

AD-A156 752

20000811030

2

Reproduced From
Best Available Copy

DTIC
ELECTE
JUL 18 1985
S D

DTIC FILE COPY

This document has been approved
for public release and sale; its
distribution is unlimited.

 **Lockheed Missiles & Space Company, Inc.**
SUNNYVALE, CALIFORNIA

85 7 08 105

LMSC/F035789

FINAL REPORT
BINDER-FILLER
INTERACTION IN
ENERGETIC POLYMERS
ONR CONTRACT N00014-83-C-0271

MARCH 31, 1985

R. H. MARTINSON

DTIC
ELECTE
JUL 1 8 1985
S D

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

ACKNOWLEDGEMENT

The author would like to thank his colleagues at the Lockheed Palo Alto Research Laboratory for their contributions. Dr. Jerry McCauley performed the chemical analyses, Messrs. Jack Bellin and Roy Holsinger performed the ultrasonic measurements, Mr. Robert Gorman and Dr. William Rothwell assisted with the SAXS measurements at the Stanford Synchrotron Radiation Laboratory.

The materials tested were all prepared at the Naval Weapons Laboratory, China Lake under the direction of Dr. Rena Yee and Dr. Eugene Martin who also provided advance copies of their own data. Dr. R. S. Miller of the Office of Naval Research served as contract monitor and provided several helpful suggestions.



Version For	
PLAS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
MATERIALS	2
CHEMICAL ANALYSES	4
ULTRASONIC WAVE SCATTERING (UWS) EXPERIMENTS	8
SMALL ANGLE X-RAY SCATTERING (SAXS) EXPERIMENTS	13
SUMMARY AND CONCLUSIONS	16
REFERENCES	18
APPENDIX I: ULTRASONIC DATA	AI-1
APPENDIX II: SMALL ANGLE X-RAY SCATTERING DATA	AII-1

LIST OF TABLES

- TABLE 1. Summary of Materials, Compositions, and Experiments Performed.
- TABLE 2. Results of Chemical Analysis of BLX-1 Material.
- TABLE 3. Results of Chemical Analyses of Class A and E RDX Received from NWC.
- TABLE 4. Particle Sizes of RDX Used in the Materials.

LIST OF FIGURES

- FIGURE 1. Block Diagram Depicting System for Acoustic Determination of Volume Dilatation.
- FIGURE 2. Ultrasonic Transducers Mounted on Propellant Specimen in Tensile Test Machine.
- FIGURE 3. Variation of Scattered X-Ray Intensity with Time During Tensile Test of BLX-4.

INTRODUCTION

The objective of this study was to measure the kinetics of the dewetting process in a variety of filled energetic polymers being studied as candidates for improved solid rocket and gun propellants in the Office of Naval Research ONR Power Program under the direction of Dr. R. S. Miller (Code 432). The experimental method used was ultrasonic and electromagnetic wave scattering (SAXS) which had been previously developed at the Lockheed Palo Alto Research Laboratory as valuable tools for characterizing strain-induced internal damage in tactical solid propellants.

As many experimental compositions as were available in the requisite amounts from the Naval Weapons Center, China Lake, were to be investigated, with 4 being the agreed upon minimum number. Actually, experiments were performed on a total of 9 different model compositions, although both ultrasonic and SAXS experiments were not carried out on every composition due to the lack of suitable specimens.

The motivation for this investigation was the "hot-spot" theory of initiation. It has been known for some time that porous explosives are much more sensitive to initiation by impact than are fully dense cast explosives. Empirical correlations between impact sensitivity and mechanical properties have also been developed. In the propulsion industry, it is widely believed that the dewetting process is central to the whole question of what determines the mechanical properties of heterogeneous propellants.

The energetics of wetting of single crystal RDX and HMX by energetic binders had been studied at NWC by Dr. Rena Yee prior to the commencement of this investigation [1]. It was hoped that

by studying the dewetting process in detail. correlations between surface energetics and dewetting behavior would be obtained.

Specific questions addressed in ^{the present work} ~~the present work~~ are:

1. What is the relation, if any, between the particle size of RDX and the voids created by dewetting?
2. Does the number density of voids caused by strain vary with solids loading in the same binder?
3. What is the influence of plasticizers on the size and number density of voids?
4. What is the relative number density of voids in compositions that fracture at different strains? The size? *and*
5. What do the growth curves of voids look like as functions of strain?

Smaller angle X-ray scattering

By combining (SAXS) and ultrasonic wave scattering (UWS) data with existing theories of scattering, partial answers to these questions can be derived. It is for the lack of adequate scattering theory rather than for the lack of experimental precision that complete and definitive answers cannot always be given.

Keywords: Charge materials

MATERIALS

The materials and test specimens for this experimental investigation were prepared at the Naval Weapons Center, China Lake, under the direction of Dr. E. C. Martin. The model materials are described in Ref. [2] and listed in Table 1.

DATE SHIPPED FROM NAC	DESIGNATION	COMPOSITION	EXPERIMENTS RUN	DATES	COMMENTS
11/17/83	BLX-1	R45M-IPDI 75% RDX (E & C)	SAX	12/02/83	Samples highly absorbing - too thick. Tensile & relaxation runs not successful.
11/17/83	BLX-2	R45M-IPDI 80% RDX (E & Screened A)	SAX	12/02/83, 12/04	
11/17/83	BLX-3	R45M-IPDI 75% RDX (E & Screened A?)	SAX	12/03/83, 12/04	
03/29/84	BLX-4-6	18.75% TMETN + 6.25% GAP + 75% RDX	SAX UWS	03/25/85, 03/26 11/02/84	
03/29/84	BLS-1	36% R45M-IPDI 64% RDX (Class E) cast	SAX	03/25/84	
03/29/84	Class A RDX	(screened)	Chemical Analysis		
03/29/84	Class E RDX		Chemical Analysis		
07/17/84	BLX-4	4.95% GAP + TMETN 45% Class E RDX; 30% Class A RDX	UWS	11/02/84	
07/17/84	BLX-8	26.72% GAP + 4.68% N-100 41.13% Class E RDX 27.42% Class A RDX	UWS SAX	10/19/84 01/17/85	Tensile runs
07/17/84	BLX-9	9.18% GAP + 2.09% N-100 +22.63% BTTN 39.54% Class E RDX 26.36% Class A RDX	UWS SAX	11/02/84 01/17/85	Tensile runs
07/17/84	BLX-6	PBX 29.01% Class A RDX 43.51% Class E RDX	UWS	11/05/84	
07/17/84	BLX-11	23.2% R45M-IPDI 45% Class E RDX 30% Class A RDX cast	UWS	11/05/84	

LMSC-F035789

TABLE 1. Summary of Materials, Compositions, and Experiments Performed.

Because of the physical nature of some of the materials such as brittleness or stickyness, NWC was not always able to prepare test specimens in the geometries specified by LMSC. For instance, the cutting of SAXS specimens into thin uniform slices whose major faces were accurately parallel did not prove possible. The limited amount of material available meant that UWS specimens usually turned out to be smaller than is desirable for such experiments. It was decided jointly by NWC and LMSC to accept the existing limitations on purity, shape, and numbers of test specimens in order to avoid delaying the experimental program. There is no doubt, however, that more consistent experimental data could have been obtained with better test specimens.

CHEMICAL ANALYSES

During early SAXS experiments it was noticed that the x-ray absorption of samples received from NWC appeared to be higher than calculated from the nominal elemental composition. It was therefore decided to analyze some of the specimens chemically.

Results of chemical analyses performed on BLX-1 and neat RDX are shown in Tables 2 and 3. The analyses were done by igniting the samples in air and weighing the residues which were then subjected to semiquantitative emission spectrographic analyses. It was believed that major heavy elemental impurities with the exception of Bismuth would be found in RDX rather than in the binder. Therefore, samples of both Type A and E RDX were obtained from NWC and analyzed chemically. The results are shown in Table 3.

It was, indeed, found that most of the impurities are contained in the RDX. Bismuth-containing chemicals are

Weight-percent residue after ignition - 0.011%.

Semiquantitative emission analysis of ash as oxides (in percent):

Mg	.0022
Si	.0020
Bi	.0018
Fe	.0013
Na	.0009
Sn	.0005
Cr	.0007
Ca	.0004
B	.0004
Pb	.0002
Cu	.0002
Ag	.0002
Ti	.0001
Mn	.0001
Al	<u>.0001</u>
	.011

TABLE 2. Results of Chemical Analysis of BLX-1 Material.

Two samples of RDX received from NWC were air oxidized by thermal decomposition in platinum crucibles. The weight of each sample was nearly 4 grams. The ash was subjected to emission spectrographic analysis.

Sample	<u>A</u>	<u>E</u>
Percent residue after ignition	0.0074 $\pm$.0005	.0072 $\pm$.0005
Spectrographic analysis (as oxides)		
Mg	17 ppm	18 ppm
Si	16	17
Fe	13	13
Ca	7	7
Cr	4	4
Ni	4	4
Cu	4	4
Pb	2	0
Na	1	1
Ti	2	2
Zn	1	<1
Al	2	2
Sn	1	1
Ag	1	<1
B	1	1

TABLE 3. Results of Chemical Analyses of Class A and E RDX
Received from NWC.

deliberately added to the mixes. Even though the total amount of metals in BLX-1 (and probably in the other mixes) is only about 100 ppm, the x-ray absorption is affected significantly by these impurities.

PARTICLE SIZE DISTRIBUTIONS

NWC provided the following information regarding the particle size distributions of RDX used in the mixes:

Class E RDX - Average diameter: 4 microns

Class C RDX - 80% > 150μ
20% < 150μ

Screered Class A RDX

<u>Microns</u>	<u>Weight %</u>
- 20	9.5
20 - 40	8.0
40 - 60	11.8
60 - 80	17.7
80 - 100	23.0
100 - 120	18.2
120 - 150	11.8

TABLE 4. Particle Sizes of RDX Used in the Materials.

ULTRASONIC WAVE SCATTERING (UWS) EXPERIMENTS

The basic methodology of ultrasonic testing developed at LMSC for measuring internal mechanical damage in propellants and other filled polymers is described in References [3] and [4].

Briefly, pulsed ultrasonic wave transmission measurements are made as the test specimen is deformed mechanically. From measurements of wave speed changes, the volume dilatation is calculated according to existing propagation theory for porous materials. The average scatterer size is then calculated from the measured attenuation and dilatation by invoking the theory of Rayleigh scattering.

Over a period of several years of experimentation at LMSC it has been found that the correlation between ultrasonically measured dilatation and dilatation measured directly is usually very good for a variety of filled polymers and propellants. However, it has also been found that Rayleigh scattering theory yields a mean scatterer size that is substantially larger than is reasonable, and that the number density of scatterers is smaller than seems reasonable. Indeed, in those few cases in which the frequency dependence of ultrasonic attenuation has been measured in strained propellants, it has been found that the attenuation varies approximately as the square of the frequency, rather than as the fourth power as required by Rayleigh's law. This observation shows that pure Rayleigh scattering probably is not the only source of incremental attenuation in strained solid propellants. Accordingly, the vacuole sizes derived from applying Rayleigh scattering theory to ultrasonic attenuation experiments cannot be regarded as quantitative, particularly in the usual case when a distribution of scatterers contributes to the total attenuation. Nevertheless, for lack of other useful scattering theory, we have in this report included calculations

of the mean size and number density of vacuoules according to Rayleigh theory.

The basic measurements taken during the ultrasonic experiments are:

1. Uniaxial extension of the specimen.
2. Transverse contraction of the specimen.
3. Change in transit time of the transmitted ultrasonic waves.
4. Change in attenuation of the transmitted ultrasonic waves.
5. Ratio of the speeds of shear waves and longitudinal waves in undeformed specimens.

A block diagram of the ultrasonic measurement apparatus is shown in Figure 1 and a photograph of the transducer holder mounted on a propellant specimen is shown in Figure 2.

