OTTAWA October 11th, 1940.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 907.

An Examination of an Aluminium Alloy Extrusion.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

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CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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An Examination of an Aluminium Alloy Extrusion.

Origin of Material and Object of Investigation:

On September 28th, 1940, Wing Commander A. L. Johnson, R. C. A. F., Ottawa, Ontario, sent in two ends of an aluminium alloy extrusion, labelled respectively LC 139 and LC 276, and a copy of a letter from Mr. A. E. Marsden, Chief Inspector, British Purchasing Commission (Aircraft), New York City. Mr. Marsden's letter stated that the extrusion had been made by the Bohn Aluminum and Brass Corporation for use as a Lysander spar boom. It further added that difficulties had been experienced in obtaining straight members with uniform tensile properties and suggested that faulty heat treatment or a straining of the member on straightening after solution heat treatment might have been responsible for the trouble. Through Wing Commander Johnson Mr. Marsden requested that the material in the extrusion be examined in order to determine, if possible, the cause of the difficulties encountered.

Specification Requirements:

The extrusion was manufactured to the requirements of Specification 2-L-40. It is of interest to compare the pertinent requirements of this specification with the similar requirements of Specification L-40, which Specification 2-L-40 replaced:

Chemical Requirements -

Specification.	Cu, %	Ni, %	Mg, %	Fe, %	Ti, %	Si, %
L-40	1.5-2.5	0.5-1.5	0.6-1.2	0.8-1.5	0.2 max.	1.0 max.
2-L-40	1.5-4.0	2.0 max.*	0.3-1.5	0.3-1.5	0.2 max.*	1.5 max.*

(Cont'd below)

	Mn, %	Ce, %	Cb, %	Cr, %
(L-40)	-	-	-	-
(2-L-40)	1.0 max.*	0.3 max.*	0.3 max.*	0.2 max.*

* Optional constituents.

(Continued on next page)

(Specification Requirements, cont'd) -

Mechanical Requirements for Extrusions Greater than 3/8" in Thickness:

Specification	Ultimate tensile stress, p.s.i.	0.1% Proof stress, p.s.i.	Elongation, % in 2 inches
L 40 and 2-L-40	60,500	47,000	10

Heat Treatment Requirements:

L-40. - Heat uniformly at temperature not less than 510° C. and not more than 535° C. and quench in water. Age by heating between 155° C. and 175° C. for 10 to 20 hours. Aging may be accelerated by heating, for not more than 2 hours, between 195° C. and 205° C.

2-L-40. - Heat uniformly at a temperature not less than 495° C. and not more than 535° C. and quench in water or oil. Age by heating for requisite period between 155° C. and 185° C.

Chemical Analysis:

Drillings were taken from the LC 139 sample and analysed. The following results were obtained:

Copper, p.c.	Magnesium, p.c.	Iron, p.c.	Silicon, p.c.	Manganese, p.c.	Nickel, p.c.	Titanium, p.c.
4.28	1.44	0.20	0.09	0.64	None detected.	0.005

Tensile Tests:

Tensile test bars were machined from both received samples and from a piece of Sample LC 139 that had been

(Tensile Tests, cont'd) -

heated to 510° C. in a salt bath, quenched in water, and drawn at 155° C. for 15 hours. All tensile test bars were broken in an Amsler Universal testing machine. The following results were obtained:

Specimen	Ultimate stress, p.s.i.	0.1% Proof Stress, p.s.i.	Elongation in 2 inches, p.c.
LC 139	76,400	51,000	16.5
LC 276	75,250	51,000	18.5
LC 139, heat treated	75,250	54,000	Broke outside gauge marks.

Microscopic Examination:

Four samples were cut from Sample LC 139, two from the outside and two from the middle of the extrusion, the samples in each location being immediately adjacent. One of the outside samples was heated to 535° C. in a salt bath, quenched in water, and then aged at 155° C. for 15 hours. One of the samples from the middle of the extrusion was heated to 510° C. in a salt bath, quenched in water, and aged for 5 days at room temperature. A specimen cut from the heat treated tensile test specimen, the two heat treated samples and the two "as received" samples were then given a metallographic polish, the last two specimens being polished so that both transverse and longitudinal sections could be examined. Figures 1 and 2, photomicrographs at X500 magnification, were obtained respectively from unetched transverse and longitudinal sections. In a greater part of the section, the inclusions are separated as shown in Figure 1, but areas in which the inclusions are

(Microscopic Examination, cont'd) -

clustered, as shown in Figure 2, are common. The majority of the inclusions shown are the Cu-Mn-Fe-Al constituent although some $CuAl_2$ particles are also present. At higher power a large number of very small, watery inclusions may also be distinguished. These may be the α Al-Mg constituent. The particles do not show up in Figures 1 and 2 because they lack size and definition. The specimen that had been heated to 535° C. was burnt, as there was fused material around the grain boundaries. The specimen that had been heated to 510° C. appeared to be sound.

