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Dimensional Stability of Ti-6Aℓ-6V-2Sn

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DIMENSIONAL STABILITY OF Ti-6Aℓ-6V-2Sn*

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ABSTRACT

The dimensional stability of Ti-6Aℓ-6V-2Sn has been examined. It is shown that in the duplex annealed condition Ti-6Aℓ-6V-2Sn is dimensionally stable at temperatures up to 448K for 512 hrs. Solution treated Ti-6Aℓ-6V-2Sn undergoes large dimensional changes during both initial aging between 673 and 973K and subsequent exposure to low temperatures ($\leq$ 448K). These results indicate that if close dimensional tolerances must be maintained, duplex annealed Ti-6Aℓ-6V-2Sn should be selected. Selection of treated and aged Ti-6Aℓ-6V-2Sn should only be considered if accompanied by full scale environmental testing.

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I. INTRODUCTION

Increased utilization of new higher strength-to-weight-ratio materials brings with it many questions. One involves the selection of dimensional tolerances for eventual hardware production. Specification of these tolerance levels normally dictates that the dimensional stability of the particular alloy selected be known. The dimensional stability of a material refers to its ability to maintain its original size and shape over a period of time under specified environmental conditions. Any changes in size or shape must be accounted for both during manufacture and ultimate storage/use. This is particularly important when periodic disassembly of the system is required.

The investigation reported herein was part of a larger examination of Ti-6Aℓ-6V-2Sn [1-3]. The present study's intent was to examine the dimensional stability of beta-extruded Ti-6Aℓ-6V-2Sn as affected by heat treatment and subsequent low temperature exposure.

II. EXPERIMENTAL PROCEDURE

The chemical analysis of the Ti-6Aℓ-6V-2Sn alloy evaluated in this examination is given in Table 1. The material was alpha-beta blocked at 1173K prior to being beta extruded at 1248K. This procedure resulted in a final extrusion ratio of 4.4:1. All dimensional stability samples were removed from 140 to 150 mm long prolongations taken from the original 470 mm diameter, 57 mm wall thickness hollow extrusion.

Prior to specimen fabrication 32 mm arcs of the ring prolongation were either (a) duplex annealed or (b) solution treated at 1123K and water quenched. The duplex annealing treatment consisted of 1173K-2 hrs, air cool, 2 hrs at 1058K, air cool. These heat treatments were selected since they represent the most favorable machining conditions for Ti-6Aℓ-6V-2Sn [4].

Table 1

Chemical Composition of Ti-6Aℓ-6V-2Sn

Element	Wt. Pct.	Element	Wt. Pct.	Element	Wt. Pct.
Aℓ	5.7	Cu	0.77	N	0.011
V	5.7	Fe	0.75	C	0.02
Sn	2.1	O	0.155	H	45 ppm

The dimensional stability specimens were machined as shown in Fig. 1. These dimensions were selected so that known reference orientations in the extrusion could be recognized during subsequent measurement and heat treatment steps. Following initial length measurements the samples were encapsulated in quartz ampoules under a partial pressure of approximately one-half atmosphere ultra-high purity argon. All heat treatments of these samples were then performed in furnaces controlled to ± 1K.

Length measurements of the Ti-6Aℓ-6V-2Sn gage block used standard laser interferometry metrological techniques. Subsequent examination of the errors involved in these procedures indicated that the reported length measurements are accurate to ± 20 μ in./in.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Duplex Annealed

The results of the influence of a low temperature exposure on the dimensional stability of duplex annealed Ti-6Aℓ-6V-2Sn are shown in Fig. 2. These observations indicate that the duplex annealed condition is stable to within +35/-50 μin./in. while undergoing thermal exposures for times to 512 hrs at temperatures up to 448K.

Solution Treated and Aged

Fig. 3 shows that solution treated Ti-6Aℓ-6V-2Sn undergoes large orientation-dependent changes in dimensions when aged at temperatures between 673 and 973K. The most likely cause for the overall decrease in stability as the aging temperature increases is related to the gradual relaxation of the high residual stresses introduced by the original solution treatment and water quench. The perturbation observed at and above 823K may be related to the onset of coarse α precipitation, although quantitative confirmation of this suggestion is presently lacking.

