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TITLE

VOLUME INCREASE ANALYSIS OF PRODUCTION TEST 040

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SUBJECT **VOLUME INCREASE ANALYSIS OF PRODUCTION TEST 040**

Introduction

This statistical analysis examines volume increase data from PTA-040. The purpose of this analysis is to compare four 1.25 enriched uranium core alloys (Standard, British, High Silicon, and Modified British), two heat treatments (Induction and Salt Bath), and the alloy-treatment interaction. The four core alloys were each processed using the two treatments and then canned as 5.540" AlSi fuel elements. Test pieces were charged in 16 tubes with 40 pieces per tube. The eight fuel types (4 alloys x 2 treatments) were arranged in a series of Latin squares in the test tubes to eliminate the effect of position and tube.(1)

Analysis

A comparison of volume increase was deemed worthwhile after analyzing PTA-040 with regard to fuel element distortion.(2) Volume increases in the present analysis were calculated by H. D. Huber using OD and ID measurements taken at C-Basin with consideration for can wall corrosion and geometric distortion. These volume increase calculations were not completely substantiated, since a thorough check with water displacement measurements at the Radiometallurgical Laboratory was not possible. Despite this fact, the present analysis was continued since a good correlation between the volume increase calculations and element exposure* was observed.

Volume increase vs. element exposure is plotted in Figures 1-5 for the four alloys. Due to a biased in profilometer readings at C-Basin, as mentioned in (2), tubes 39, 40, 49, and 51 are excluded from the illustrations. The regression curves are quadratic fits as calculated by the George program; and the bands are 95% confidence intervals on the means. The element exposures were calculated from the fitted flux, revised according to (3). Linearly, the plotted points for all four alloys can be extrapolated back to 0% volume increase at 0 exposure, indicating further reliability of the data.

* This analysis is based on element exposure which is partly a function of position in the process tube and is therefore related to uranium temperature.

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The curves follow an almost linear regression turning up slightly at exposures greater than 2000. Below an exposure of 1600 the data indicate very little difference in volume increase among the alloys. At higher exposures the Standard alloy appears to exhibit a significantly higher volume increase. The other alloys seem to have approximately the same amount of swelling, though the British alloy swelling is somewhat greater in the biased tubes. No significant difference is apparent between heat treatments for any of the four alloys, though swelling is slightly greater for the induction heat treated pieces.

Since primary concern in this test was volume increase at high exposure, a special analysis of high exposure pieces was made. The center six Latin squares in the test design, containing pieces from positions 9 through 32 in the tubes, were considered. Sixteen volume increase values are substituted into the critical region data for an analysis of variance. Two outlier values are eliminated, eight negative volume increase calculations are discarded, and six values are inserted where no volume increase calculations were made. The above errors can be atrributed, in most of the cases, to poor ID and OD measurements at C-Basin. Substituted values are determined from the missing value equation for Latin squares as outlined in [4]. Element exposures at the above critical positions are illustrated in Figure 6.

Table I gives the critical region mean volume increase values for each alloy, each heat treatment, and each fuel type. To determine if the differences in Table I are significant, the Duncan Multiple Range Test is applied as explained in [5]. The four alloys are ranked highest to lowest according to volume increase. Six comparisons on the differences are made; highest to lowest (i.e. Standard to High Silicon), highest to second lowest, highest to second highest, second highest to lowest, second highest to second lowest, and second lowest to lowest. The procedure is repeated for treatments.

Results

The volume increase differences between the Standard alloy and British alloy, the Standard alloy and the Modified British alloy, and the Standard alloy and the High Silicon alloy are all significant at the .01 level. The other differences among the alloys are not significant. Comparing the heat treatment effect in each alloy, the difference between Induction and Salt Bath is not significant.

The above Duncan Multiple Range Test on Means After Experimentation is illustrated in Table II.

RC Stein/srh

Attachments

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TABLE I

Alloy

Standard	2.39
British	1.88
Modified British	1.81
High Silicon	1.70

Heat Treatment

Induction	2.02
Salt	1.87

Fuel Type

Standard - Induction	2.43
Standard - Salt	2.34
British - Induction	1.99
British - Salt	1.77
Modified British - Induction	1.91
Modified British - Salt	1.71
High Silicon - Induction	1.73
High Silicon - Salt	1.67

TABLE II

DUNCAN MULTIPLE RANGE TEST

$$\text{Standard error} = \sqrt{\frac{\text{error mean square}}{\text{no. of observations}}}$$

Where error mean square is the residual mean square calculated by analysis of variance

p = no. of means included in the range

Range (E) = value read from Significant Studentized Ranges Tables for ∞ degress of freedom at .05 significance level.

LSR = least significant ranges calculated by multiplying the standard error by Range (E) (if difference is greater than LSR it is significant for that range)

Alloy Differences

	High Silicon (1.70)	Mod. British (1.81)	British (1.88)
Standard (2.39)	.69*	.58*	.57*
British (1.88)	.18	.07	
Modified British (1.81)	.11		

p =	2	3	4
Range (E) =	2.77	2.92	3.02
Standard error =	.0653		
LSR =	.181	.191	.197

Heat Treatment Differences

	High Silicon (.06)	Standard (.09)	Mod. British (.20)
British (.22)	.16	.13	.02
Modified British (.20)	.14	.11	
Standard (.09)	.03		

p =	2	3	4
Range (E) =	2.77	2.92	3.02
Standard error =	.1310		
LSR =	.363	.383	.396

* Significant difference

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REFERENCES

(1) BNWL-CC-933, 11-23-66. "1.25 Enriched Uranium Test Charging Pattern," H. D. Huber.

