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### Publication Date

1986-11-01

LBL-22573  
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LBL-22573  
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November 1986

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Berkeley, California 94720

Prepared for the U.S. Department of Energy  
under Contract DE-AC03-76SF00098

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# Temperature Variation of the Elastic Constants of Aluminum Alloy 2090-T81

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Aluminum is often the material of choice for weight-critical structures used at cryogenic temperatures. Current aerospace applications include the external tank of the space shuttle, currently manufactured from aluminum alloy 2219. Future applications might include tanks for proposed hypersonic vehicles. Aluminum-lithium alloys have been proposed for these applications because they provide mechanical properties comparable or superior to those of existing aerospace aluminum alloys at 7-10% lower density and higher stiffness. Since stiffness is an important design criterion for structures like tanks, the elastic constants for these materials at low temperature are important design properties. This note focuses on a particular aluminum-lithium alloy, 2090-T81, that may see cryogenic service.

Aluminum-lithium alloys of commercial compositions have elastic moduli at room temperature approximately 7-12% higher than those of conventional aluminum alloys. The increase in elastic modulus is related primarily to the amount of lithium in the alloy, so it can vary significantly even within the specified composition ranges of commercial alloys [1,2].

The temperature variation of the elastic constants of various commercial aluminum alloys has been studied previously [3,4]. All aluminum alloys behave similarly, displaying an increase in elastic modulus of about 12% between room temperature and 4 K. This note confirms this trend for the aluminum-lithium alloy 2090-T81. Titanium alloys, which are also used for cryogenic tanks, show a smaller increase in stiffness at low temperatures [4].

The alloy studied in this investigation, 2090-T81, has a nominal chemical composition of Al-2.7Cu-2.2Li-0.12Zr in weight percent. The chemical composition limits and the actual chemical composition, as determined by atomic absorption spectroscopy, are given in Table 1. In longitudinal and transverse orientations, this alloy shows improved strength, elongation, and fracture toughness at low temperatures. The mechanical properties at 298 K, 77 K, and 4 K are given in reference 5.

The elastic-constant measurements were performed using ultrasonic (10 MHz) pulse techniques. The experimental procedure is described in detail elsewhere [4,6]. Except for high-strain cases, dynamic elastic constants equal static elastic constants within the usual uncertainty of the latter. For the dynamic values, we estimate the uncertainty as 0.1%. Static and dynamic values should show essentially identical temperature behavior.

Figure 1 shows the Young's modulus and Poisson's ratio of 2090-T81 alloy as a function of temperature between 295 K and 4 K. The values at selected temperatures are listed in Table 2. The room-temperature value of the Young's modulus lies close to the reported average values from static tensile tests [2]. The temperature variation is similar to that observed for other aluminum alloys [4].

**Acknowledgment:** The authors thank the Aluminum Company of America for supplying the material used in these measurements. This study was supported at the Lawrence Berkeley Laboratory by the Director, Office of Energy Research, Office of Basic Energy Science, Material Sciences Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. J. Glazer is supported by an AT&T Bell Laboratories PhD Scholarship.

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**Table 1 Chemical composition limits for 2090 alloy and actual composition of the material used in this study (in weight percent)**

element	Al	Cu	Li	Zr	Fe	Si	Mg	Mn	Ti
composition limits	bal	2.4-3.0	1.9-2.6	0.08-0.15	0.10	0.12	0.25	0.05	0.15
actual composition	bal	2.86	2.05	0.12	0.02	< 0.01	< 0.01	< 0.005	0.02

**Table 2 Elastic constants of 2090-T81 alloy**

Elastic constant	Temperature			
	295 K	77 K	20 K	4 K
E (GPa)	78.3	86.9	87.6	87.6
( $10^6$ psi)	11.36	12.60	12.70	12.70
$\nu$	0.320	0.308	0.307	0.307

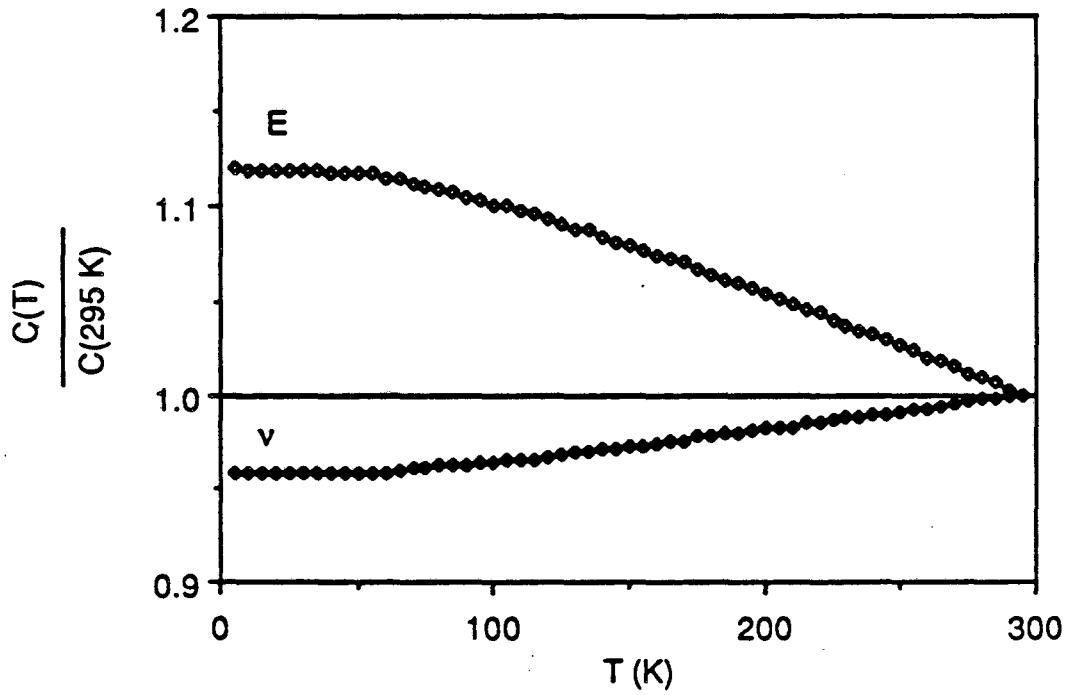


Fig. 1 Young's modulus (E) and Poisson's ratio ( $\nu$ ) of 2090-T81 alloy as functions of temperature. The plotted values are ratios between the actual values and the room-temperature values given in Table 2.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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