The influence of low temperature exposure on the dimensional stability of solution treated and aged Ti-6Aℓ-6V-2Sn is shown in Figs. 4 and 5. These observations indicate that even if solution treated and aged Ti-6Aℓ-6V-2Sn were finish machined after aging, the alloy is still not dimensionally stable and close tolerance fit ups would not be maintained during service at 348-448K. Thus, any attempt to use solution treated and aged Ti-6Aℓ-6V-2Sn under these circumstances would require verification by exposure of a full scale test assembly to the expected thermal environments.

IV. CONCLUSIONS

The results of this study indicate that beta-extruded Ti-6Aℓ-6V-2Sn can be used in the duplex annealed condition with adequate assurance of its maintaining dimensional tolerances during the thermal exposures normally experienced by weapons systems. On the contrary, solution treated and aged Ti-6Aℓ-6V-2Sn is generally unstable and should not be used without adequate auxiliary environmental testing.

ACKNOWLEDGEMENTS

The author wishes to acknowledge J. Smith and H. Meidal for their assistance, respectively, in heat treatment and measurement of the dimensional stability specimens.

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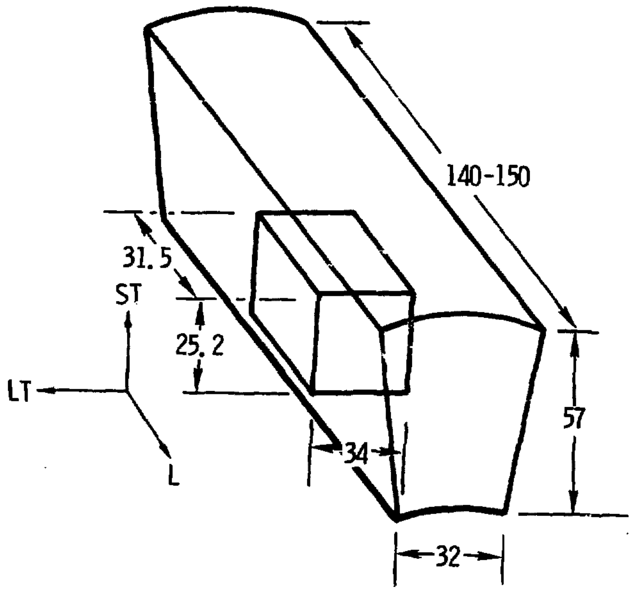


Figure 1: Nominal Dimensions and Orientation of Dimensional Stability Specimen (mm.). Specimen Surface Finish ≤ 5 RMS.