(2) BNWL-CC-1278, 7-12-67, "Statistical Analysis of Production Test A040," H. D. Huber.

(3) DUN-2854, 7-21-67, "Modifications of Weasel Data Calculations," R. C. Stein.

(4) "Experimental Design," W. G.Cochran and G. M. Cox, 1957.

(5) "Fundamental Concepts in the Design of Experiments," C. R. Hicks.

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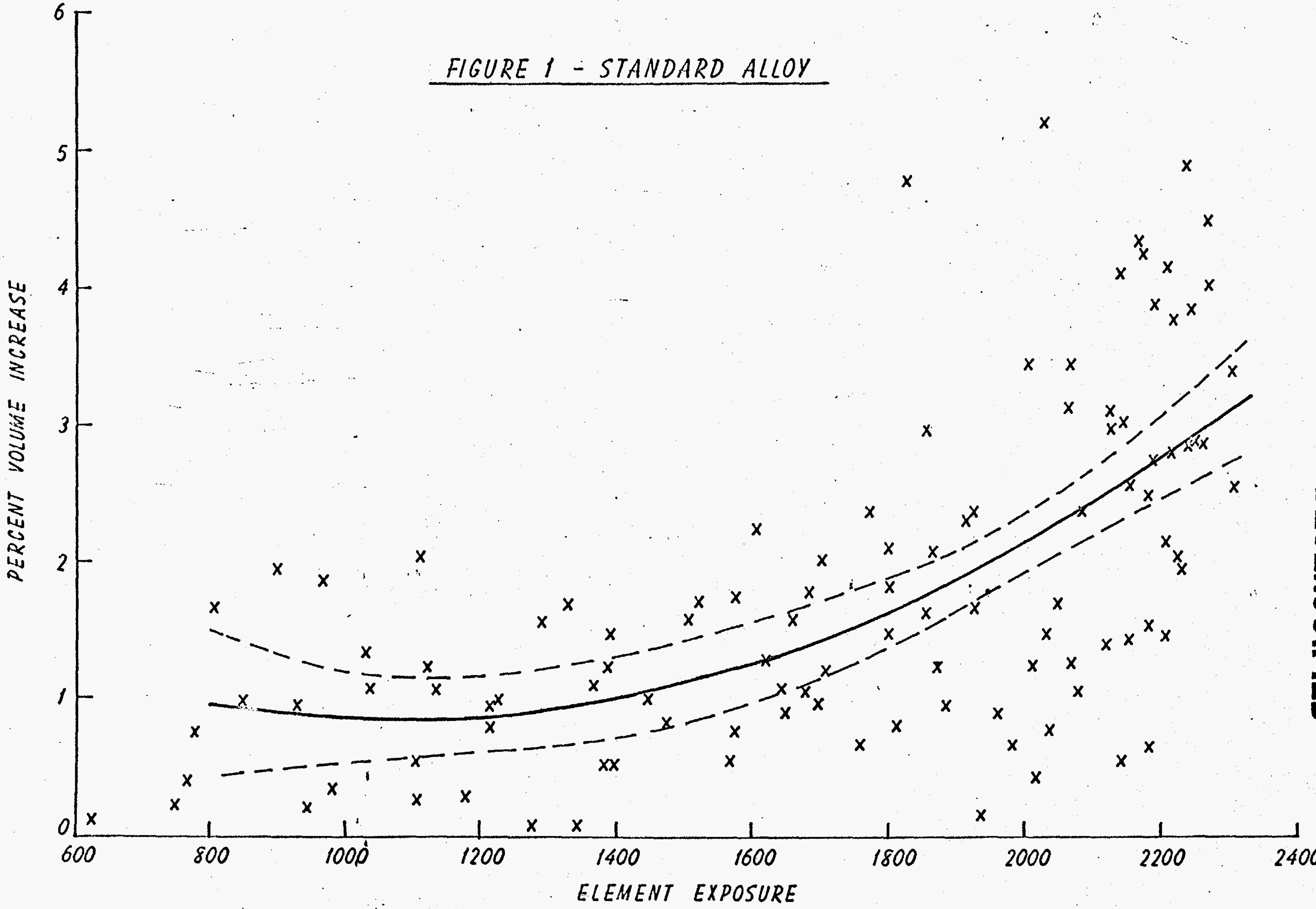
[redacted]