All specimens were then etched in Keller's reagent (hydrofluoric 1 part, hydrochloric 1.5 parts, nitric 2.5 parts, water 95 parts) and re-examined. The structures of the transverse and longitudinal sections of the "as received" material from the centre of the extrusion are shown respectively in Figures 3 and 4, while Figures 5 and 6 respectively show structures of the transverse and longitudinal sections of the "as received" material in the outside of the extrusion. All four photomicrographs are at X500 magnification. Material in both centre and outside of the extrusion appears to be fine-grained, although there are areas in which the grain size is difficult to develop. The large white inclusions shown in Figures 3 and 4 are $CuAl_2$. None of these inclusions appears in Figures 5 or 6 but there were some $CuAl_2$ particles in the material in the outside of the extrusion. The black etching particles present in all photomicrographs are the Cu-Mn-Fe-Al constituent. The small light etching particles that appear in clusters are considered to be the α Al-Mg constituent. These particles do not appear to

(Microscopic Examination, cont'd) -

be as numerous and are certainly less clustered in the metal on the outside of the extrusion.

Figure 7, a photomicrograph at X500 magnification, shows the structure of the specimen that had been quenched from 510° C. and then aged at room temperature for 5 days. This photomicrograph was obtained from an area immediately adjacent to the area from which Figure 4 was obtained. Although the grain size is only developed in one area, it appears no larger than the grain size in the "as received" material. The amount of black etching Cu-Mn-Fe-Al particles, large light etching $CuAl_2$ particles, and small light etching α Al-Mg particles appears to be about the same as in the "as received" sample. The sample from the heat treated tensile test specimen had a structure similar to that shown in Figure 7.

The structure of the sample quenched from 535° C. and drawn at 155° C. is shown at X500 magnification in Figure 8. Fused material may be seen along the grain boundaries. The number of the insoluble dark etching Cu-Mn-Fe-Al inclusions is about the same as in the other samples examined. There does not appear to be any $CuAl_2$ or α Al-Mg inclusions in this material.

DISCUSSION:

Specification Requirements -

Changes made in the composition requirements when Specification 2-L-40 superseded Specification L-40 are quite important, for the changing of nickel from a compulsory to an optional constituent allows for the use of a quite

(Discussion, cont'd) -

(Specification Requirements, cont'd) -

different type of alloy. When nickel is present in a wrought copper-aluminium alloy, on heating a Cu-Ni-Al compound precipitates, while in a nickel-free copper-aluminium alloy the precipitant is $CuAl_2$. The latter compound melts at a lower temperature than the Cu-Ni-Al constituent, consequently burning commences at a lower temperature in the nickel-free alloy. A duralumin type alloy which would be allowed by Specification 2-L-40 has a fusion point of 540° C., while an alloy of the composition specified in Specification L-40 has a fusion point of 580° C. (page 135, Heat Treatment of Aluminium and Its Alloys, by Budgeon). A solution heat treatment temperature which might be quite satisfactory for the nickel-bearing alloy, then, might produce burning in the nickel-free material. In addition to this, the two alloys require different aging treatments, an age hardening at room temperature being recommended for the duralumin type alloy while the nickel-bearing alloy must be artificially aged at between 155° C. and 175° C. As a result the latter alloy remains soft after heat treatment while the duralumin type alloy starts to age almost immediately. The absence of immediate age hardening in the nickel-bearing alloy probably has some effect on the amount of work needed to straighten after quenching and consequently on the amount of warping that occurs on the machining of a straightened and aged member.

The duralumin type alloy and the nickel-bearing

(Discussion, cont'd) -

(Specification Requirements, cont'd) -

alloy are quite definitely different materials, then, and should receive different heat treatments. Specification 2-L-40 is unsatisfactory in allowing a nickel-free material and then specifying a heat treatment suited only to a nickel-bearing copper-aluminium alloy.