Two basic equations derived in Reference [3] have been used to reduce the ultrasonic data. These equations are:

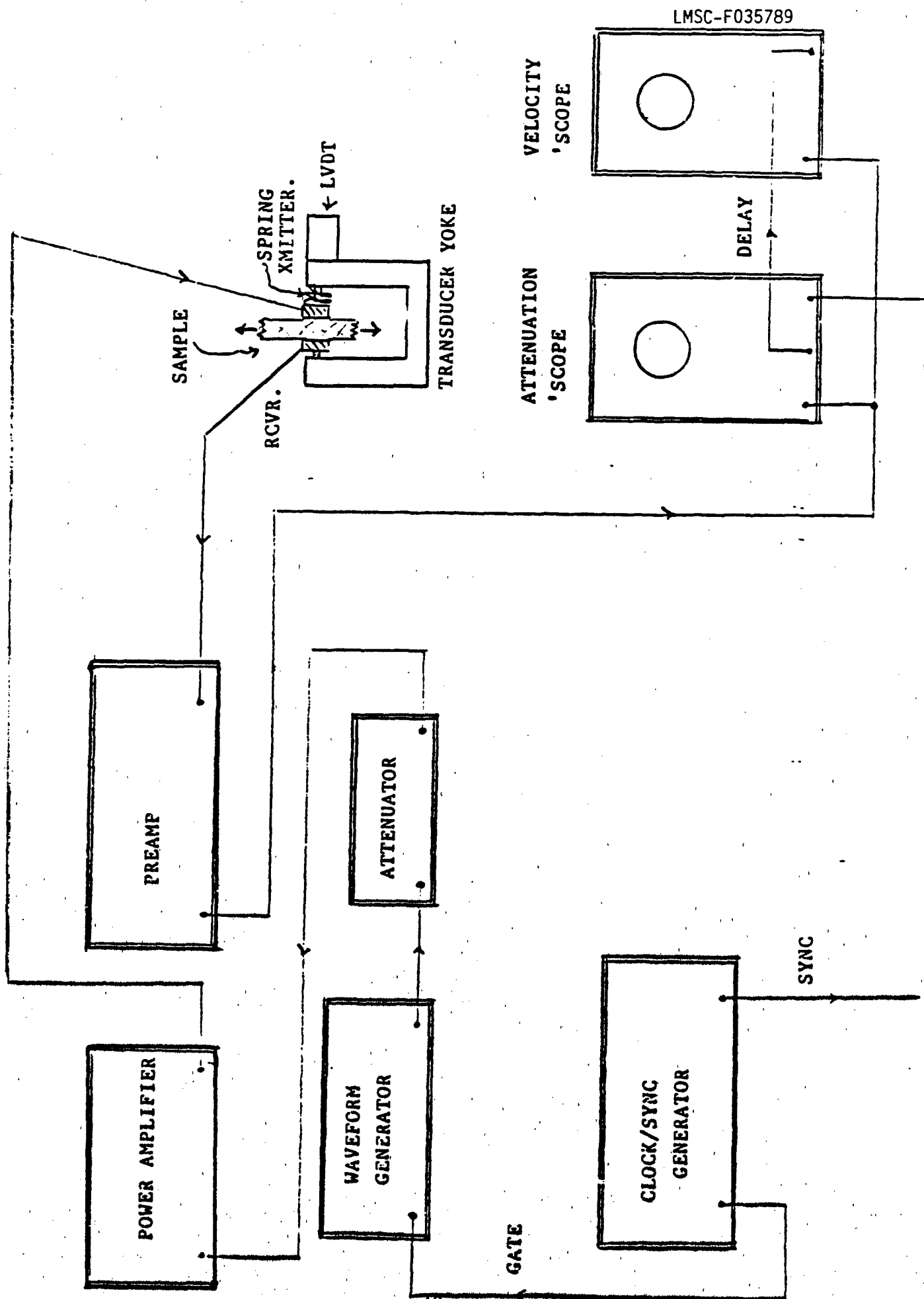
$$\frac{\Delta V}{V_0} = \frac{1}{b} \left[\frac{\frac{\Delta C}{C_0}}{1 - \frac{\Delta C}{C_0}} \right] \quad (1)$$

$$\Delta \alpha = \frac{1}{6} \gamma k^4 a^3 \frac{\Delta V}{V_0} \quad (2)$$

where $b = \frac{3}{8(1 - \frac{3}{2\nu_0})}$

$$k = \frac{2\pi}{\lambda}$$

Fig. 1 Block Diagram Depicting System for Acoustic Determination of Volume Dilatation



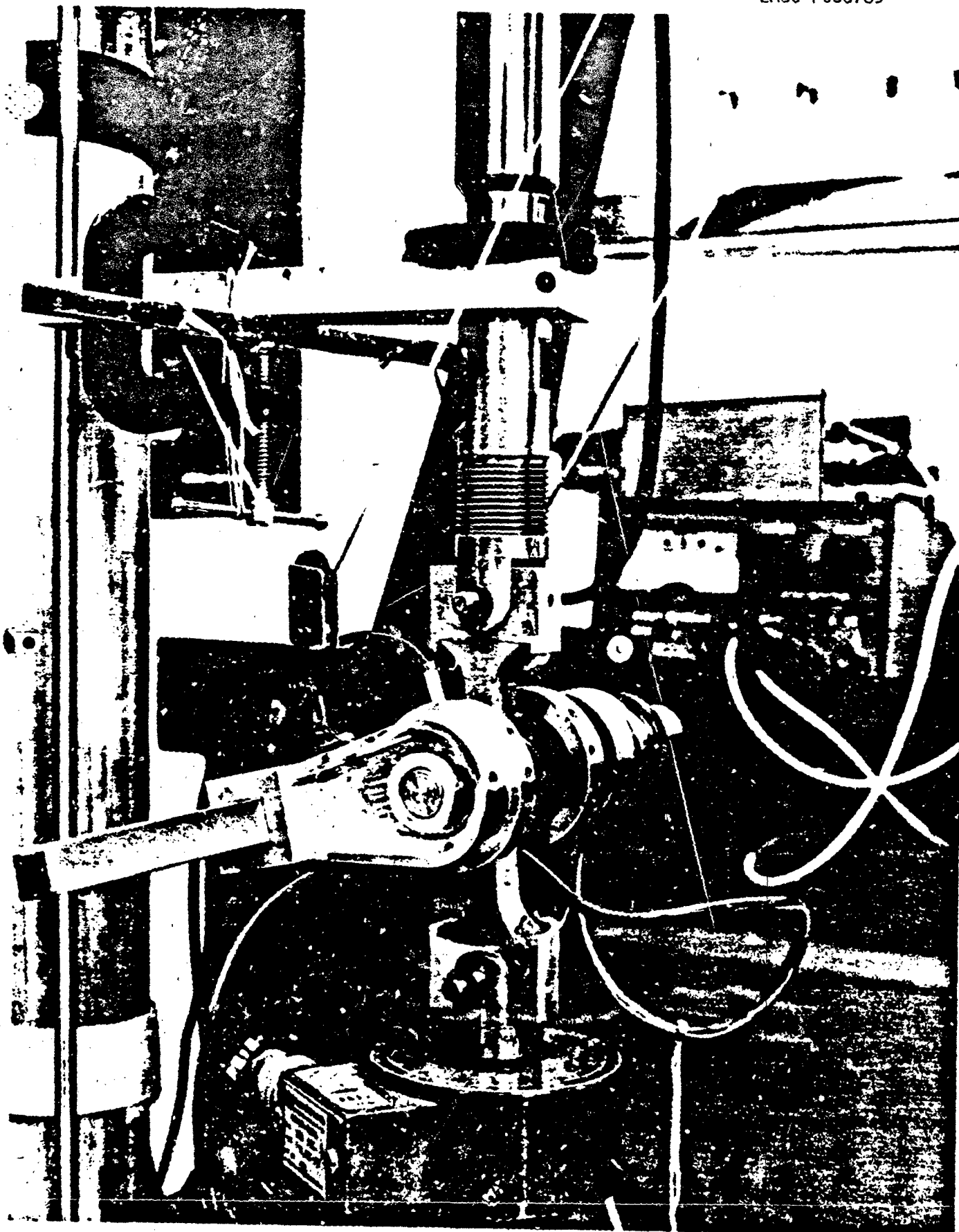


Fig. 2 Ultrasonic Transducers Mounted on Propellant Specimen in Tensile Test Machine

and the function g is a known function of Poisson's ratio ν_0 while $\frac{\Delta C}{C_0}$ is the fractional change in longitudinal wave speed and $\frac{\Delta V}{V_0}$ is the fractional dilatation and λ is the ultrasonic wave length.

Plots of the ultrasonic data for BLX-4, BLX-6, BLX-8, BLX-9, and BLX-11 are included in Appendix 1. Each data set consists of 6 plots which show:

1. The load-strain curve.
2. Relative change in sound speed.
3. Relative change in attenuation.
4. Calculated volume dilatation.
5. Calculated void radius.
6. Calculated void number density.

Included also in Appendix 1 are plots of volume dilatation data obtained from NWC and a table of longitudinal and transverse wave speeds for 5 undeformed specimen compositions.

The ultrasonic data in Appendix 1 appear remarkably similar for all the materials tested. Since the RDX particle distribution and solids loading are essentially the same for BLX-4, 6, 8 and 11, this result is to be expected. Apparently the binder affects the sound speed variation and the incremental attenuation only slightly. Of course, the binder composition affects the stress-strain curve, particularly the yield point and the strain to break which increases with plasticizer content.

It is troubling that there is not better quantitative agreement between the dilatation measured at NWC and the dilatation derived from ultrasonic measurements. Part of the reason for this is probably the "squat" specimens that were used for the ultrasonic measurements - the strain distribution in

these specimens was probably not one of uniaxial tension over the whole length of the active area of transducer.

Within the limits of Rayleigh scattering theory, the voids appear to grow rapidly to a mean radius of 0.03 cm and remain essentially of constant size thereafter as the specimen extends. The number density of voids increases with strain as is shown on the plots.

The quantitative values of void radius and number density are likely to be in error in these plots, but the qualitative nature of the variation with strain may be correct. It is, in any case, similar to what we have observed in tactical propellants. It would take a major theoretical effort to improve the scattering theory in order to derive quantitative void distribution data from ultrasonic measurements on these materials.

SMALL ANGLE X-RAY SCATTERING (SAXS) EXPERIMENTS

The objective of the SAXS investigation was to study the kinematics of void nucleation in the model materials when these were mechanically deformed. Since it was expected that rapid events (seconds) would be encountered, it was decided to use the Stanford Synchrotron Radiation Laboratory's SAXS facilities which generate x-ray fluxes 10^2 to 10^3 times more intense than conventional x-ray tubes. It was hoped that the scattering data describing void nucleation processes could be acquired fast enough on this high flux facility to yield acceptable signal to noise ratios with an integration time of 0.1 seconds. Prior experiments at SSRL had demonstrated that this could be done for strong scatters [5].

The basic SAXS experiment consists of deforming the sample in a monochromatic x-ray beam and registering the angular dependence of the scattered intensity with an x-ray detector. It is necessary that the detector be sensitive enough and have a fast enough response time to register time dependent events on the time scale of interest.

A system that appeared to meet these requirements had been designed and built at SSRL on Beam Line I by Dr. G. B. Stephenson. This system, which is described in detail in Dr. Stephenson's dissertation [6], was modified by the addition of a specimen deformation device to yield a complete apparatus for the SAXS study of deformed polymers. The modified system is described in Reference [7].

Initial SAXS experiments on BLX-1, BLX-2 and BLX-3 were run at SSRL during the time period 12/2 to 12/4, 1983. On examining these data it was found that all these specimens absorbed x-rays to a much greater extent than had been calculated, resulting in poor signal to noise ratios. This observation prompted the chemical analyses the results of which have been reported above.

On the basis of these results, new specimens were designed which were about 30% thinner. Acceptable x-ray transmission was observed for the specimens BLX-4-6 and BLS-1 during the run period 3/25 to 3/26, 1984. However, excessive detector noise, possibly caused by radiation damage to the detector appeared in these data. The data for BLX-4-6 are shown in Appendix II.

The data in Appendix II represent differences between the scattering from the undeformed sample and the deformed sample corrected for changes in x-ray absorption. The relative intensity is plotted on logarithmic scale vs. the length of the

scattering vector $\frac{4\pi}{\lambda} \sin \frac{\Theta}{2}$, where Θ is the scattering angle and λ is the x-ray wavelength.

We have interpreted the SAXS data according to the theory of Guinier, according to which

$$I(h) = C V_a V_p (\Delta\rho)^2 e^{-\frac{R_g^2 h^2}{3}}$$

In this equation

- $I(h)$ = x-ray intensity distribution
- V_a = mean atomic volume
- C = concentration of voids
- V_p = volume of particles (or voids)
- $\Delta\rho$ = the difference in local average electron distribution inside and outside the particle (or void)
- R_g = radius of gyration
- h = $\frac{4\pi}{\lambda} \sin \frac{\Theta}{2}$
- λ = x-ray wavelength
- Θ = scattering angle.

For spherical particles with radius R_s ,

$$R_g^2 = \frac{3}{5} R_s^2$$

The theory of Guinier applies strictly only to dilute concentrations of monodisperse scatterers. However, it is widely used as an approximation to interpret experimental data even in the case that distributions of particles are present. In this case it is believed to yield semi-quantitative results for R_g .

The general results of our SAXS experiments are that a distribution of voids with diameters from 150 to 800Å form near the yield points of the model compositions BLX-4, BLX-C, and

BLX-9. There is an apparent fluctuation of the concentration as the specimen is extended further, which we interpret as evidence that the concentration of voids is heterogeneous. The reason for this is that as the specimen is extended in the x-ray beam, different volume elements translate into and out of the beam. After rupture, the scattered intensity decays with time.

A typical plot of the variation of scattered intensity for a tensile test of BLX-4 is shown in Figure 3. Because the distribution function of the voids cannot be measured by SAXS, it is not possible to quantify the void concentration from data such as that presented in Figure 3.

SUMMARY AND CONCLUSIONS

A combined ultrasonic wave scattering and small angle x-ray scattering study of several model compositions containing RDX has been carried out. The dewetting behavior of these materials has been measured as a function of time and strain by subtracting the initial scattering from the scattering of deformed samples. The residual scattering, both of ultrasonic waves and x-rays, has been attributed to voids.

By combining the results of SAXS and UWS, it is concluded that a wide distribution of void sizes (150A to 0.03 cm) are created by mechanical strain in these materials. The concentration of voids increases with strain from the yield point to rupture, while the sizes appear to remain almost constant.

The details of the void distribution and size are not affected by binder composition and plasticizer content.