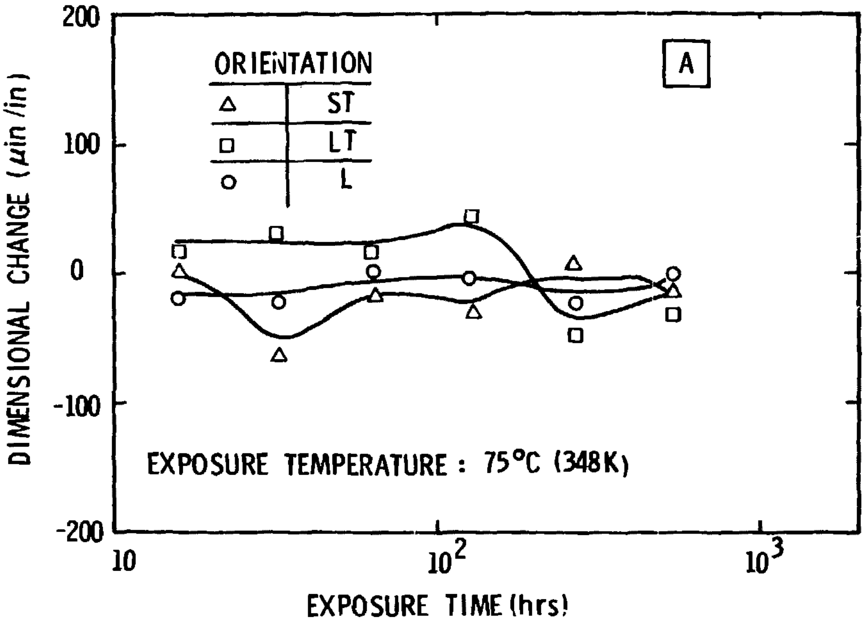
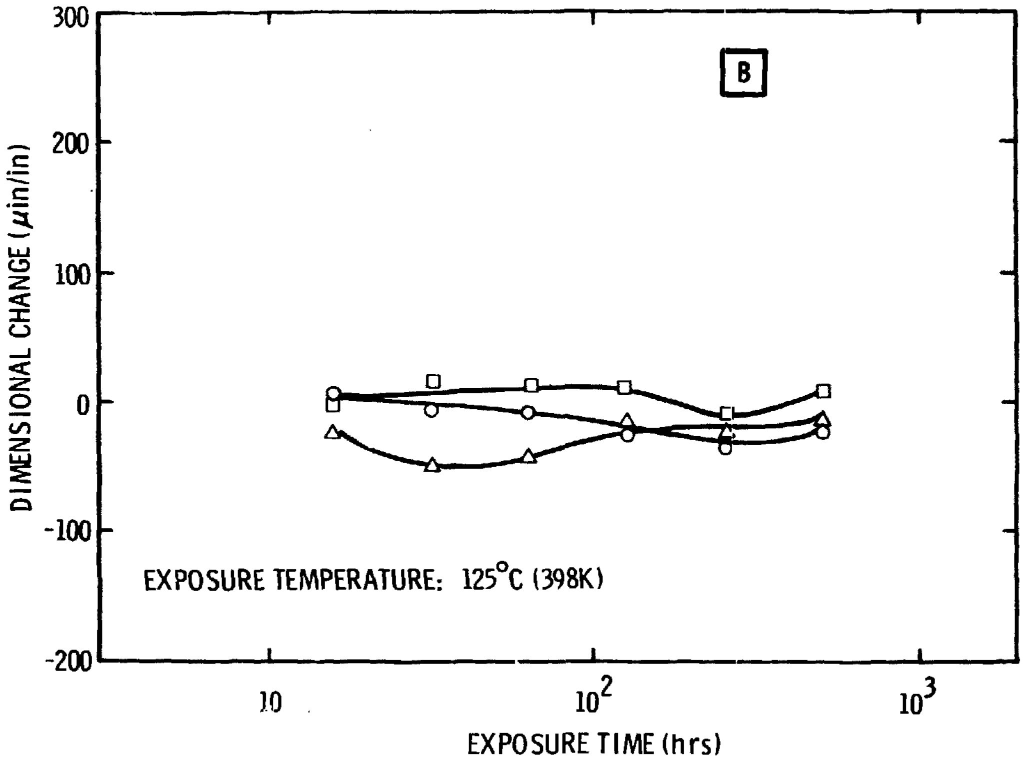


Figure 2: Dimensional Stability of Duplex Annealed Ti-6Aℓ-6V-2Sn at (a) 348K, (b) 298K and (c) 448K.



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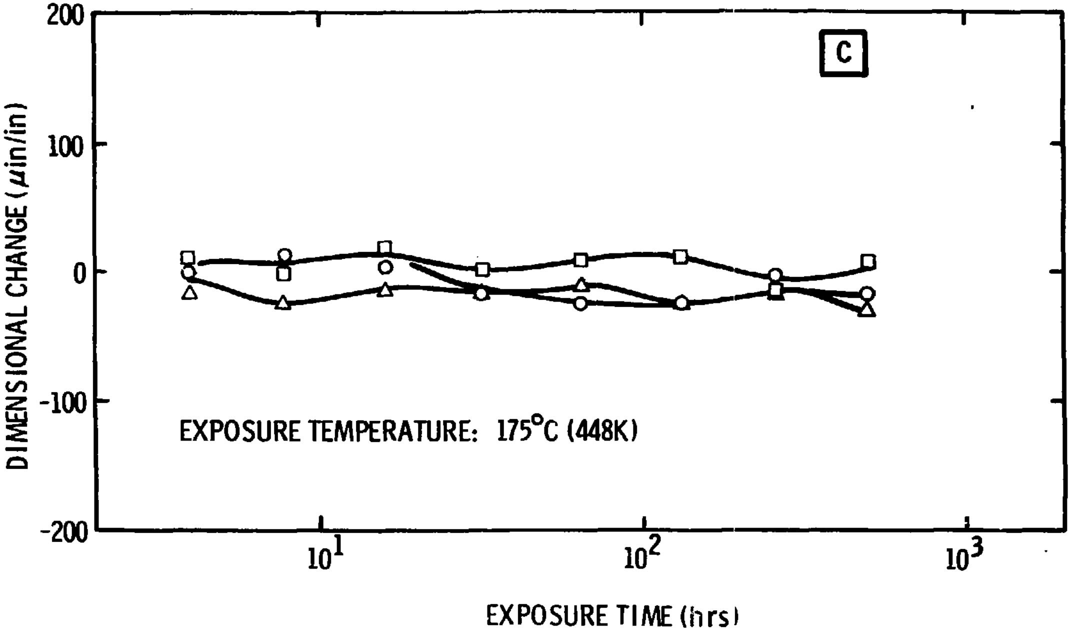