Chemical Analysis -

The alloy in the extrusion is Aluminum Company of America alloy 24-S, which has the following average composition:

Copper, p.c.	Silicon, p.c.	Manganese, p.c.	Magnesium, p.c.
4.4	-	0.5	1.5

The copper content in the extrusion exceeds the maximum specified in Specification 2-L-40.

The Aluminum Company of America recommend heating 24-S metal between 488° C. and 500° C. for the solution heat treatment, the recommended temperature range being even lower than the 500° C. - 510° C. range advocated for 17-S, the duralumin alloy. Cold water is recommended as a quenching medium. The Aluminum Company specify a room temperature aging for 24-S material and state that 24-S metal ages even faster than 17-S, the duralumin alloy.

It may be seen that the heat treatment specified in Specification 2-L-40 is widely at variance with the heat treatment advocated by the Aluminum Company of America for their 24-S alloy.

(Discussion, cont'd) -

Tensile Tests -

The tensile properties of both the "as received" and heat treated metal meet the specification requirements. If, however, the metal had been heat treated at the upper limits given in Specification 2-L-40 the properties would have been poor as the metal would have been burnt.

Microscopic Examination -

The irregular grouping of the inclusions in the specimens examined indicates microscopic irregularities in composition. The clustered condition of the α Al-Mg particles is especially marked. One would expect this constituent to be in solution but apparently a higher temperature is needed to effect this, as the constituent is only in solution in the metal quenched from 535° C.

The burning found in the material quenched from 535° C. is to be expected, as a nickel-free alloy should not be heat treated to this temperature. The absence of burning, along with the satisfactory tensile properties, in the heat treated test bar shows that satisfactory properties can be produced if the metal is heat treated near the minimum temperatures specified.

The fine grain size of the "as received" material shows that the extrusion temperature was satisfactory. The material could not have been severely cold worked in straightening after the quenching operation as there was no marked grain growth in the heat treated metal. The presence of α Al-Mg particles in the specimen aged at room temperature shows that the elevated temperature aging was not responsible for the precipitation of this constituent.

Conclusions:

The difficulties encountered in the manufacture of a satisfactory Lysander spar boom are considered to be due to Specification 2-L-40 allowing for the use of a nickel-free alloy without specifying a proper heat treatment for this material. The specification allows for the use of Aluminum Company of America 24-S alloy, the material in the specimens examined, but the specified heat treatment for this alloy is incorrect, as the solution temperature range is given at 510° C. to 535° C. when it should be 488° C. to 500° C. The aging treatment is also incorrectly specified, as 24-S alloy should be aged at room temperature for five days, while an artificial aging for 10 to 20 hours at 155° C. to 185° C. is specified. An oil quenching after solution heat treatment is also allowed, whereas 24-S material should be water-quenched. It is true the material examined has satisfactory properties, but the investigation shows that these properties can be produced by heat treating near the minimum temperatures specified. As it was definitely shown that burning occurs at 535° C., it is not surprising that the tensile properties in this material were found to be very erratic.

Warping is liable to be encountered in the solution heat treatment of any aluminium alloy. This may be avoided to some extent by packing or heat treating in jigs. The inevitable straightening that follows the quenching operation should be done before the metal ages. The nickel-bearing copper-aluminium alloy requires

(Conclusions, cont'd) -

artificial aging; consequently there is no difficulty in straightening it before aging takes place. The 24-S alloy allowed by Specification 2-L-40 ages even more rapidly than duralumin, so it should be straightened immediately after quenching as a delay would result in a greater internal straining of the metal and consequently a greater amount of warping when the member is finish-machined. Such trouble would be avoided to some extent by the use of a nickel-copper-aluminium alloy. It is also possible that warping after machining would be reduced if the member were extruded more nearly to size.

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GSF:PES.

Figure 1.

X500.

Transverse section, unetched.

Figure 2.

X500.

Longitudinal section, unetched.

Figure 3.

X500.

Transverse section, from centre of extrusion.

Etched in Keller's reagent.

Figure 4.

X500.

Longitudinal section, from centre of extrusion.

Etched in Keller's reagent.

Figure 5.

X500.

Transverse section, from outside of extrusion.

Figure 6.

X500.

Longitudinal section, from outside of extrusion.

Figure 7.

X500.

Longitudinal section from specimen quenched in water from 510° C. and aged 5 days at room temperature.

Figure 8.

X500.

Transverse section from specimen quenched in water from 535° C. and aged 15 hours at 155° C.

(NOTE: All specimens etched in Keller's reagent.

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