LOCKHEED MATERIALS ANALYSIS LABORATORY

LMSC-F035789

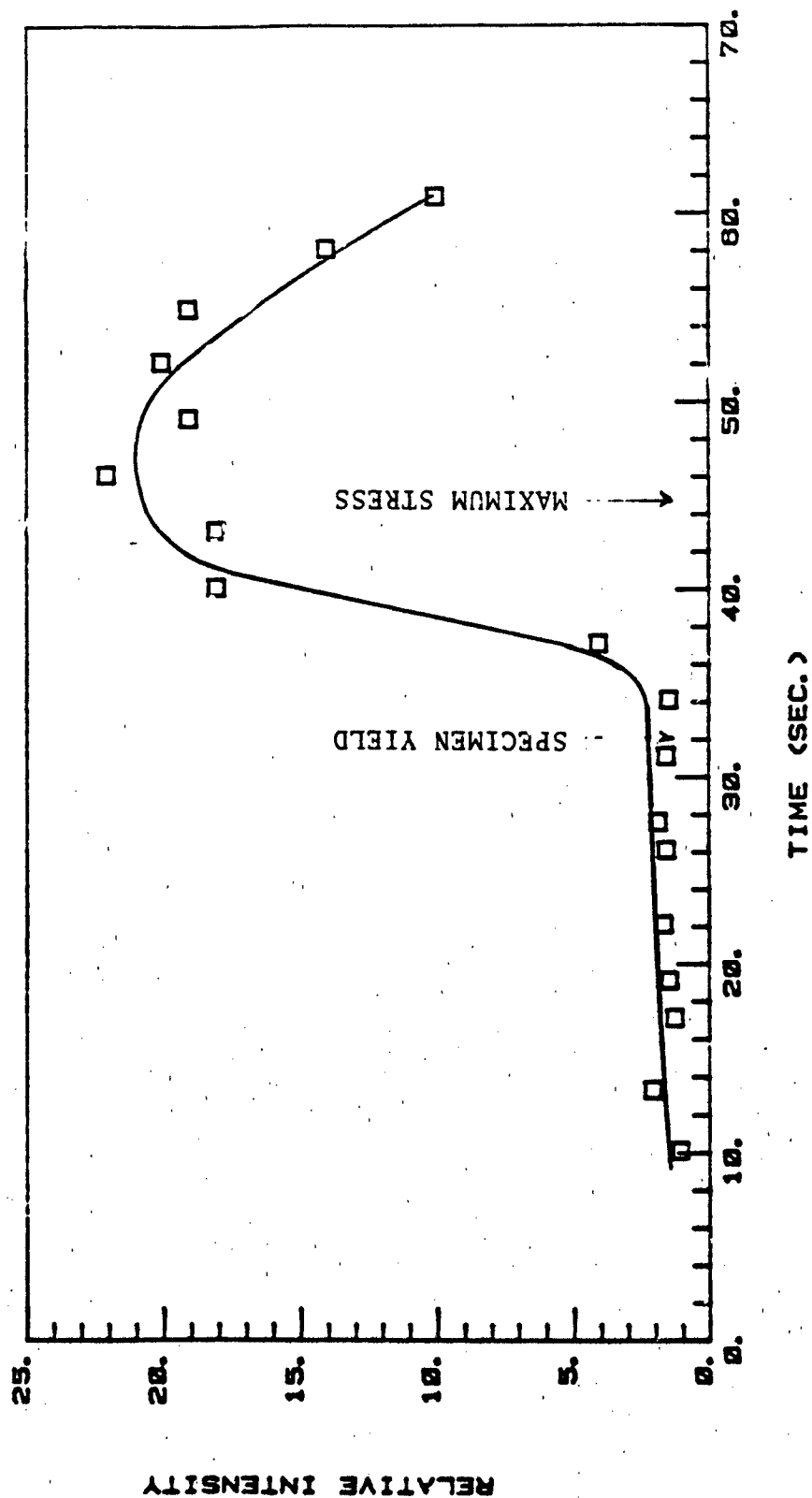


Fig. 3 Variation of Scattered X-ray Intensity With Time During Tensile Test of BLX-4

REFERENCES

1. Rena Y. Yee, "PBX Properties and Sensitivity", presented at ONR Energetic Polymer and Rubbery Propellant and Explosive Processing Science Base Workshop, Chestertown, MD, 17-19 August 1982.
2. Rena Y. Yee and E. C. Martin, "Effects of Surface Interaction and Mechanical Properties of Plastic Bonded Explosives on Explosive Sensitivity. Part 2: Model Formulation." NWC TP 6619 Naval Weapons Center, China Lake, March 1985.
3. G. C. Knollman, R. H. Martinson, and J. L. Bellin, "Ultrasonic Assessment of Cumulative Internal Damage in Filled Polymers", J. Appl. Phys. 50, January 1979, pp. 111-120.
4. G. C. Knollman, R. H. Martinson, and J. L. Bellin, "Ultrasonic Assessment of Cumulative Damage in Filled Polymers (II)", J. Appl. Phys. 51, December 1980, pp. 3164-3175.
5. W. S. Rothwell, R. H. Martinson, and R. L. Gorman, "Time Dependent Small-Angle X-ray Scattering from Stress-Induced Crazes in Polymers", Applied Physics Letters, 42, March 1983, pp. 5-7.
6. G. B. Stephenson, "Early-Stage Phase Separation in Amorphous Solids: A Time-Resolved SAXS Study", Stanford Synchrotron Radiation Laboratory Report 82/05, October 1982.
7. R. H. Martinson, "Cumulative Damage and Fracture of Propellants", LMSC-Independent Research Program Reports, 1982.

LMSC-F035789

APPENDIX 1

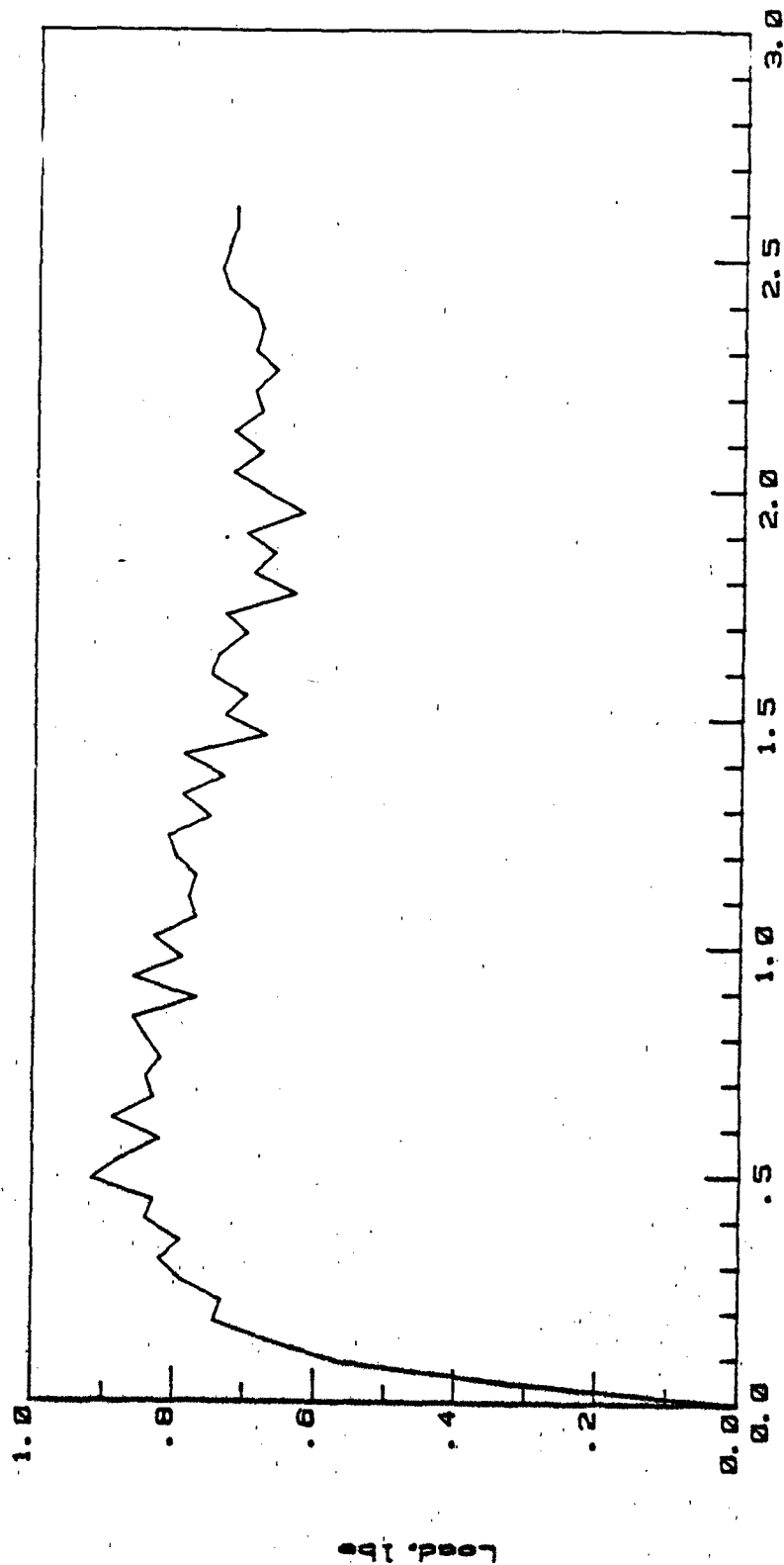
ULTRASONIC DATA

LMSC-F035789

ULTRASONIC DATA FOR BLX-6

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROPELLANT BLX-8 1.13H .54W .245T 8110584