FIGURE 1 - STANDARD ALLOY



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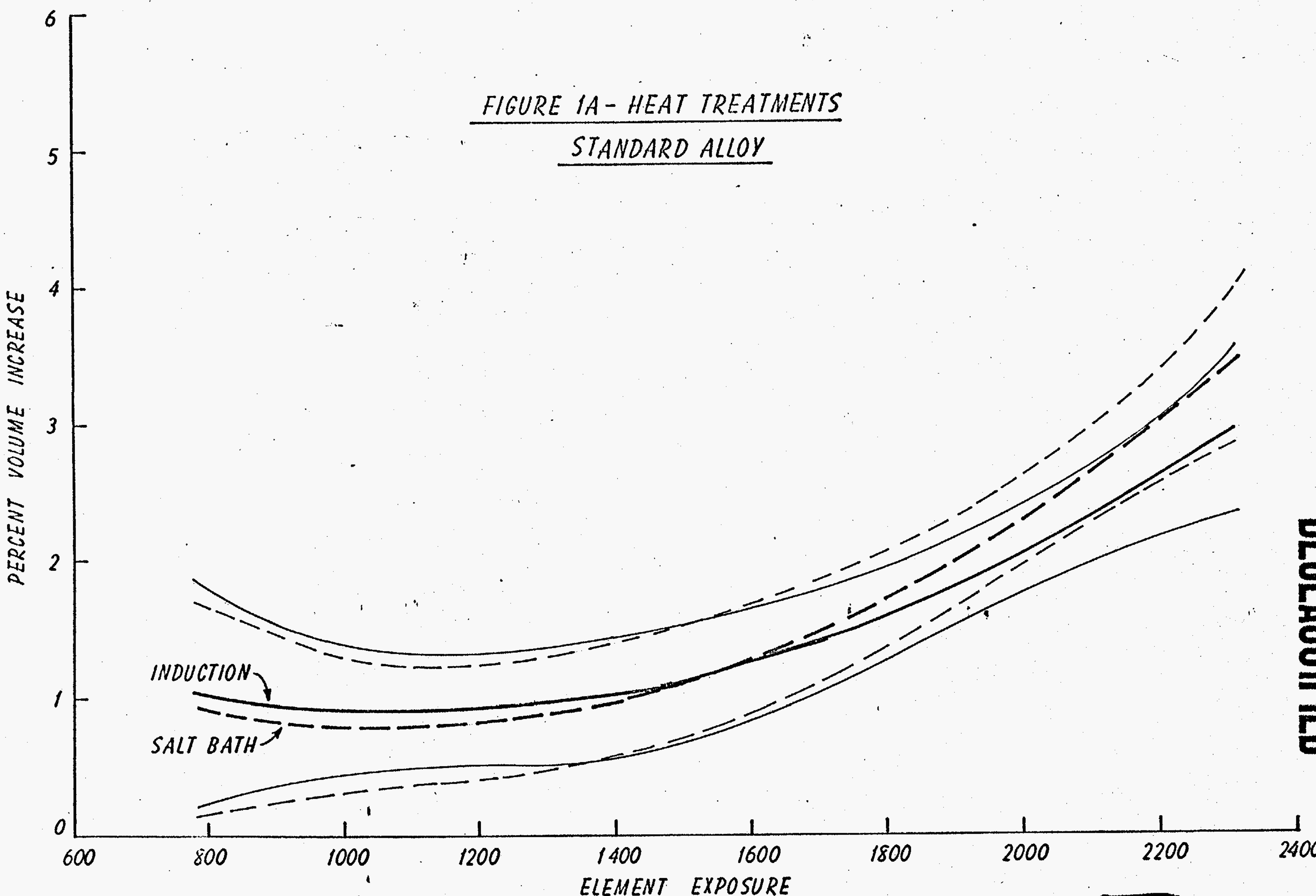

FIGURE 1A - HEAT TREATMENTS

STANDARD ALLOY

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FIGURE 2 - BRITISH ALLOY

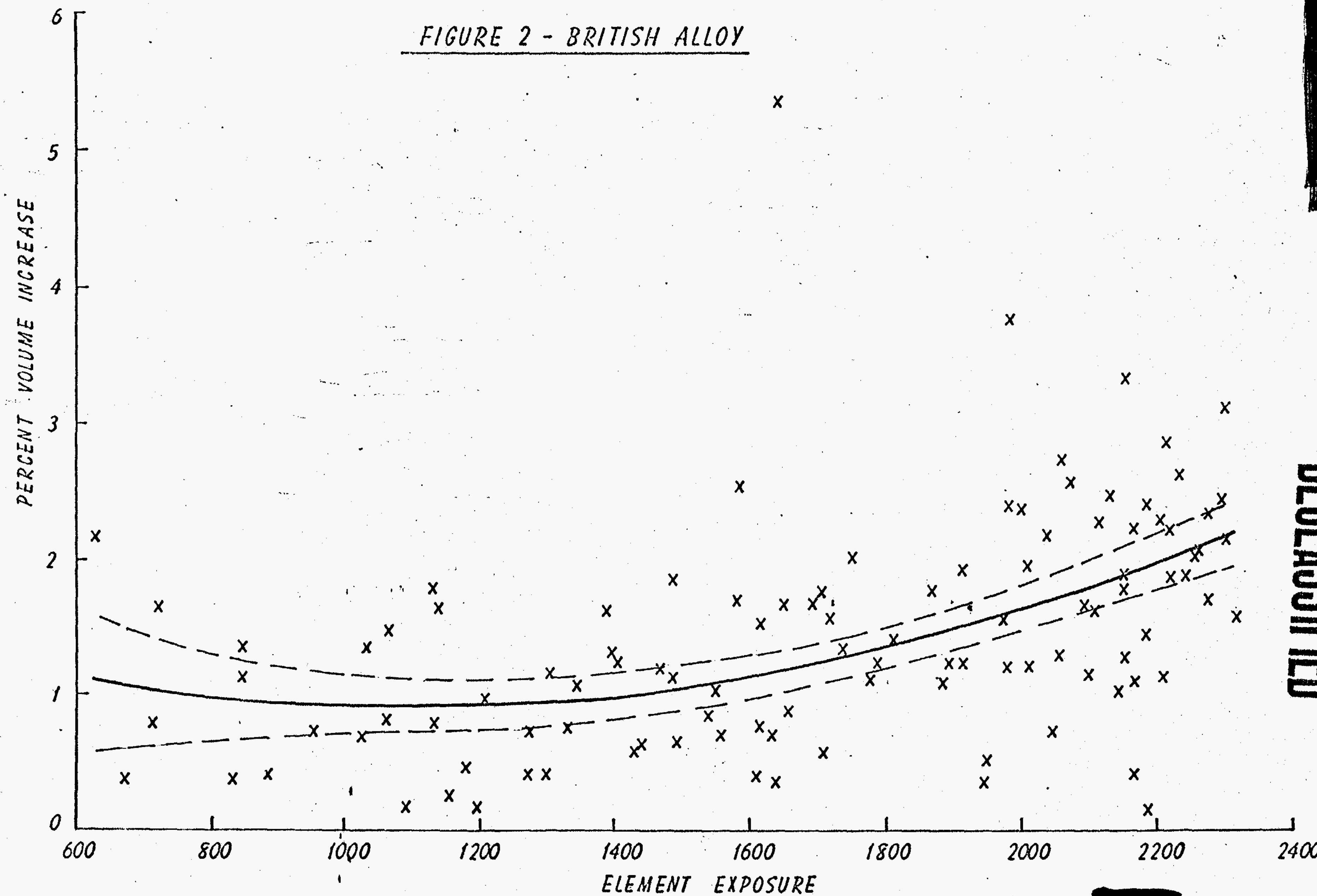

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FIGURE 2A - HEAT TREATMENTS
BRITISH ALLOY

