the thickness.

The actual radii found in this investigation are considerably smaller than recommended for fully aged 24ST sheets.

Since the behaviour of the material in the forming operations is dependent upon so many external factors, ordinary inspection methods of the material, as given in the specifications, show only the general strength and quality of the examined material but give no indication of its formability. This formability can be ascertained only by actual trial under contemplated conditions of fabrication, or by using especially designed testing apparatus.[@@]

Conclusions:

The investigation shows that no metallurgical reasons for different behaviour of the submitted material can be found.

It seems to be advisable to consider changing the production of the aircraft sections by quenching the "as received" material from the recommended temperature. Fabrication should immediately follow this quenching operation unless ageing is delayed by refrigeration.

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JWM:PES.

@@ Similar to devices shown in:
K. Matthaes - "Anwendung der Prüfverfahren im Flugzeugbau," Z.f.METALLKUNDE, vol. 30 (1938), HV. 99-113, Figs.25 and 26.