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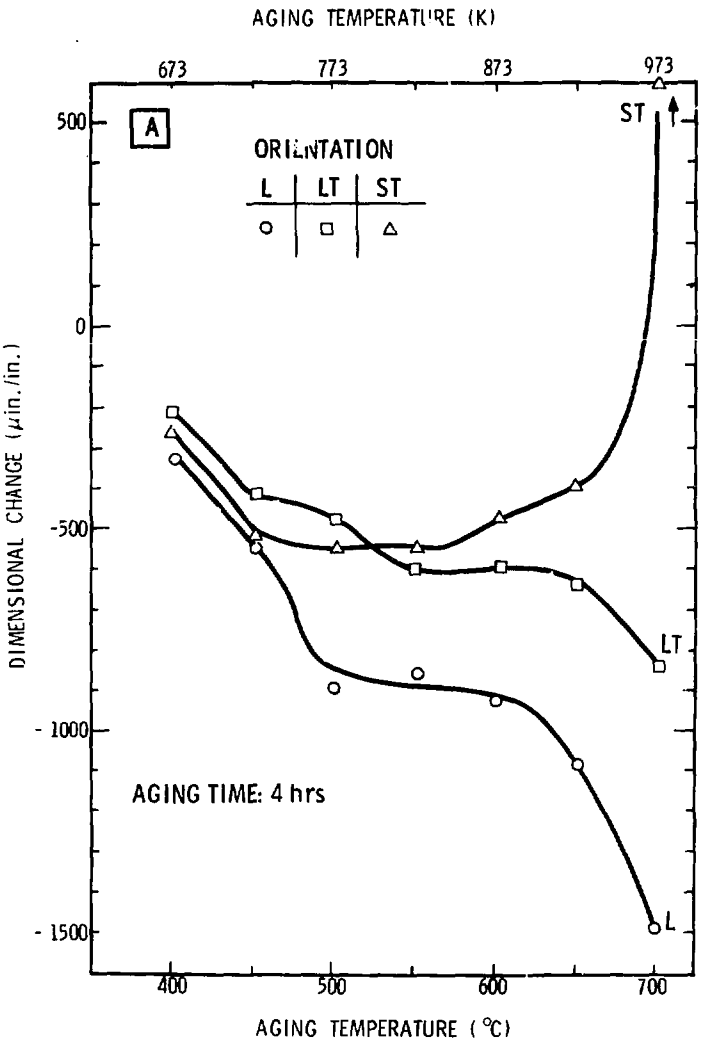
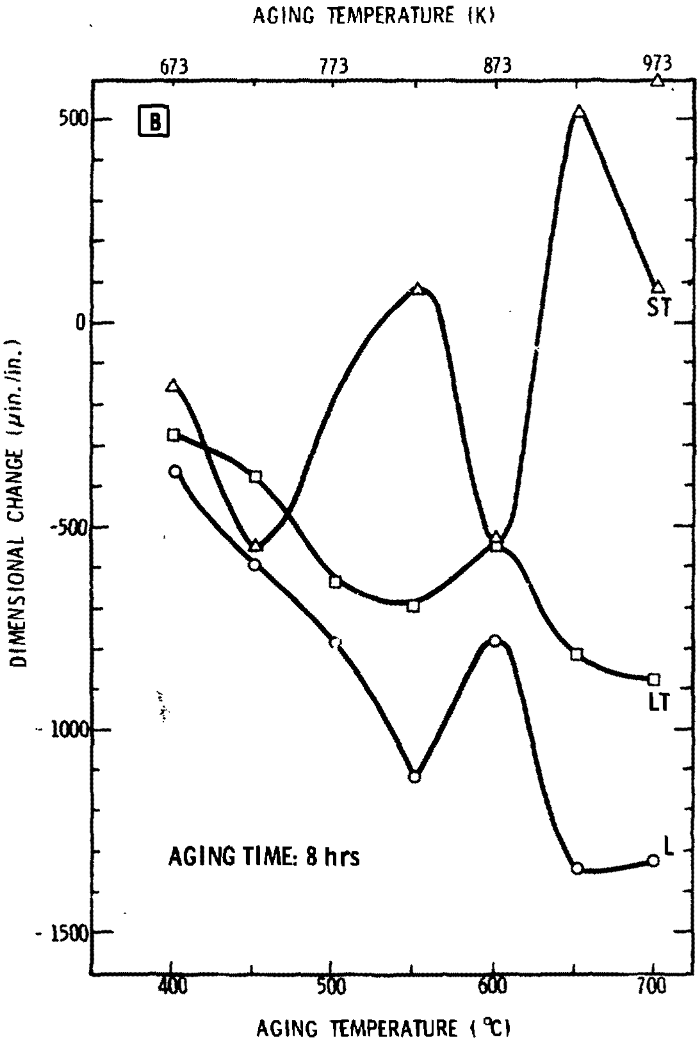