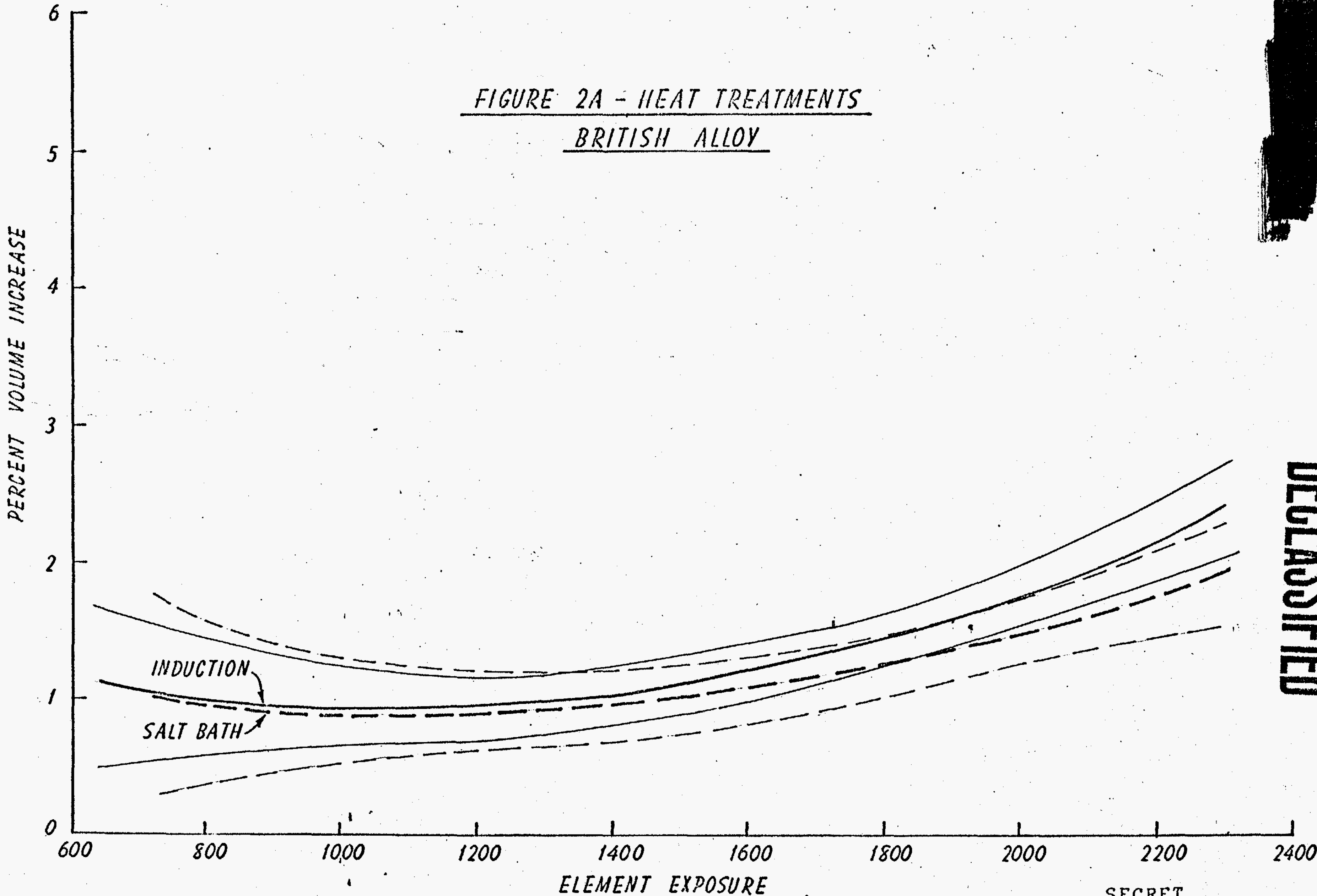

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FIGURE 3 - HIGH SILICON ALLOY