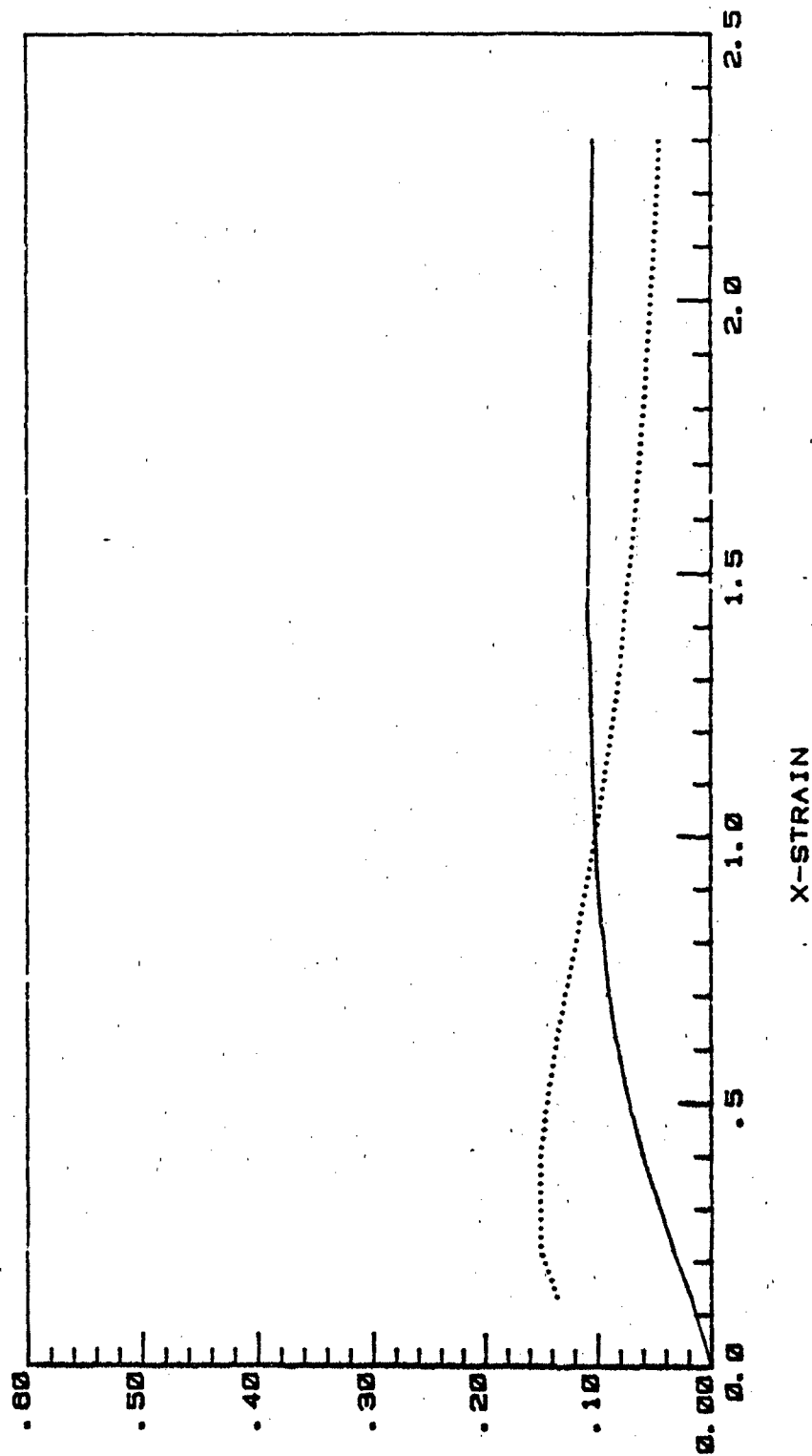
X-STRAIN

30 NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #B110584 1.13 HX 1.54W .245T 11-05-84

..... RATIO .5 — Z-STRAIN

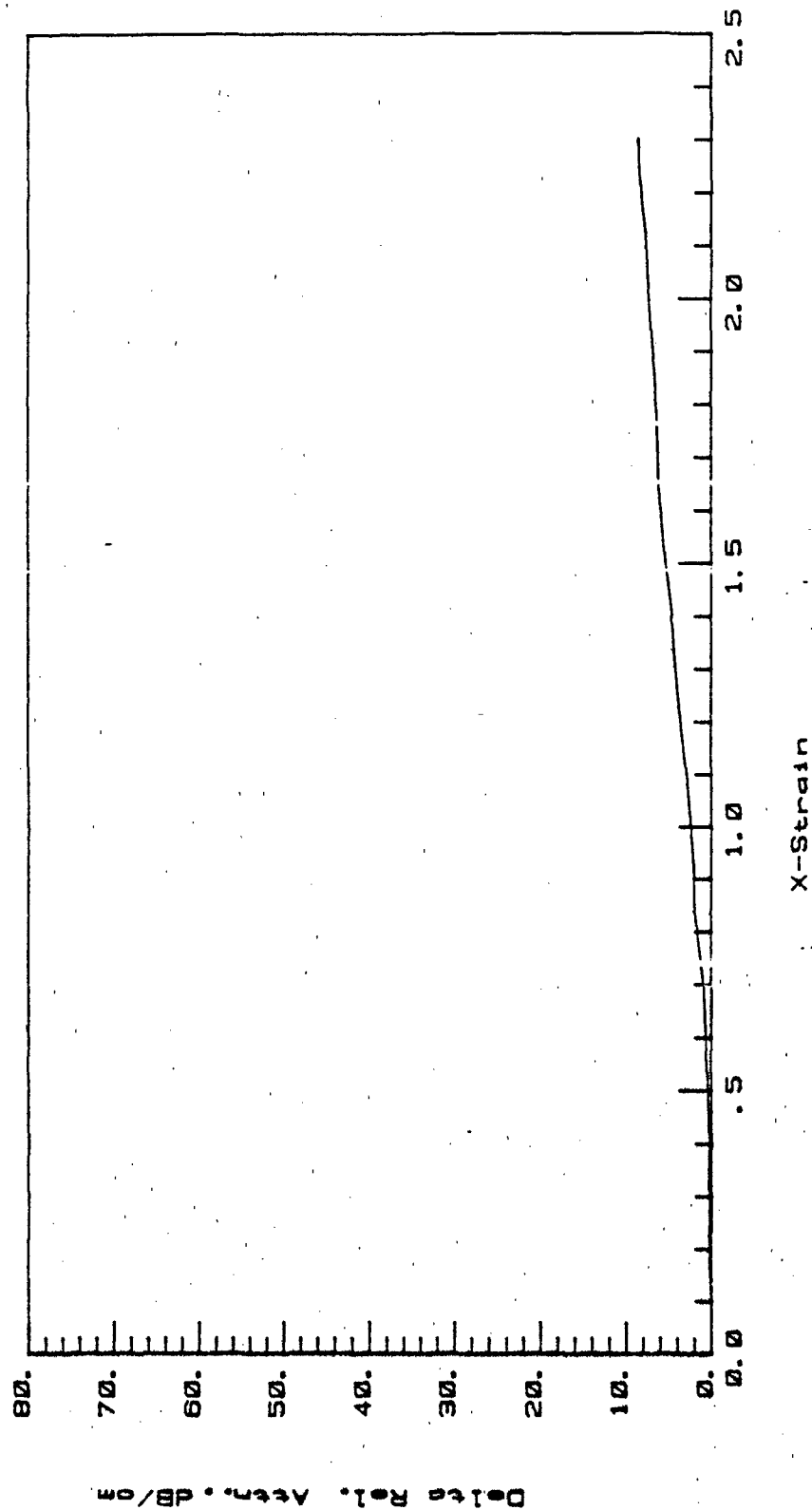


LMSC-F035789

7 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-6 #B110584 1.13 HX 1.54W .245T 11-05-84



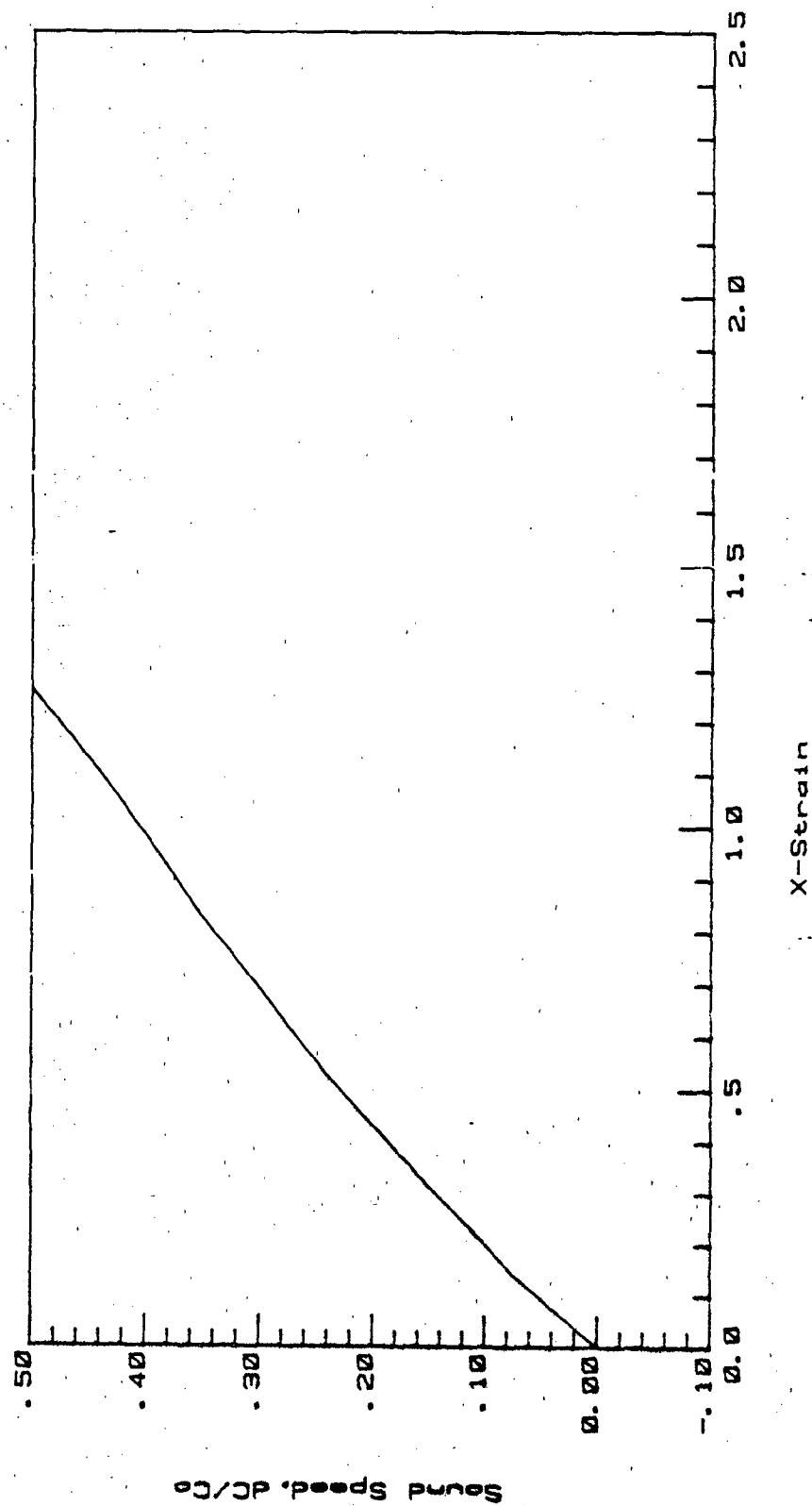
AI-5

LMSC-F035789

9 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-6 #B110584 1.13 HX 1.54W .245T 11-05-84



