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THERMAL CONDUCTIVITY OF ALUMINUM-LITHIUM ALLOYS CONTAINING UP TO 8% LITHIUM

by

L. P. Costas

Pile Materials Division

April 1960

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Savannah River Laboratory
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ABSTRACT

The thermal conductivities of aluminum-lithium alloys containing up to 8 wt % lithium were determined at temperatures between 125 and 260°C. The addition of lithium to aluminum sharply reduces the conductivity from 0.60 cal/(sec)(°C)(cm) for pure aluminum to 0.22 cal/(sec)(°C)(cm) for 2 wt % alloys; further addition linearly and more gradually decreases the conductivity to 0.16 cal/(sec)(°C)(cm) for a 7.9 wt % alloy.

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INTRODUCTION

The need for thermal conductivity data on aluminum-lithium alloys arose in the study of heat transfer in Savannah River Plant control rods. Conductivity data were available for alloys in the range of about 7 to 10.5%* lithium[1]; however, data in the range of 0.5 to 7% lithium were also desired.

SUMMARY

The addition of lithium to aluminum decreases the thermal conductivity at approximately 150°C from 0.60 cal/(sec)(°C)(cm) at zero lithium content to 0.16 cal/(sec)(°C)(cm) for 7.9% lithium. The decrease in conductivity with increasing lithium addition is not uniform, however, the greatest decrease, from 0.60 to 0.22 cal/(sec)(°C)(cm), occurs on addition of the first 2% lithium, whereas increasing the lithium content further linearly and more gradually decreases the conductivity to 0.16 cal/(sec)(°C)(cm) for a 7.9% alloy. The rapid decline of conductivity in the 0 to 2% lithium region is associated with the single-phase alloy, and the gradual and linear change beyond the 2% content is attributed to the presence of a second phase, LiAl compound.

The accuracy of the experimental values is believed to be at least ±10% and possibly ±5%, certainly sufficient for the majority of heat transfer calculations.

DISCUSSION

Five as-extruded aluminum-lithium alloy rods, ranging from 1 to 8% lithium, were tested along with an aluminum specimen of 99.9+% purity. The aluminum specimen served as a control to determine the reliability of the apparatus; its conductivity was compared with the values listed in the literature[2,3].

The thermal conductivity apparatus consisted of an electric heater mounted on top of a specimen that was one inch in diameter and two inches high which, in turn, was mounted on a water-cooled copper plate. The total heat transferred was determined by measurement of the flow and the temperature increase of the cooling water. The thermal gradient in the specimen was determined by measuring the temperature at two points along the axis of the cylinder and dividing by the distance between these points. These temperatures were determined by thermocouples inserted into holes drilled radially into the center of the specimen. To further ensure correct thermocouple readings, each

* All compositions are expressed in weight per cent.

thermocouple was wrapped once around the specimen at the level of the thermocouple hole to minimize heat conduction losses along the wires. Insulation was wrapped around the specimen. After completion of the experiment, the specimens were sectioned, and two wafers, taken between the thermocouples, were analyzed for lithium.

In order to check the reliability of the apparatus, runs were made on 99.9+% aluminum to compare the experimental values with those in the literature, References 2 and 3. Reference 2 lists the thermal conductivity as 0.497 cal/(sec)(^{o}C)(cm) at 20^{o}C, and 0.550 at 76.4^{o}C; Reference 3 specifies the conductivity at 100^{o}C only, 0.57 cal/(sec)(^{o}C)(cm). Figure 1 is a plot of these three points plus the points found experimentally in this work. It is seen that the conductivity varies almost linearly with temperatures between the range of 20 to 120^{o}C, an indication that the values obtained in this study are compatible with the presently accepted values for high purity aluminum.