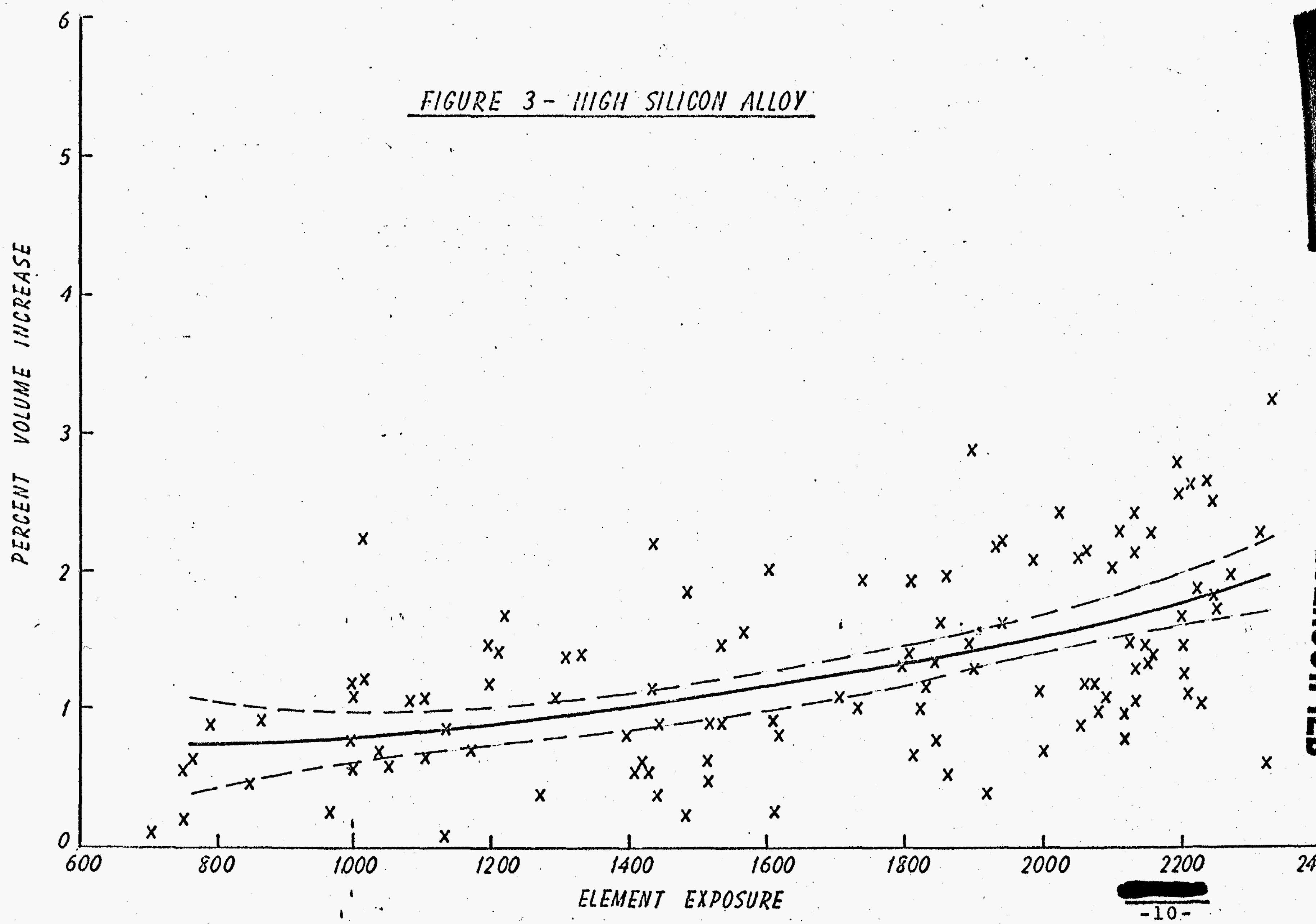

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FIGURE 3A - HIGH SILICON ALLOY