A1-6

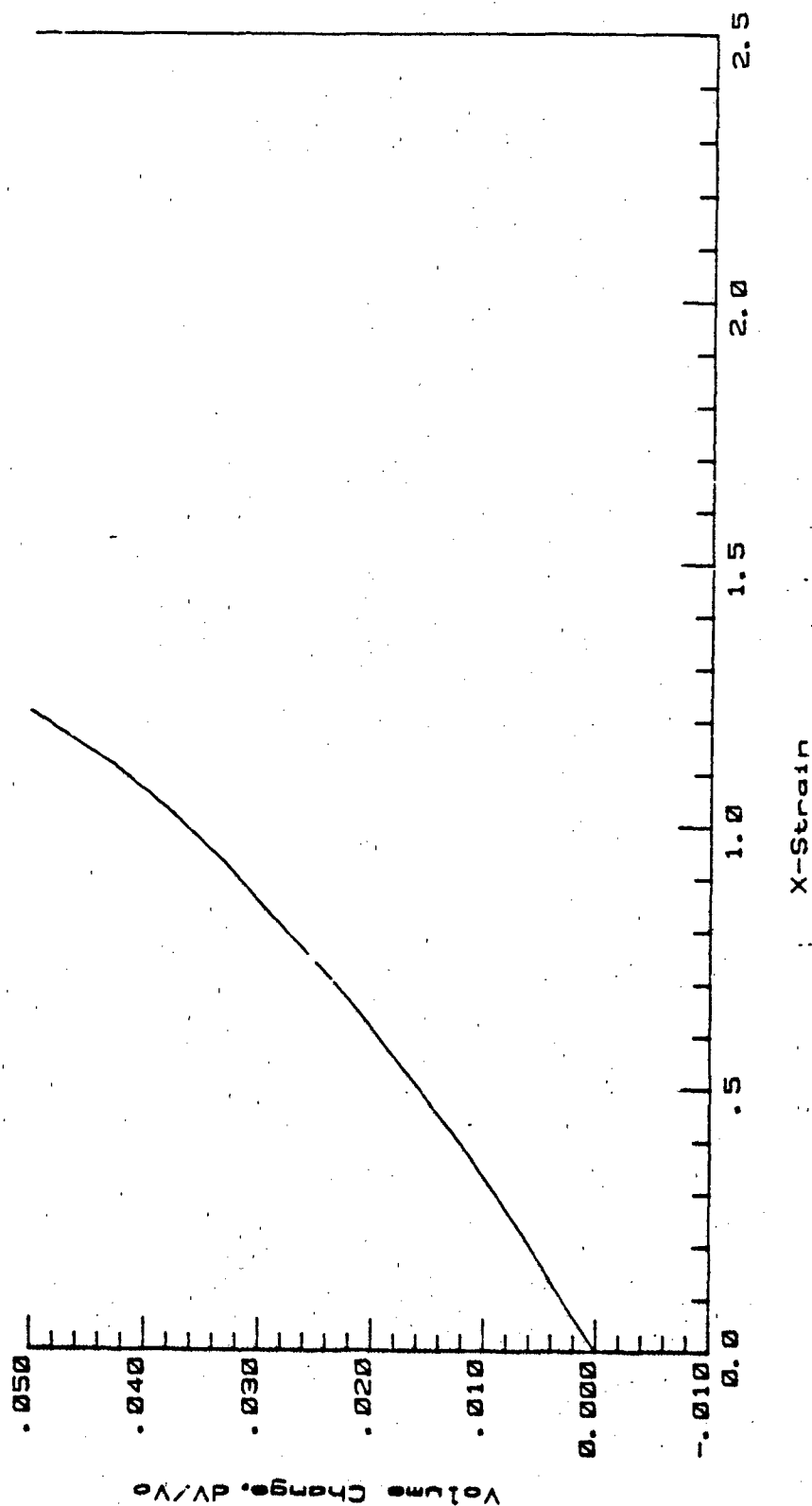
LMSC-F035789

9 NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-6 #B110584 1.13 IX 1.54W .245T 11-05-84

LMSC-F035789



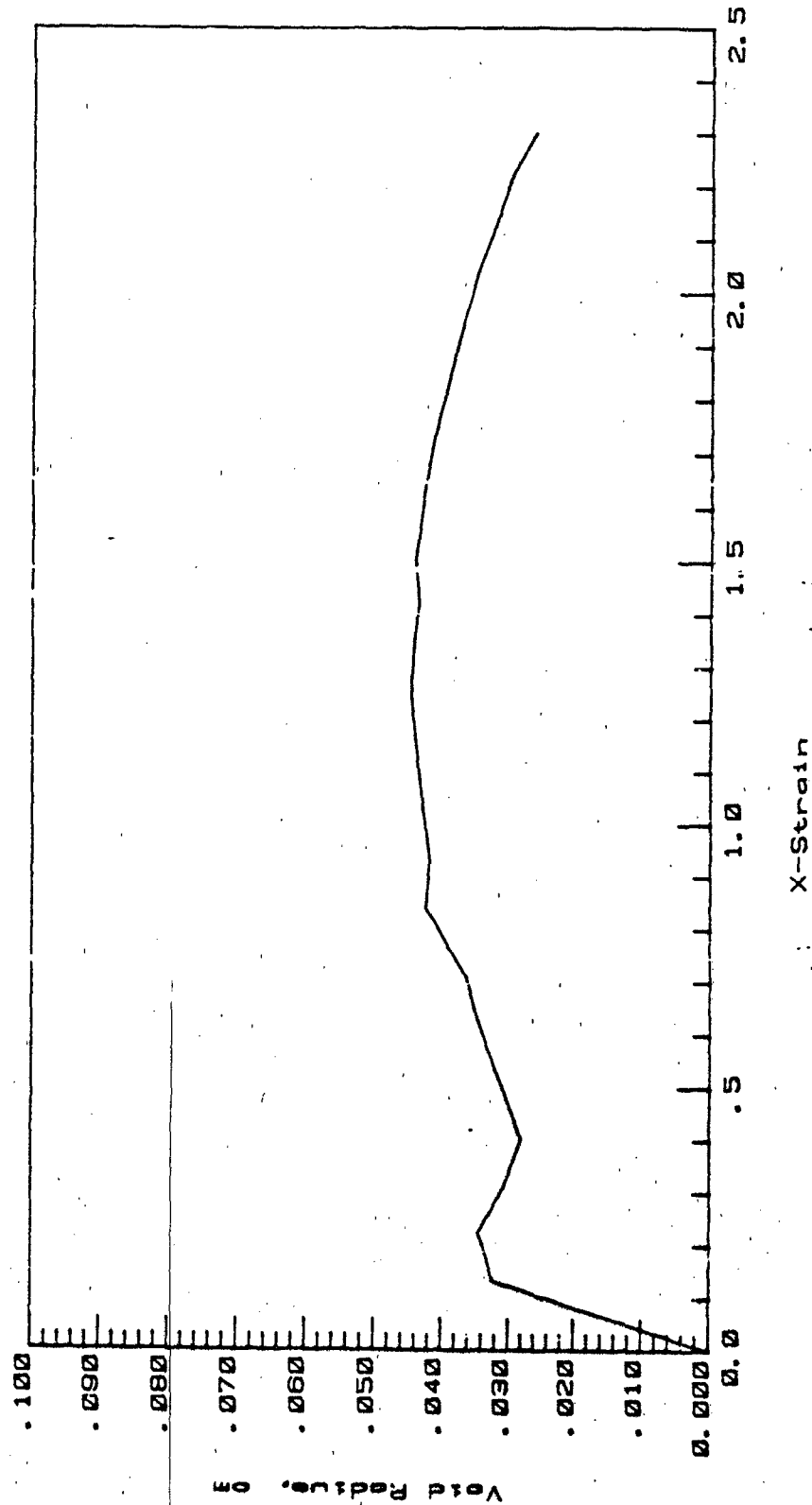
NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-6 #B110584 1.13 HX 1.54W .245T 11-05-84

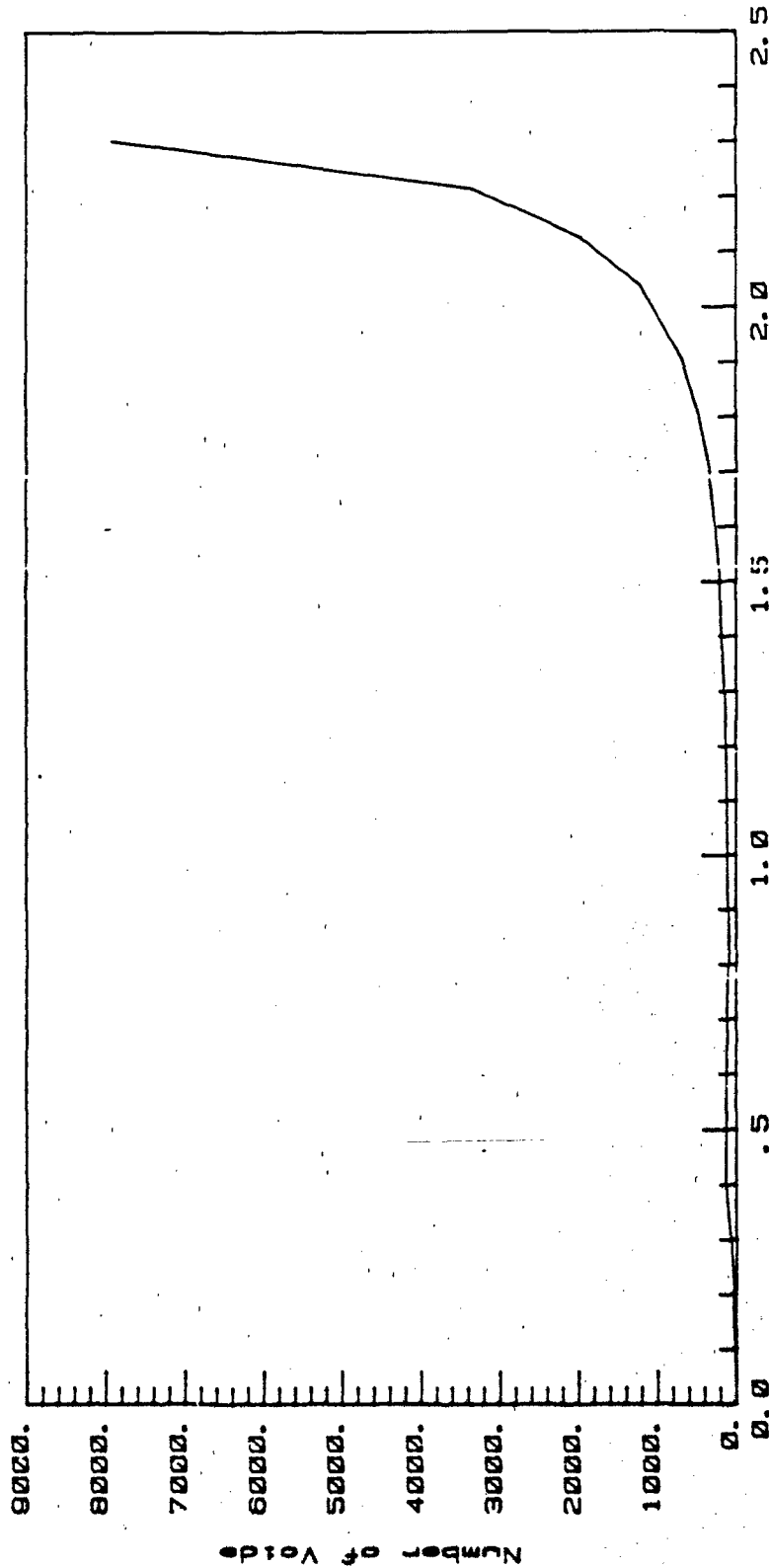
LMSC-F035789

9 NOV.. 1984



LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-6 #B110584 1.13 HX 1.54W .245T 11-05-84



AI-9

LMSC-F035789

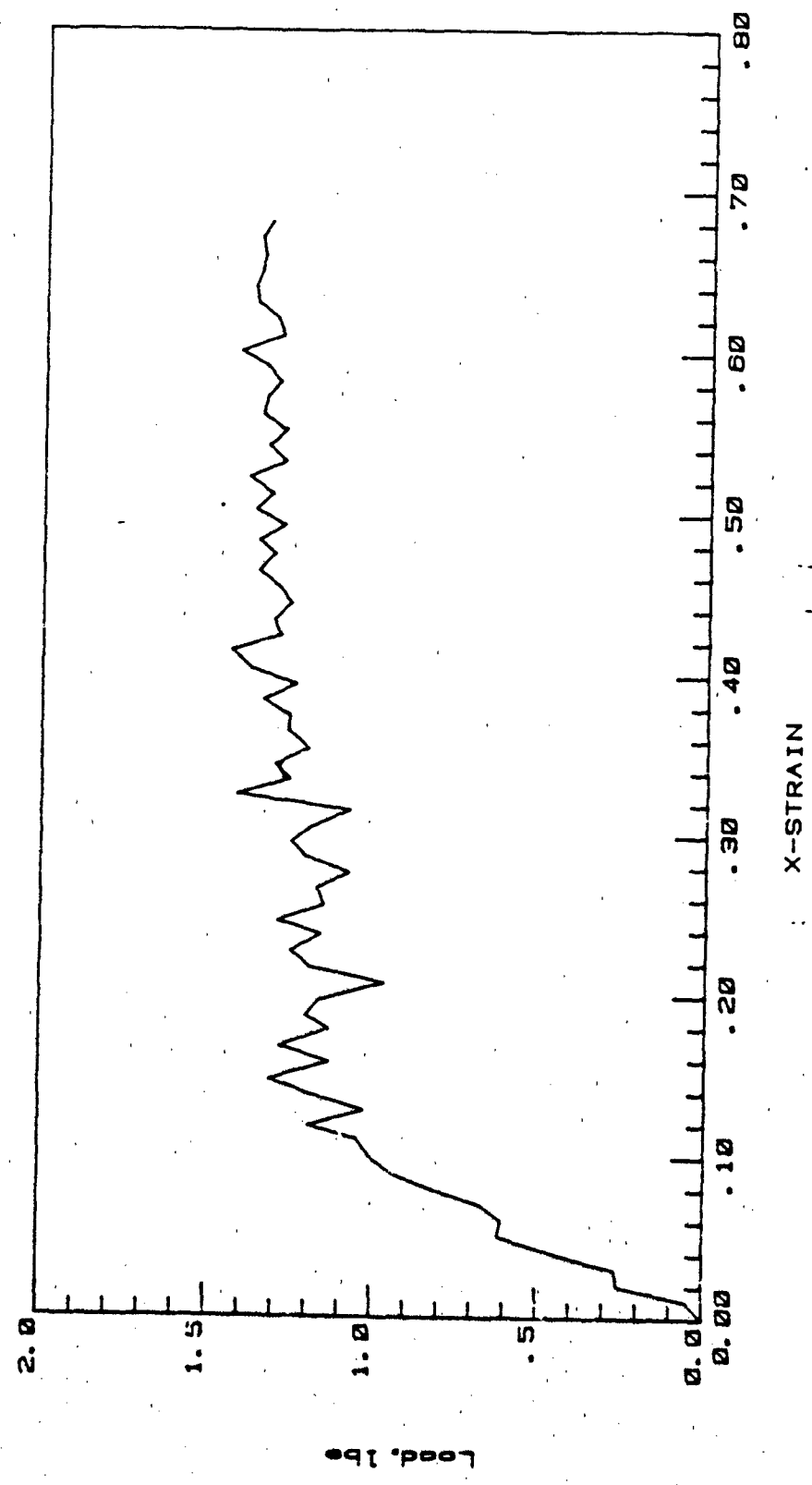
9 NOV.. 1984

LMSC-F035789

ULTRASONIC DATA FOR BLX-4

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROPELLANT BLX-4 1.015H .072W .267T B110284



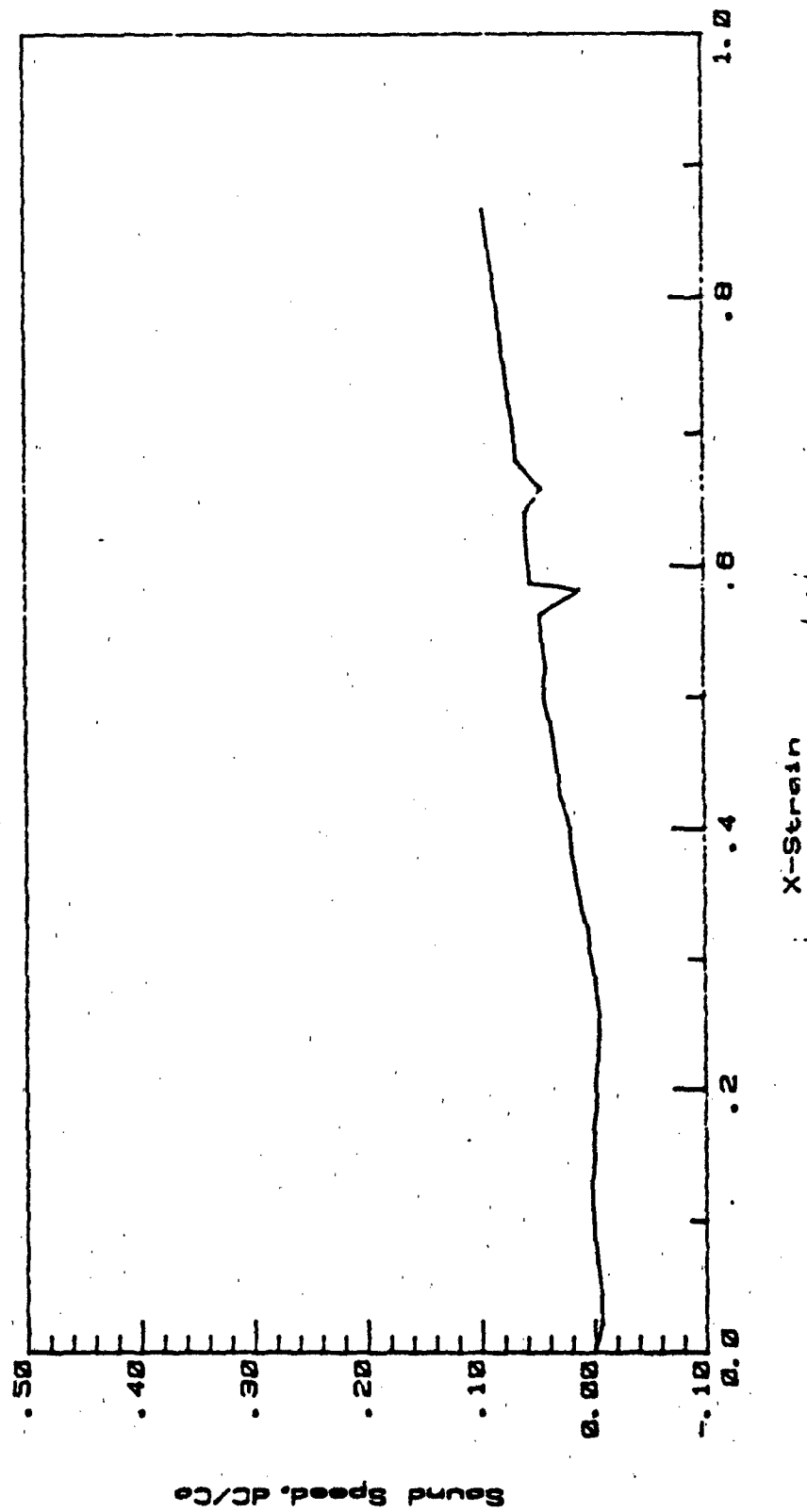
50 NOV.. 1984

LMSC-F035789

AI-11

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-4 #B110284 1.015HX.072 X .207T 11-02-84