Figure 3: Dimensional Stability of Solution Treated Ti-6Aℓ-6V-2Sn During Aging. Aging Time (a) 4 hrs and (b) 8 hrs.



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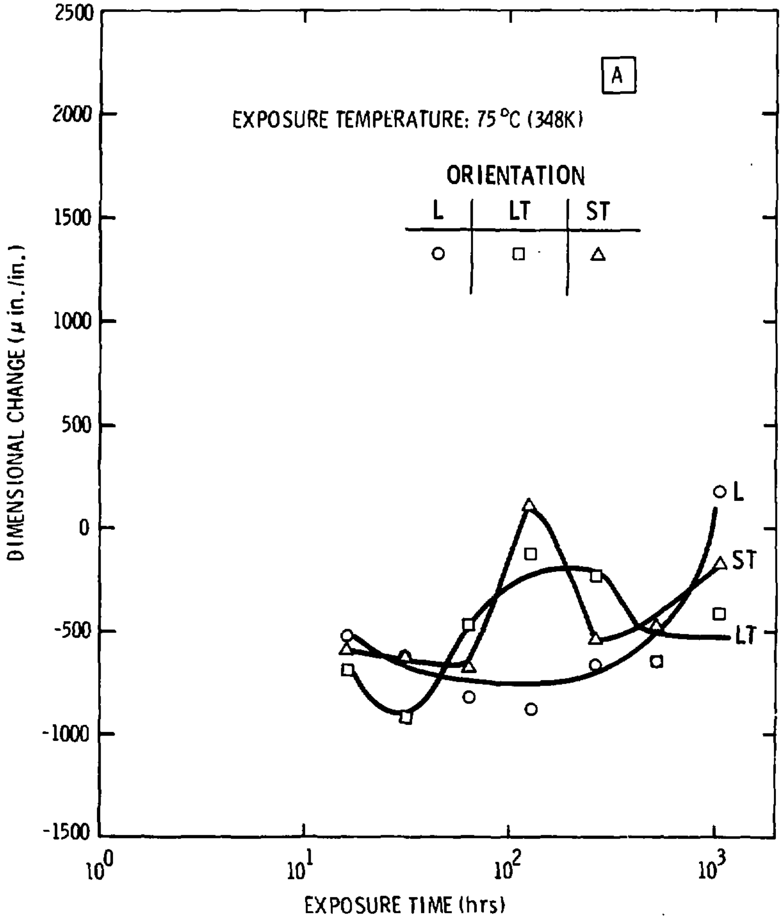