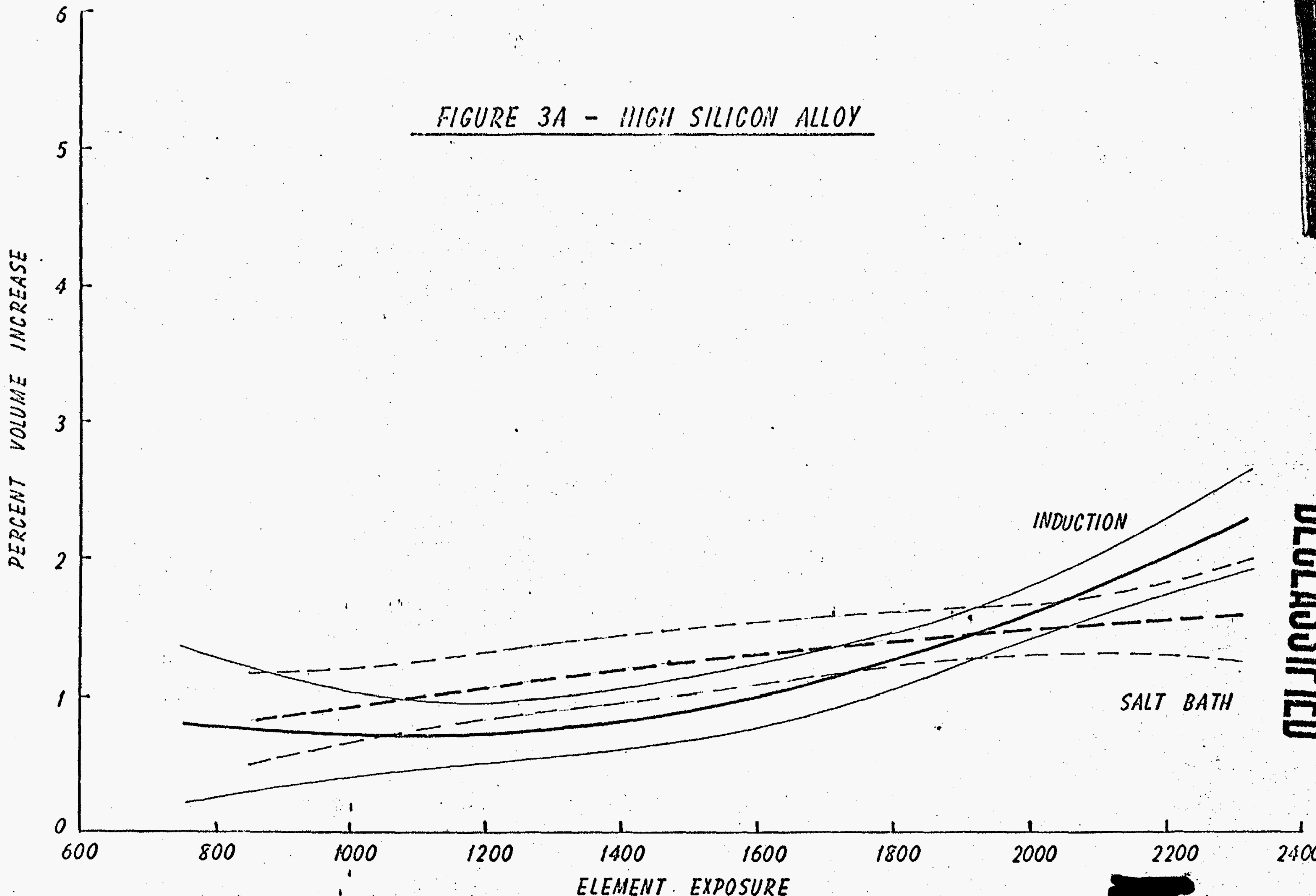

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FIGURE 4 - MODIFIED BRITISH

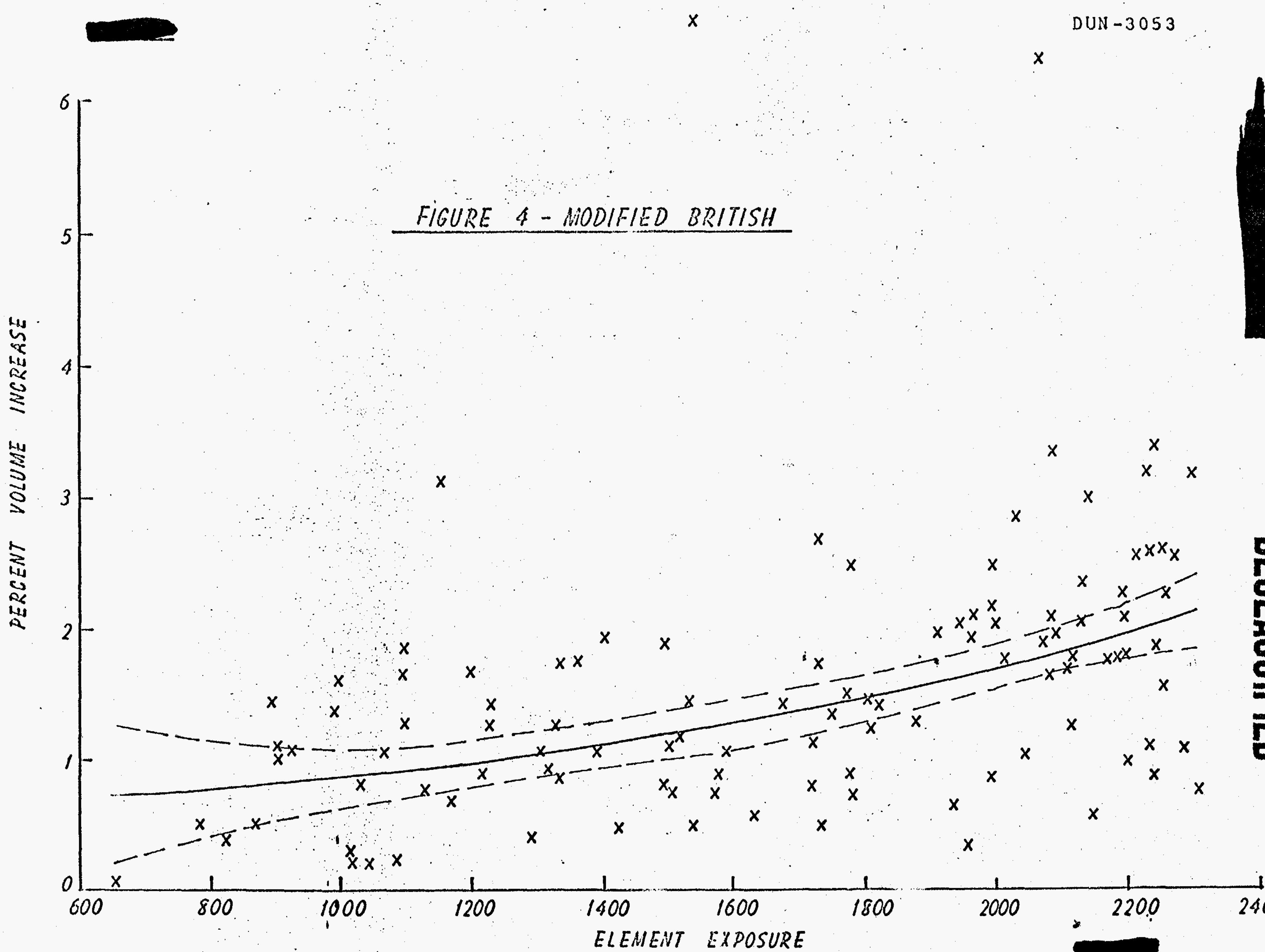

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FIGURE 