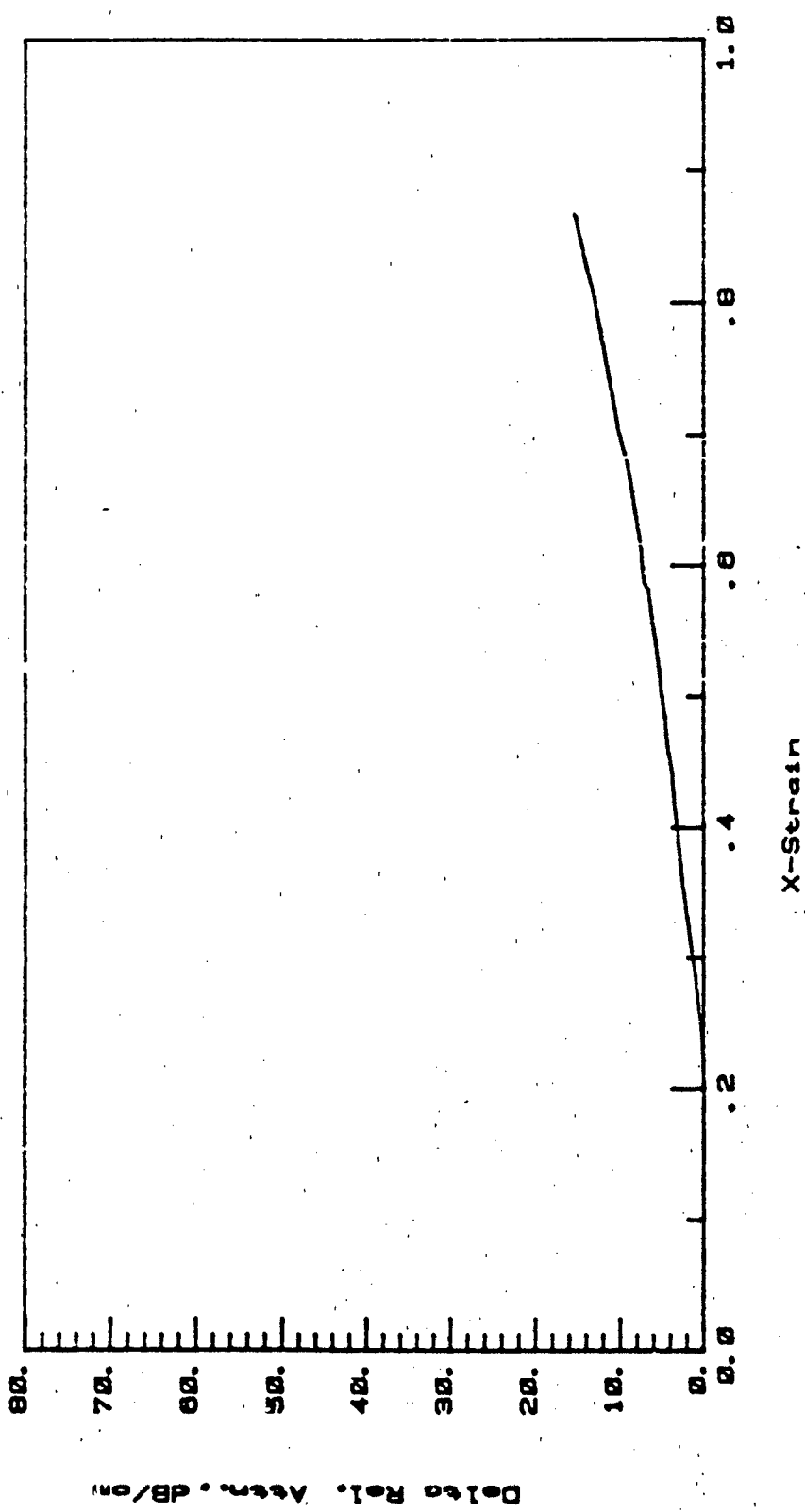
LMSC-F035789

• NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-4 #B110204 1.015HX.072 X .207T 11-02-84

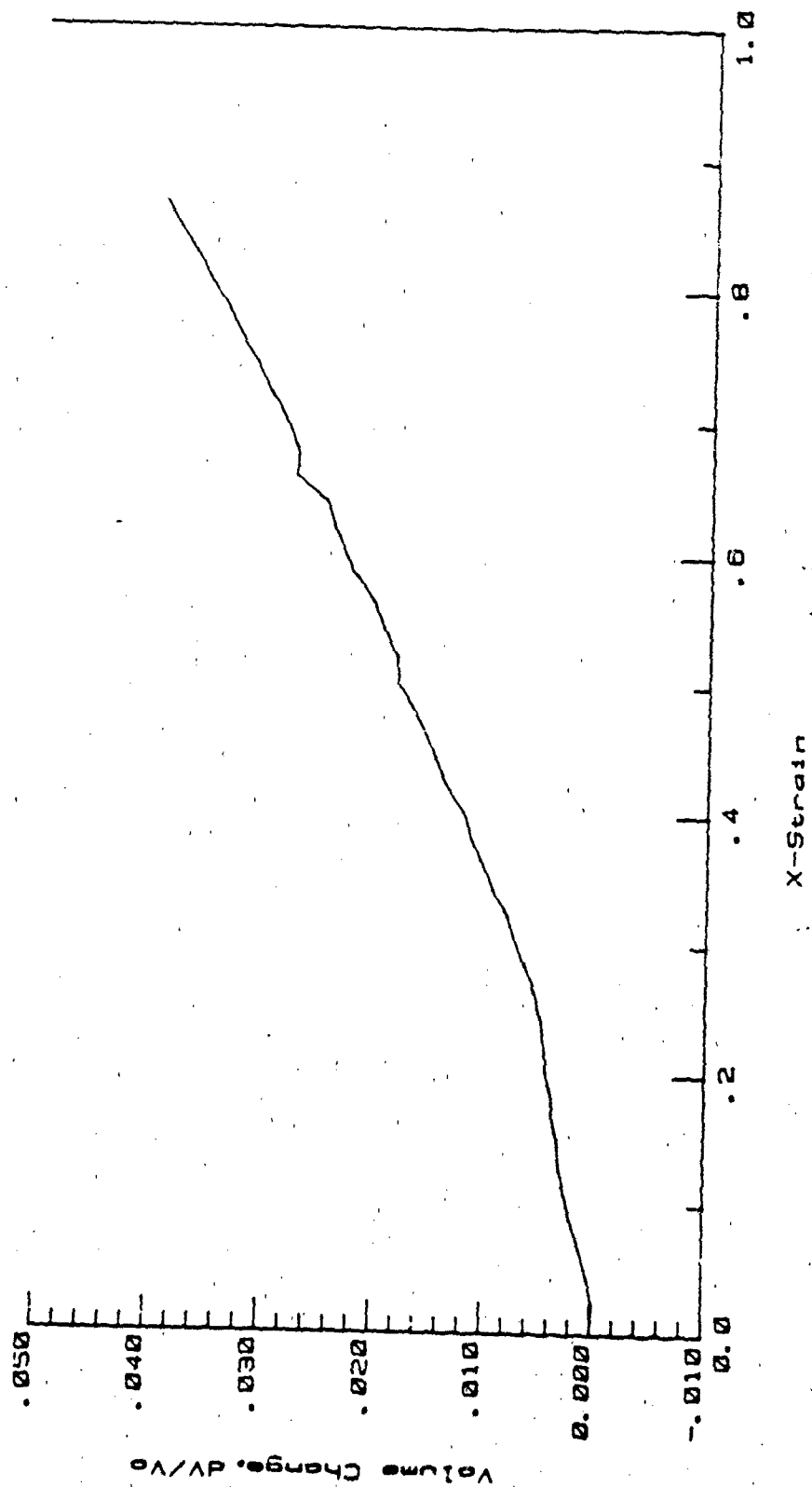
LMSC-F035789



NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-4 #B110284 1.015HX.872 X .267T 11-02-84



LMSC-F03578⁹

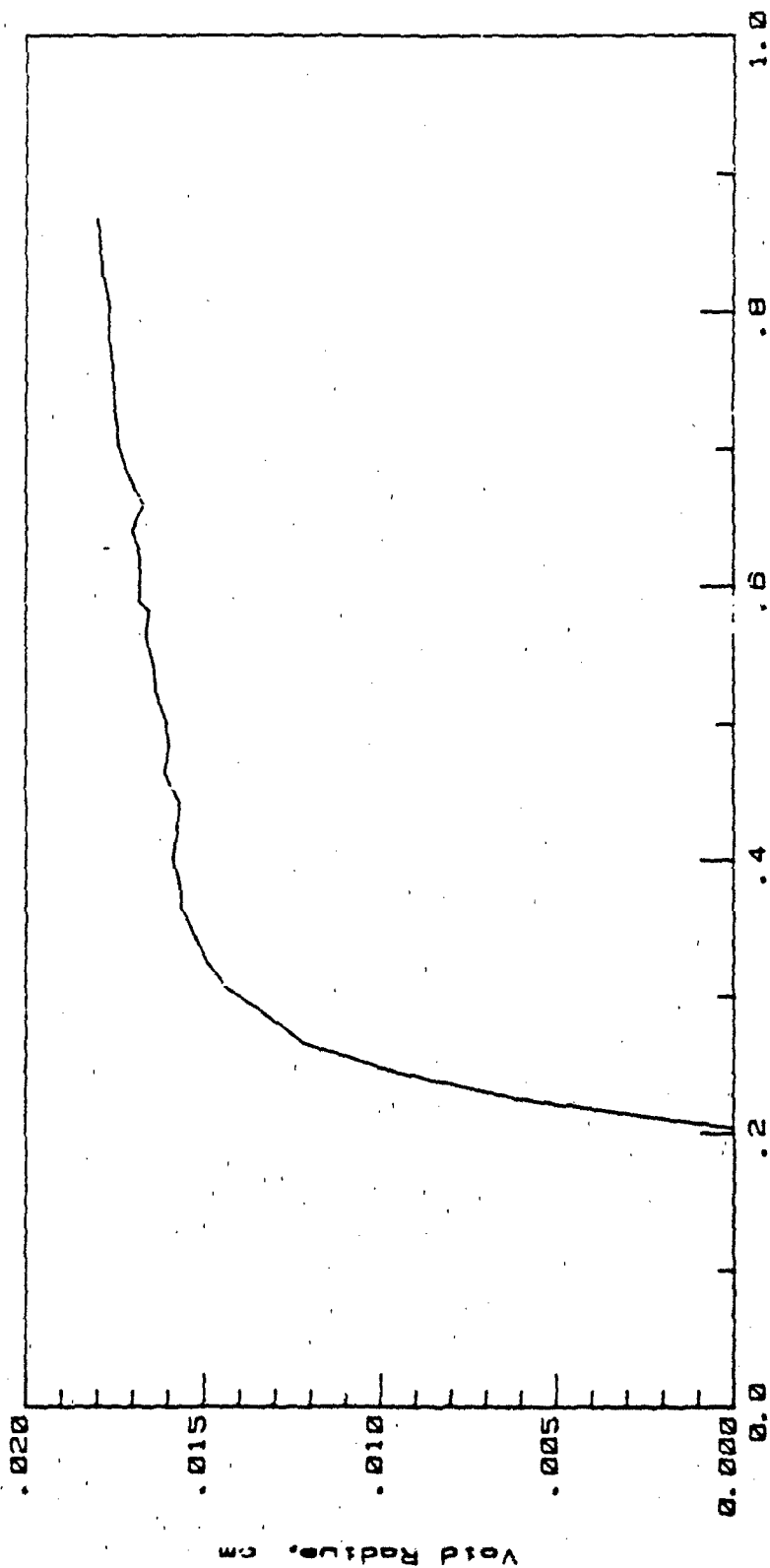
20 NOV., 1984

AI-14

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-4 #B110284 1.015HX.672 X .267T 11-02-84

(FIXED POISSON'S RATIO = .48)