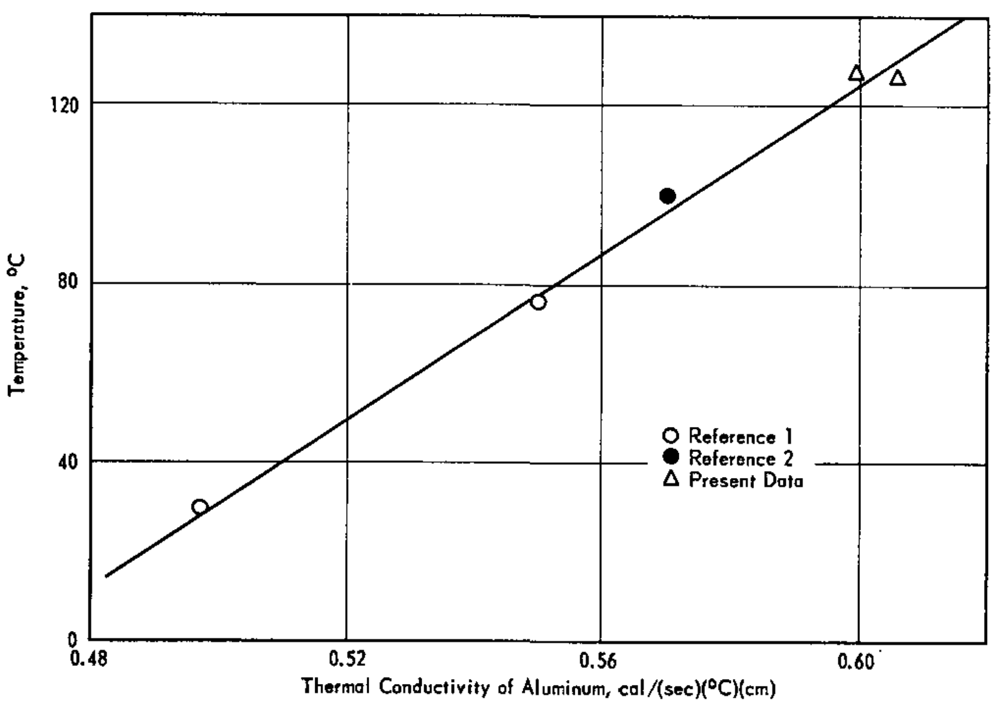

FIG. 1 THERMAL CONDUCTIVITY OF ALUMINUM VERSUS TEMPERATURE

Figure 2 is a graph of the data for the aluminum-lithium alloys; it also includes the two conductivities listed in Reference 3, namely 0.161 and 0.122 cal/(sec)(^{o}C)(cm) for 6.8 and 10.4% alloys, respectively. It is seen that all the points define a specific curve, and that the scatter of the data is quite low, with the exception of the 2.30% alloy. The scatter for the 2.30% Li alloy is attributed to errors made in recording some of the original data.

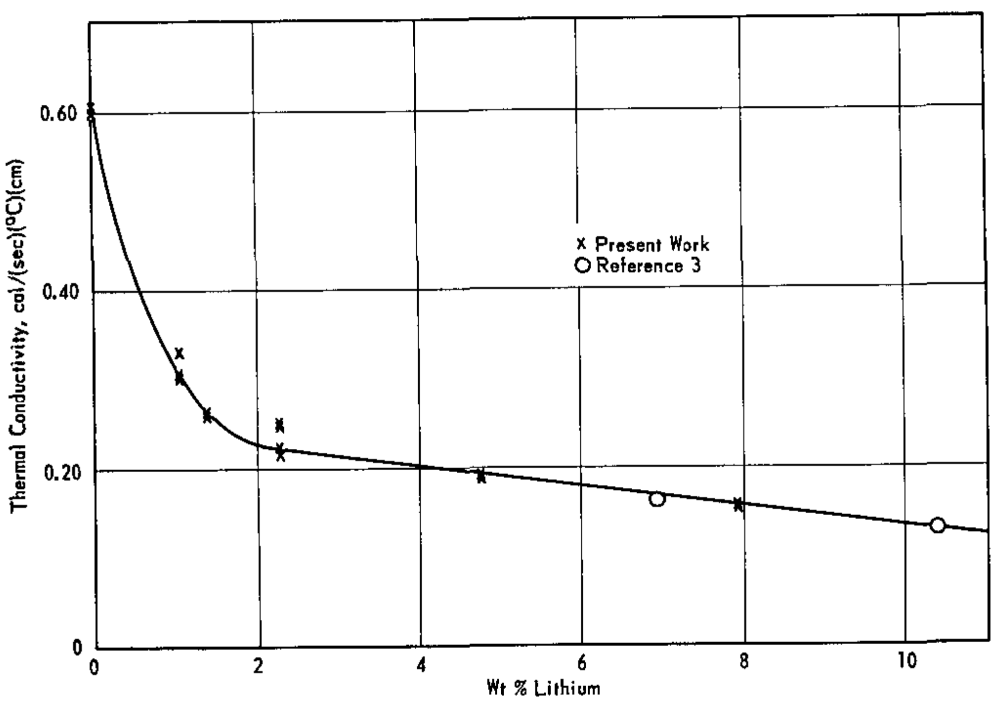

FIG. 2 THERMAL CONDUCTIVITY OF ALUMINUM-LITHIUM ALLOYS

In general, the data are believed to be accurate at least to within ±10% and quite possibly to within ±5%. The total error involved in the conductivity arises from two sources, mensuration and the change of conductivity with temperature. The first source included the error incurred in determination of water flow rate, of distance, and of temperature; the maximum possible error from these sources can be readily determined, and it is listed for each run in the table. The second source of error arises because rather large temperature differences were used to determine the thermal gradient, and, since the conductivity is temperature dependent, the use of these large temperature differences does introduce some error. In the case of pure aluminum, the experimentally determined conductivity was quite close to the expected value from the literature; therefore, the error was small. This same small error would also be expected of the low lithium alloys, but the error may be greater for alloys containing one or more per cent lithium. The listed conductivities are strictly correct only for the mean temperature and the temperature difference given in the table.

L P Costas

L. P. Costas
Pile Materials Division

Table I

Thermal Conductivity Data for Aluminum-Lithium Alloys

Metal, wt %	Thermal Conductivity, cal/(sec)(°C)(cm)	% Maximum Error	Temperature Range Employed, °C	Mean Temperature, °C
99.9+ Al	0.599	4.6	107.7 - 146.8	127.2
	0.606	4.6	106.6 - 145.6	126.1
1.07 Li	0.329	2.1	158.7 - 234.8	196.7
	0.306	2.8	157.8 - 234.0	195.9
	0.307	2.7	119.7 - 194.7	157.2
1.40 Li	0.262	4.3	148.0 - 241.0	199.5
	0.266	3.1	150.8 - 240.5	195.7
2.30 Li	0.250[a]	2.6	155.2 - 214.9	185.0
	0.249[a]	2.6	155.2 - 214.9	185.0
	0.224	6.7	122.4 - 194.5	158.4
	0.218	4.2	188.2 - 321.9	255.1
	0.218	1.6	195.6 - 322.9	259.3
4.77 Li	0.189	2.9	142.8 - 219.5	181.1
	0.191	2.9	142.0 - 218.3	180.7
7.94 Li	0.158	2.5	135.5 - 217.7	176.6
	0.155	2.5	138.5 - 221.0	179.8

(a) Errors are suspected in the recording of original data.

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