4A - HEAT TREATMENTS
MODIFIED BRITISH ALLOY

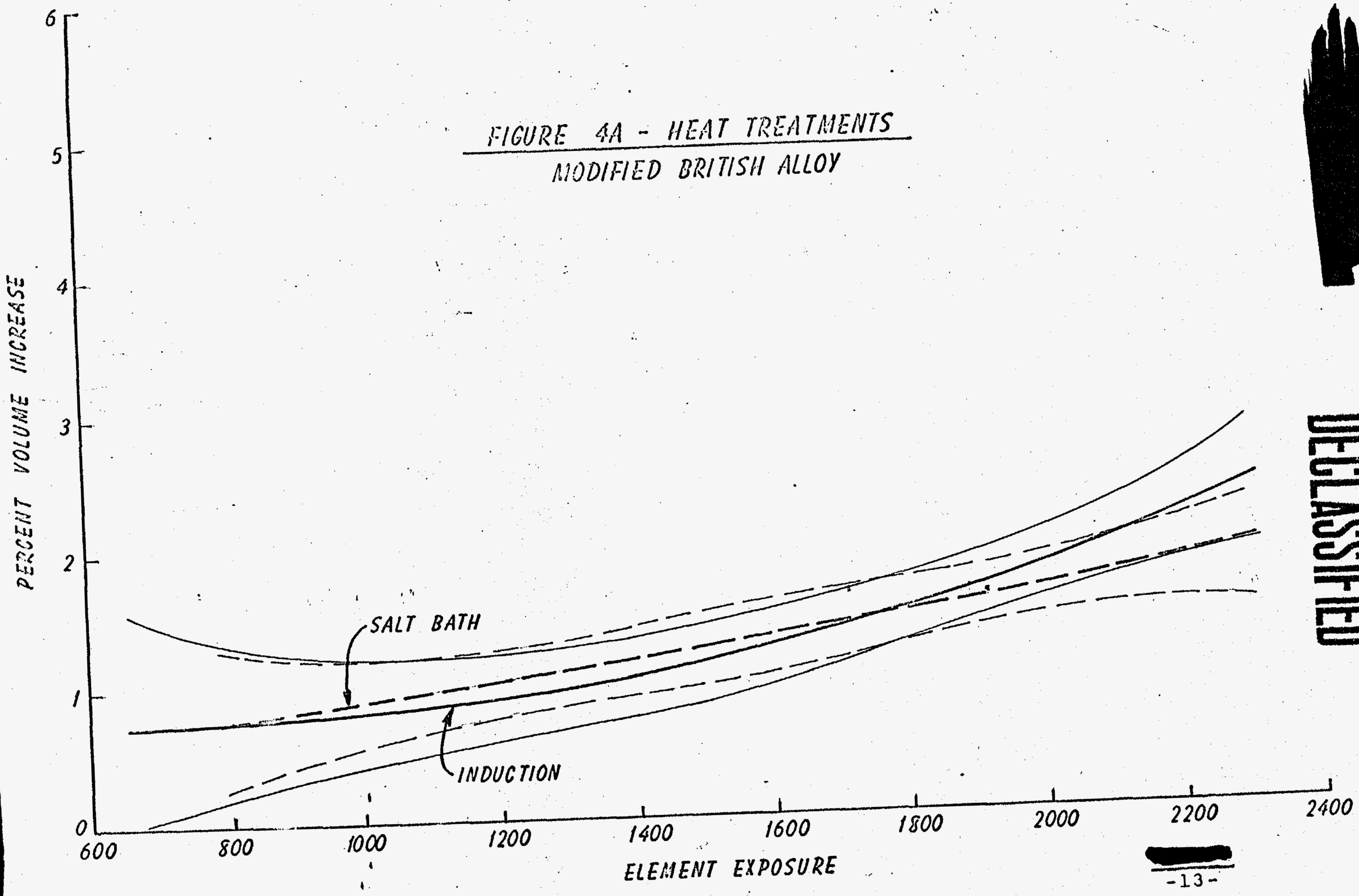

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FIGURE 5

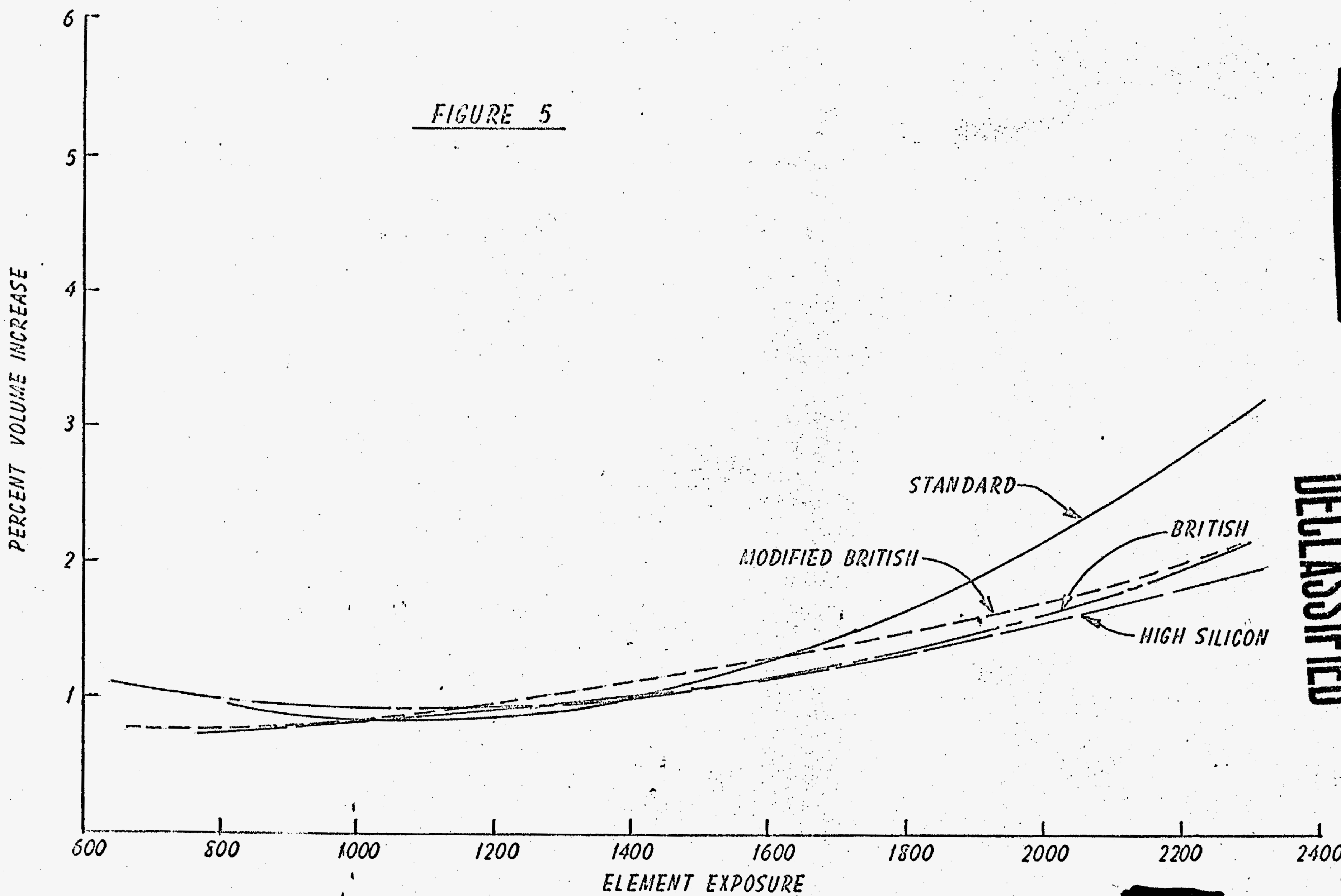