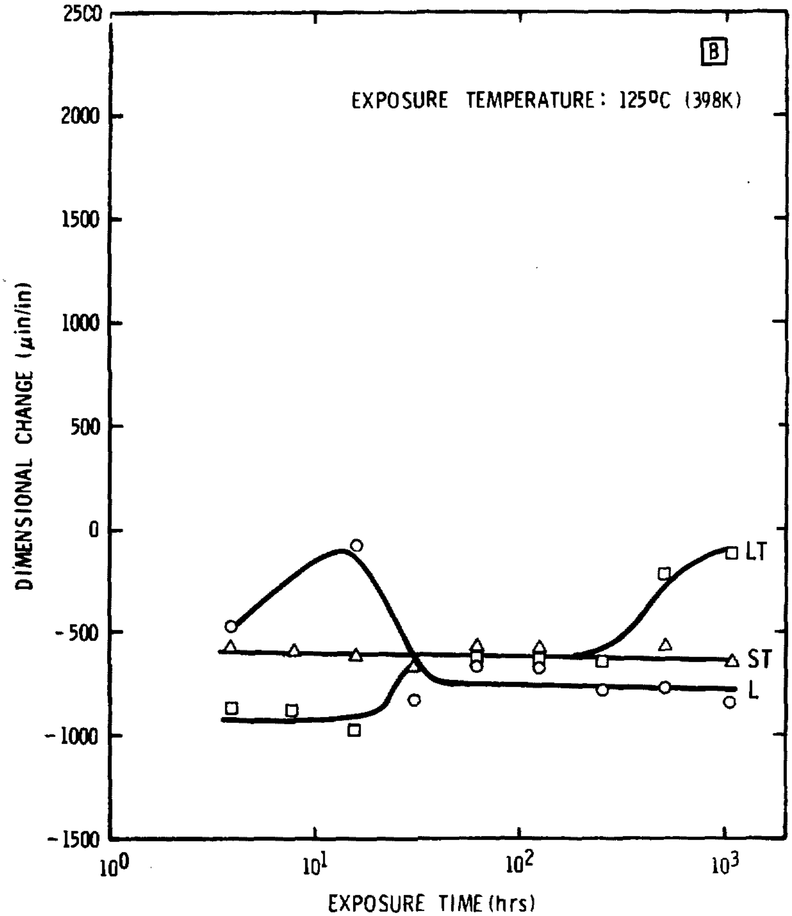


Figure 4: Dimensional Stability of Solution Treated and Aged Ti-6Aℓ-6V-2Sn at (a) 348K, (b) 398K and (c) 448K.



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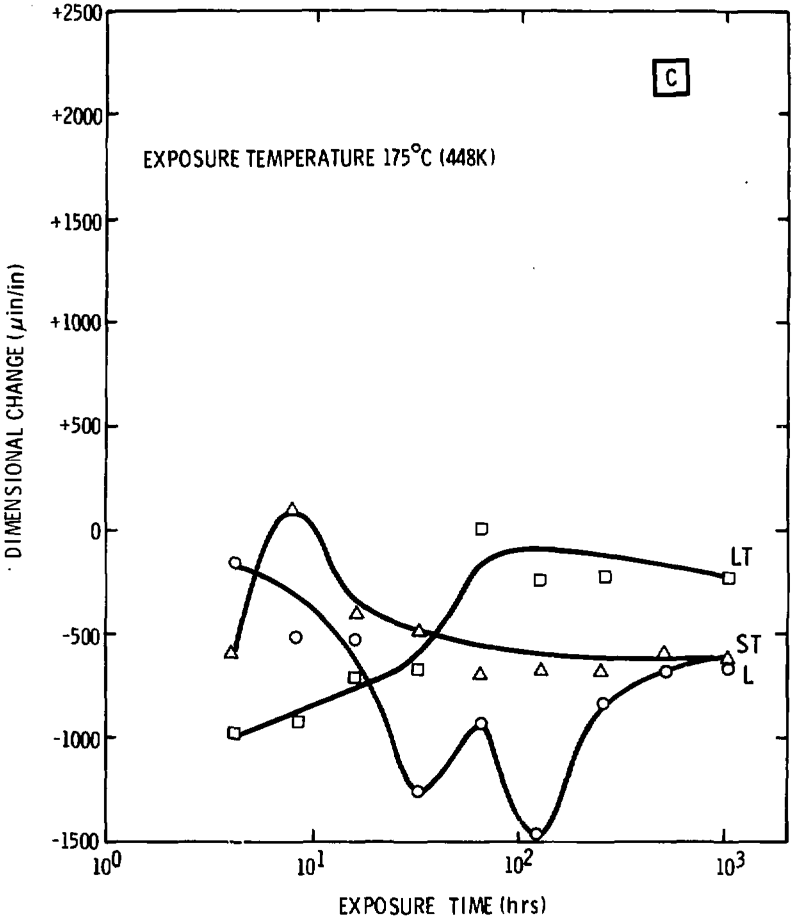