LMSC-F035789

X-Strain

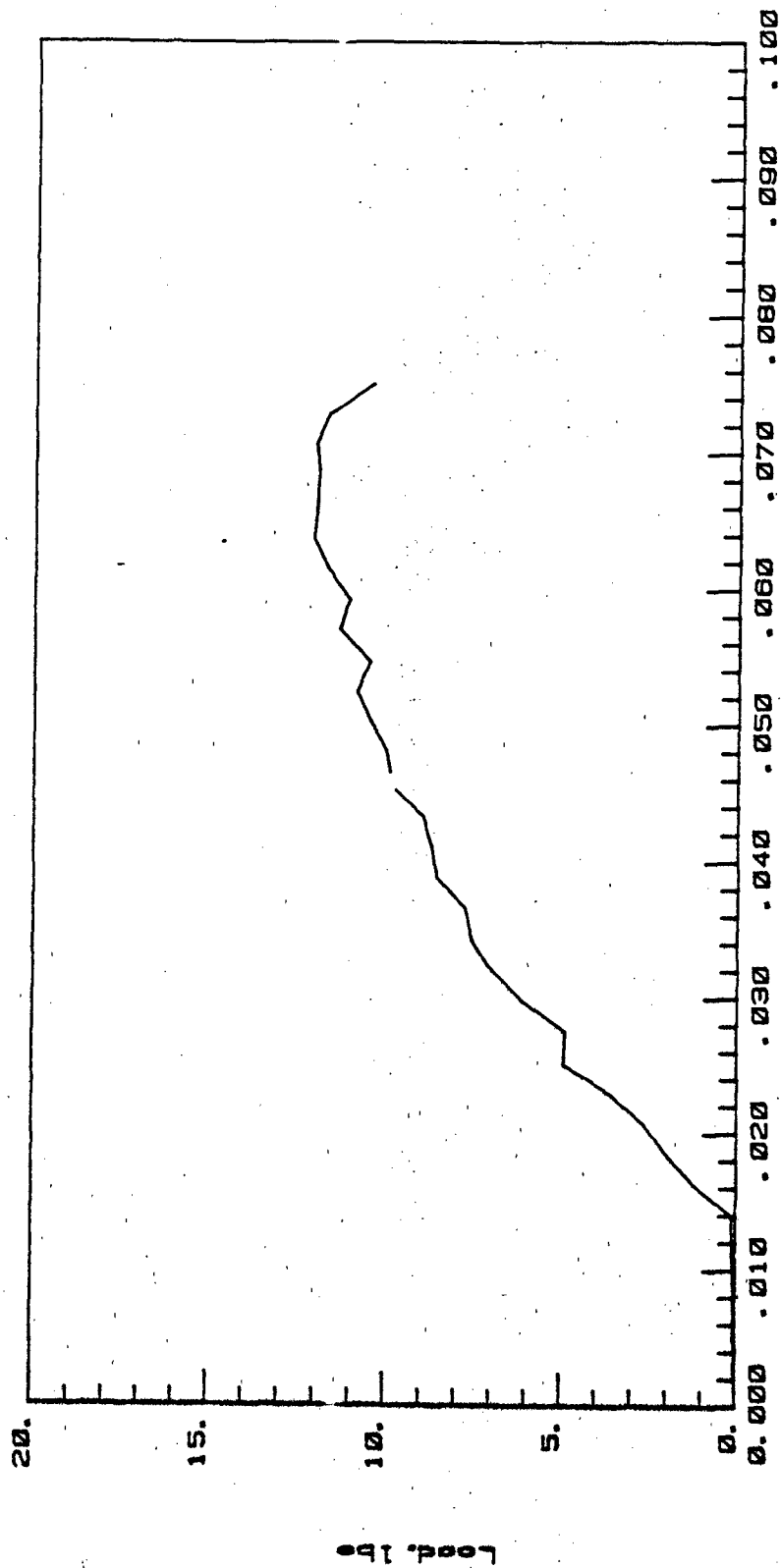
20 NOV. 1984

LMSC-F035789

ULTRASONIC DATA FOR BLX-8

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROPELLANT BLX-8 1.1 H .884W .226T C101984



LMSC-F035789

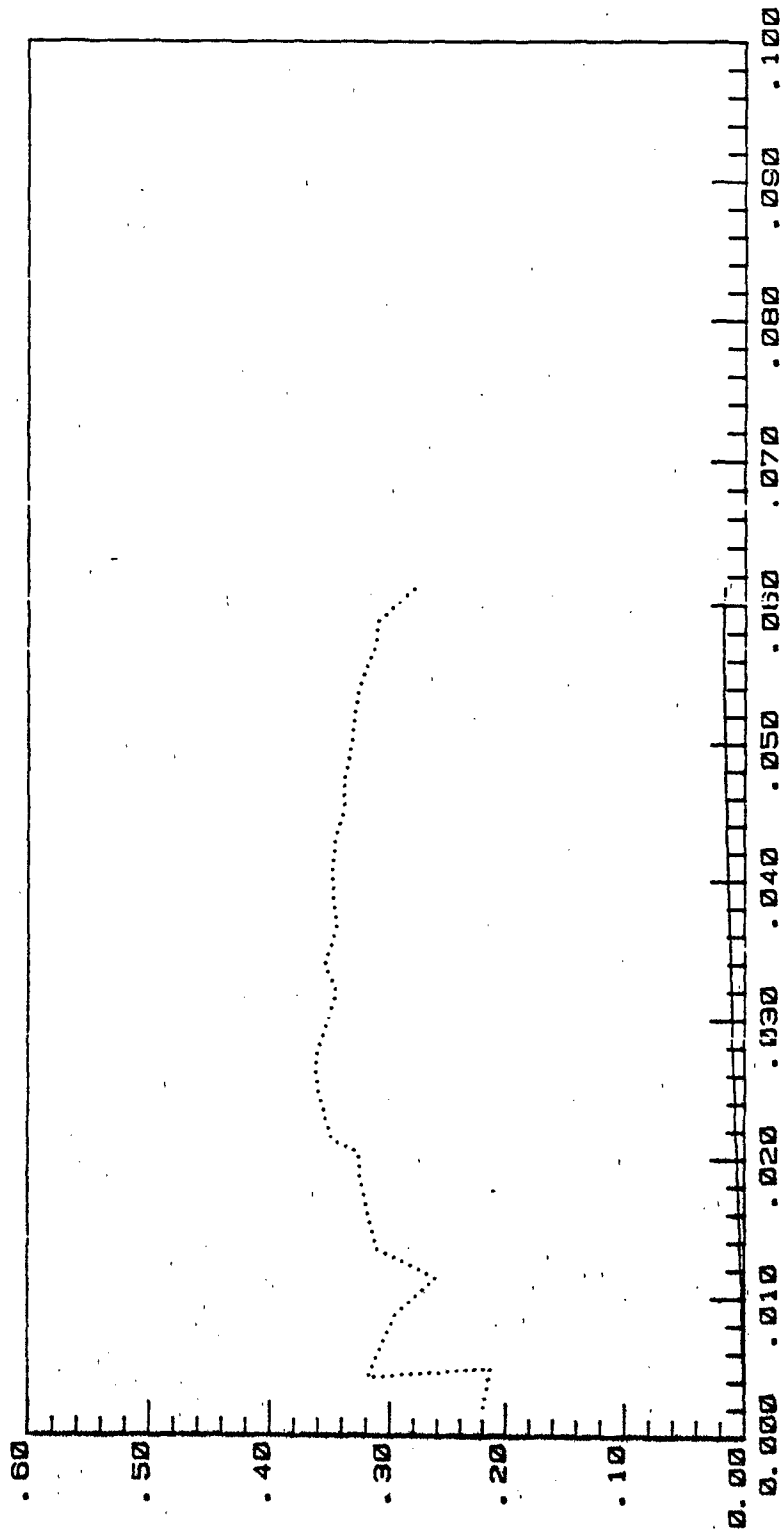
30 NOV.. 1984

AI-18

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #101984C 1.10H X.884 X .226T 10-19-84

..... RATIO 1 ——— Z-STRAIN

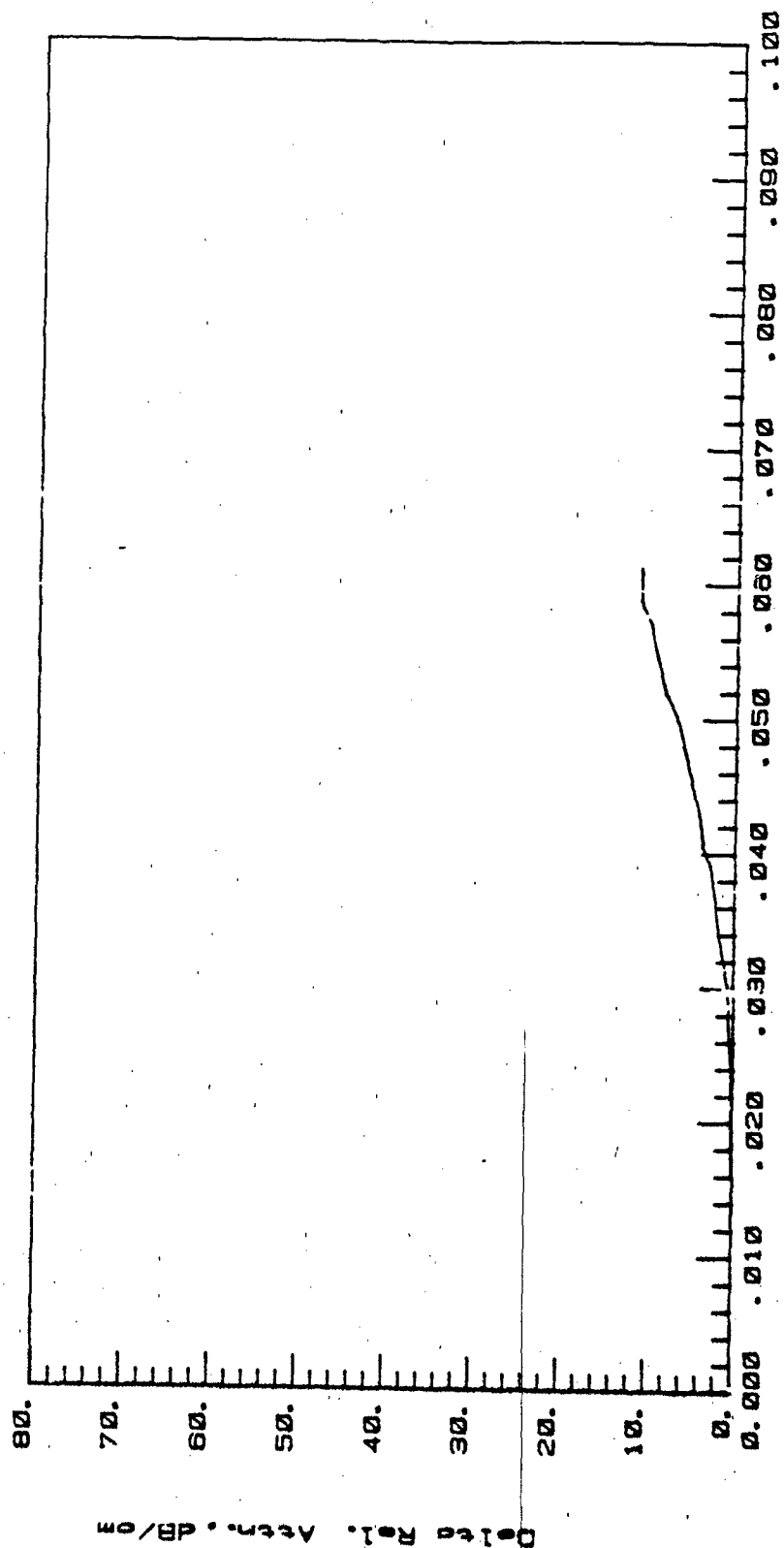


X-STRAIN

NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #101984C 1.10H X.884 X .226T 10-19-84