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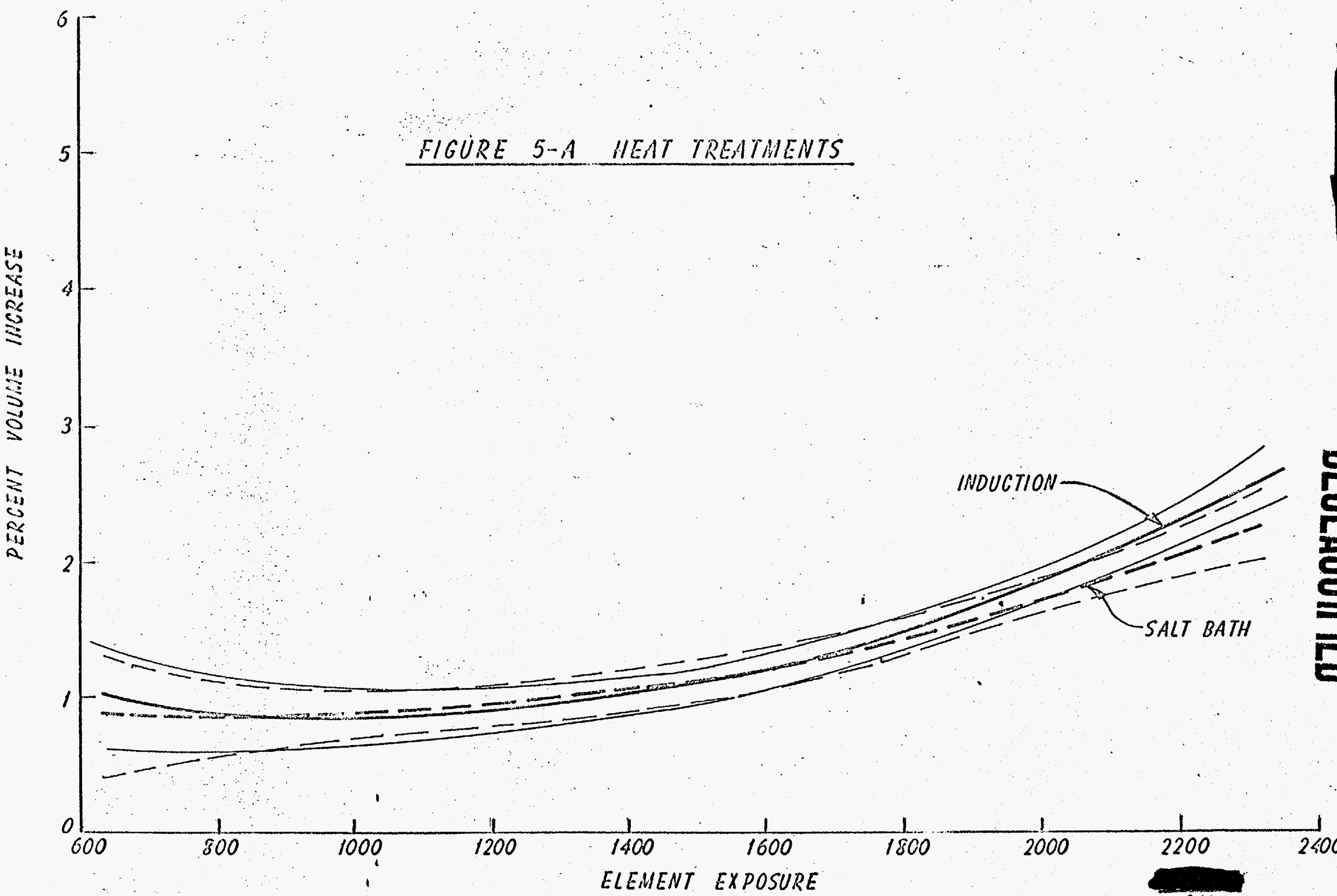
FIGURE 5-A HEAT TREATMENTS



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ELEMENT EXPOSURE IN THE CRITICAL POSITION (9-32)