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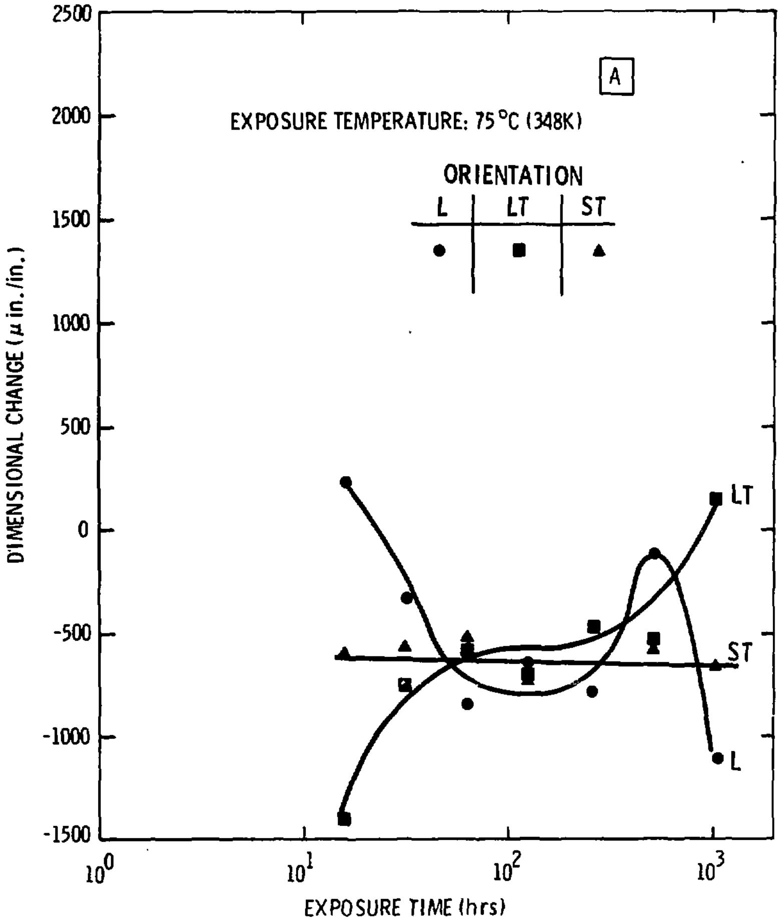
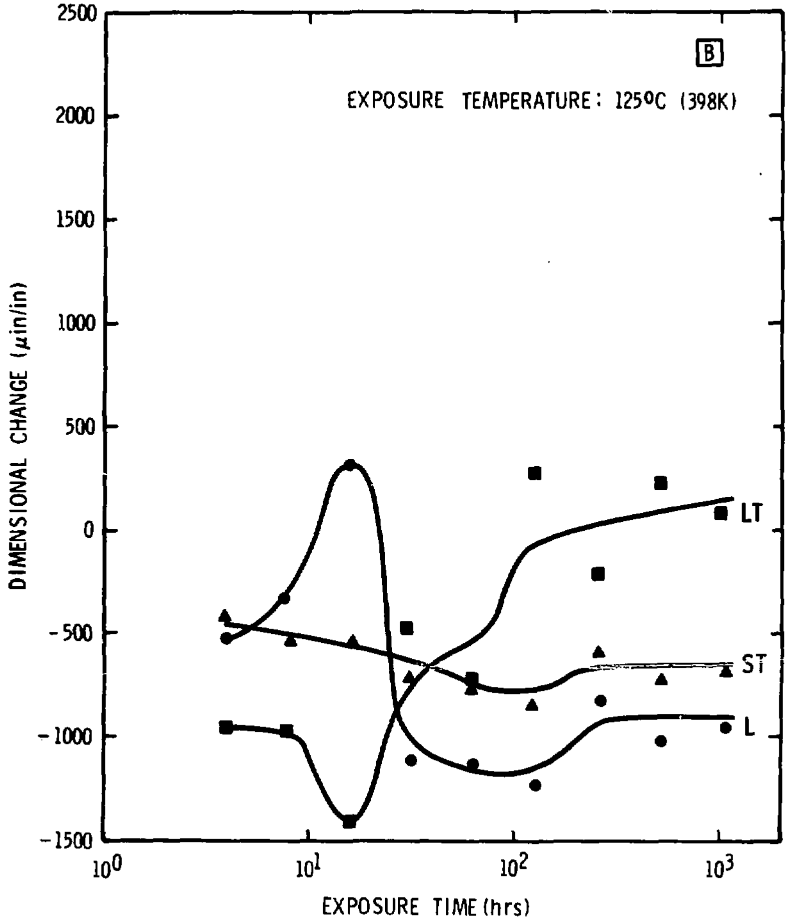


Figure 5: Dimensional Stability of Solution Treated and 873K-8 hr Aged Ti-6Aℓ-6V-2Sn at (a) 348K, (b) 398K, and (c) 448K.



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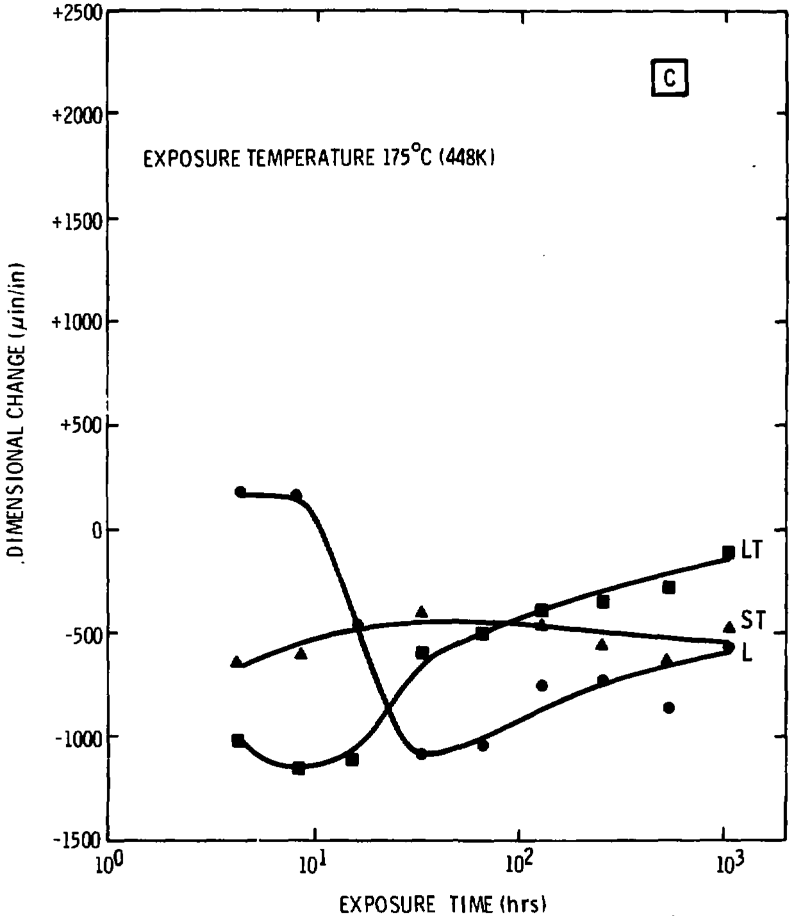

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