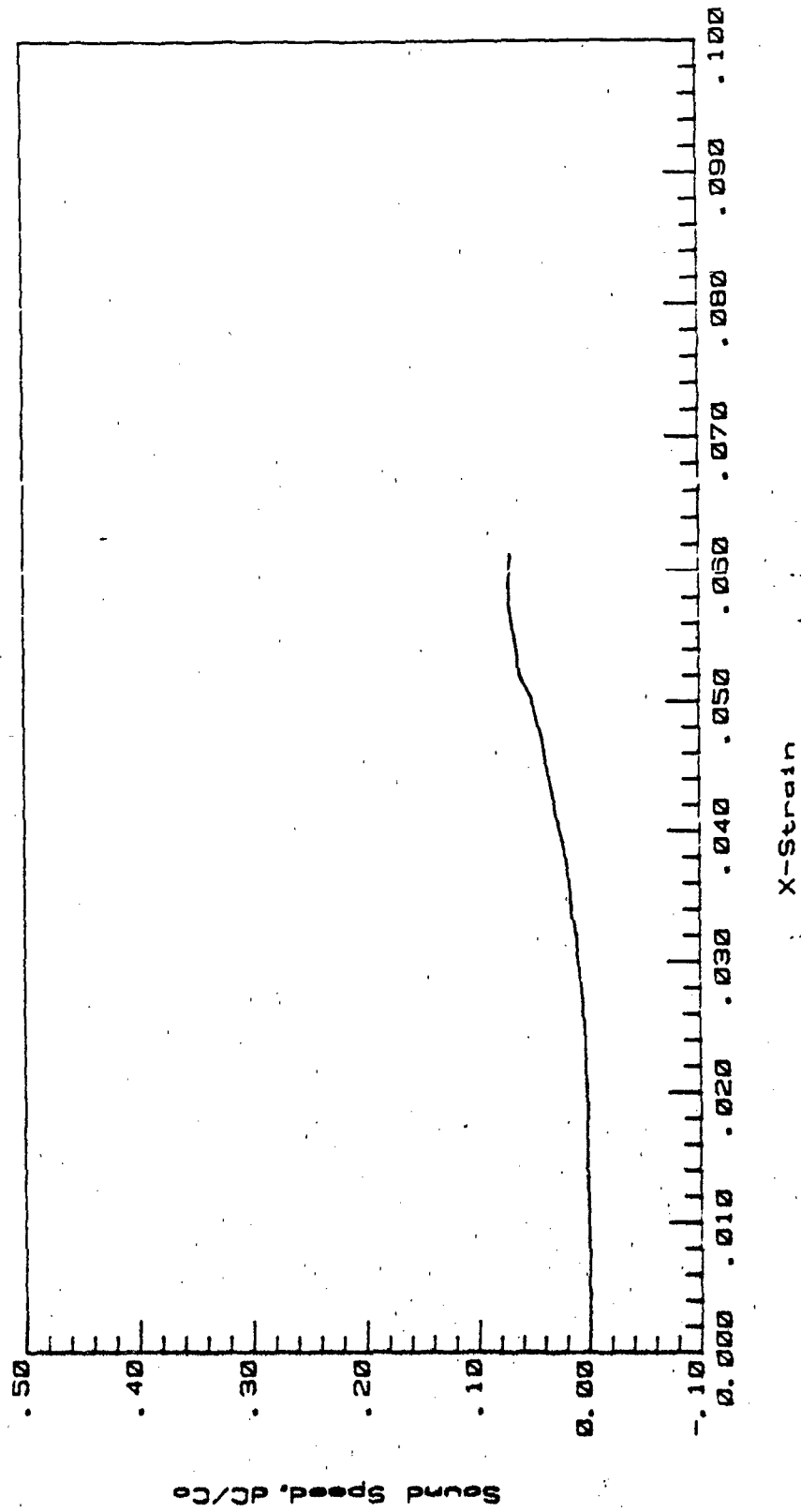
AI-20

LMSC-F035789

9 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

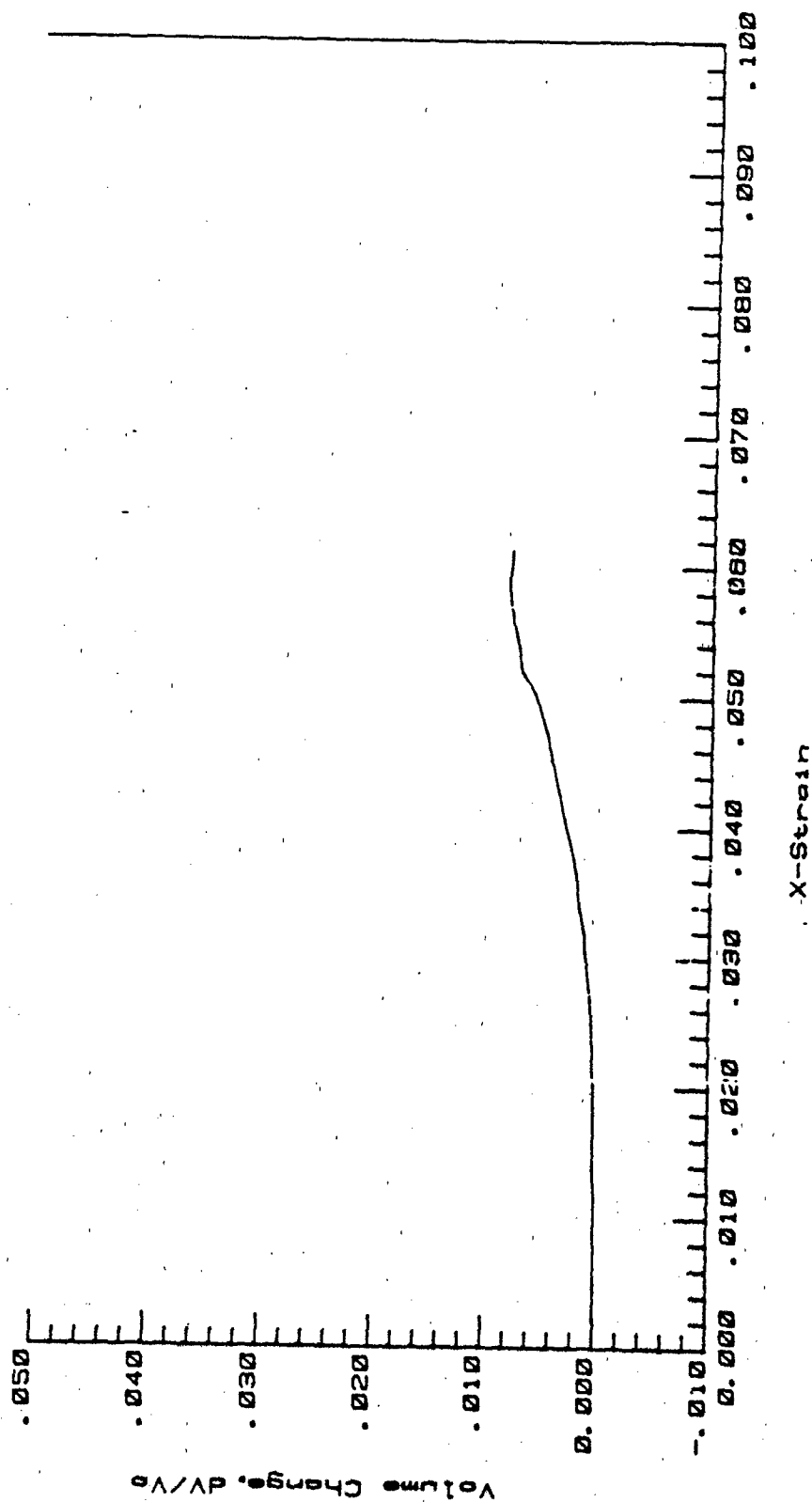
CHINA LAKE PROP. BLX-8 #101984C 1.10H X.884 X .226T 10-19-84



9 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #101984C 1.10H X.884 X .226T 10-19-84



AI-22

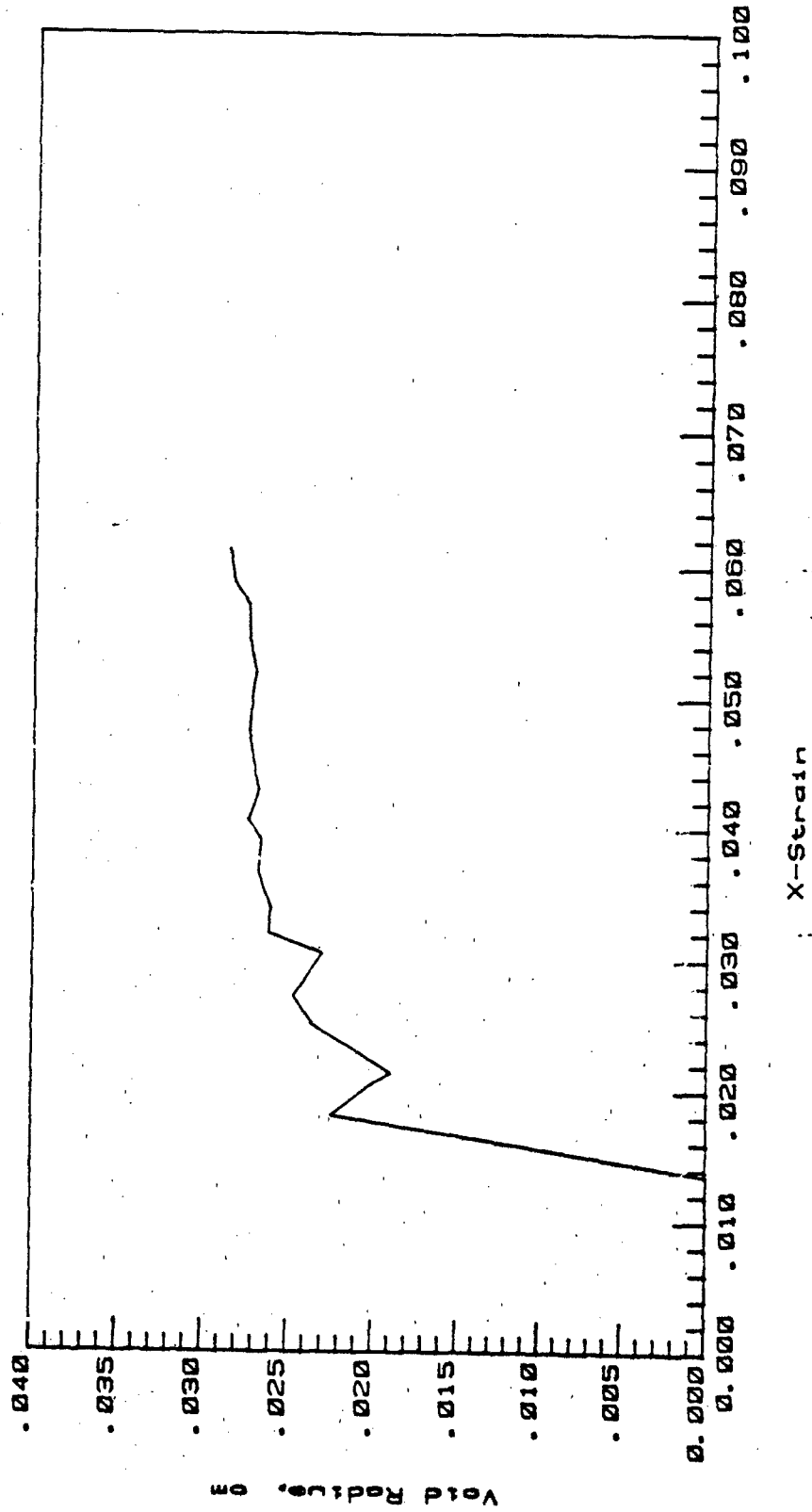
LMSC-F035789

9 NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #101984C 1.10H X.884 X .226T 10-19-84

(FIXED POISSON'S RATIO OF .48 USED)

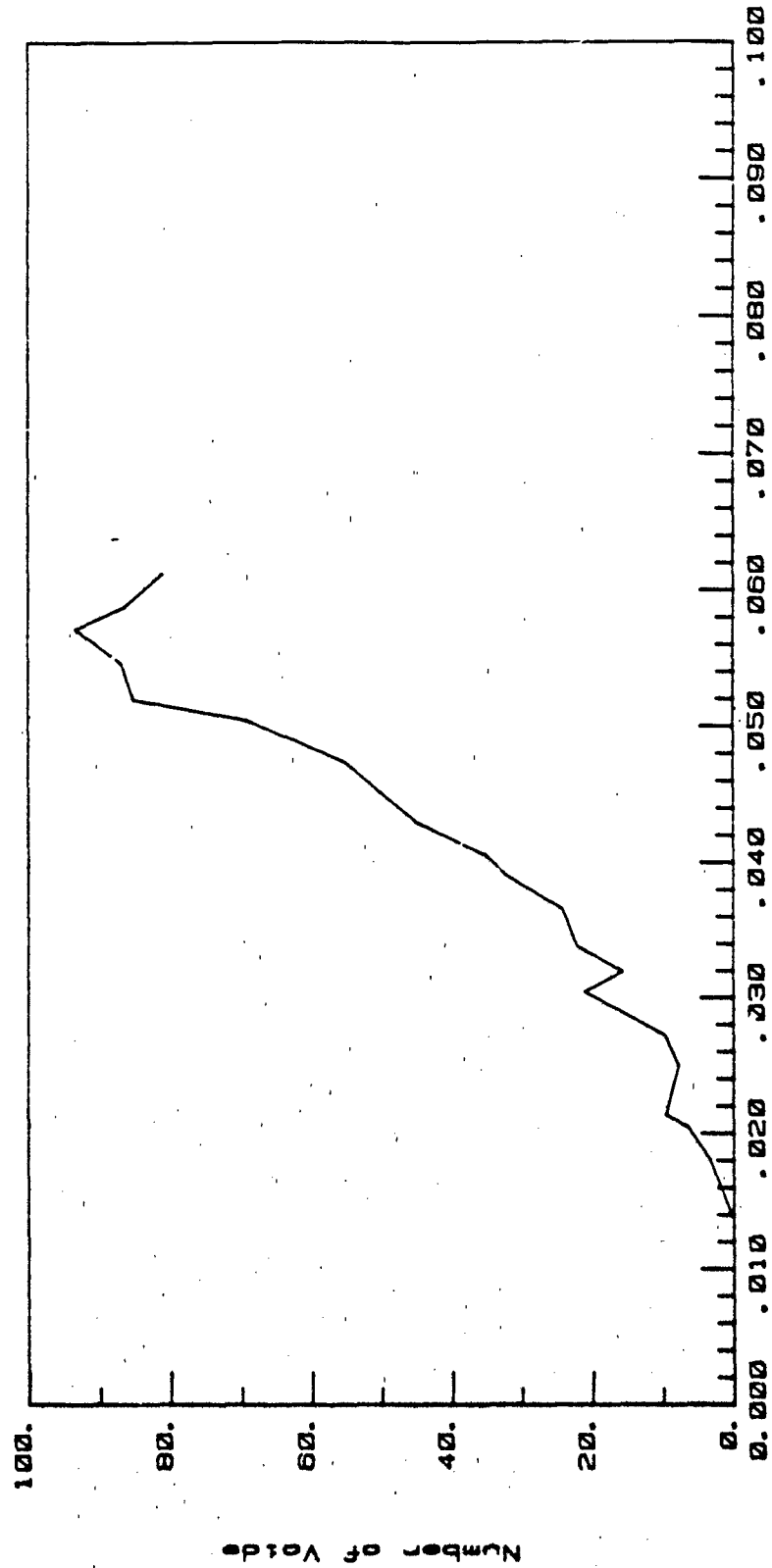


20 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #101984C 1.10H X.884 X .226T 10-19-84

(FIXED POISSON'S RATIO OF .48 USED)



X-Strain

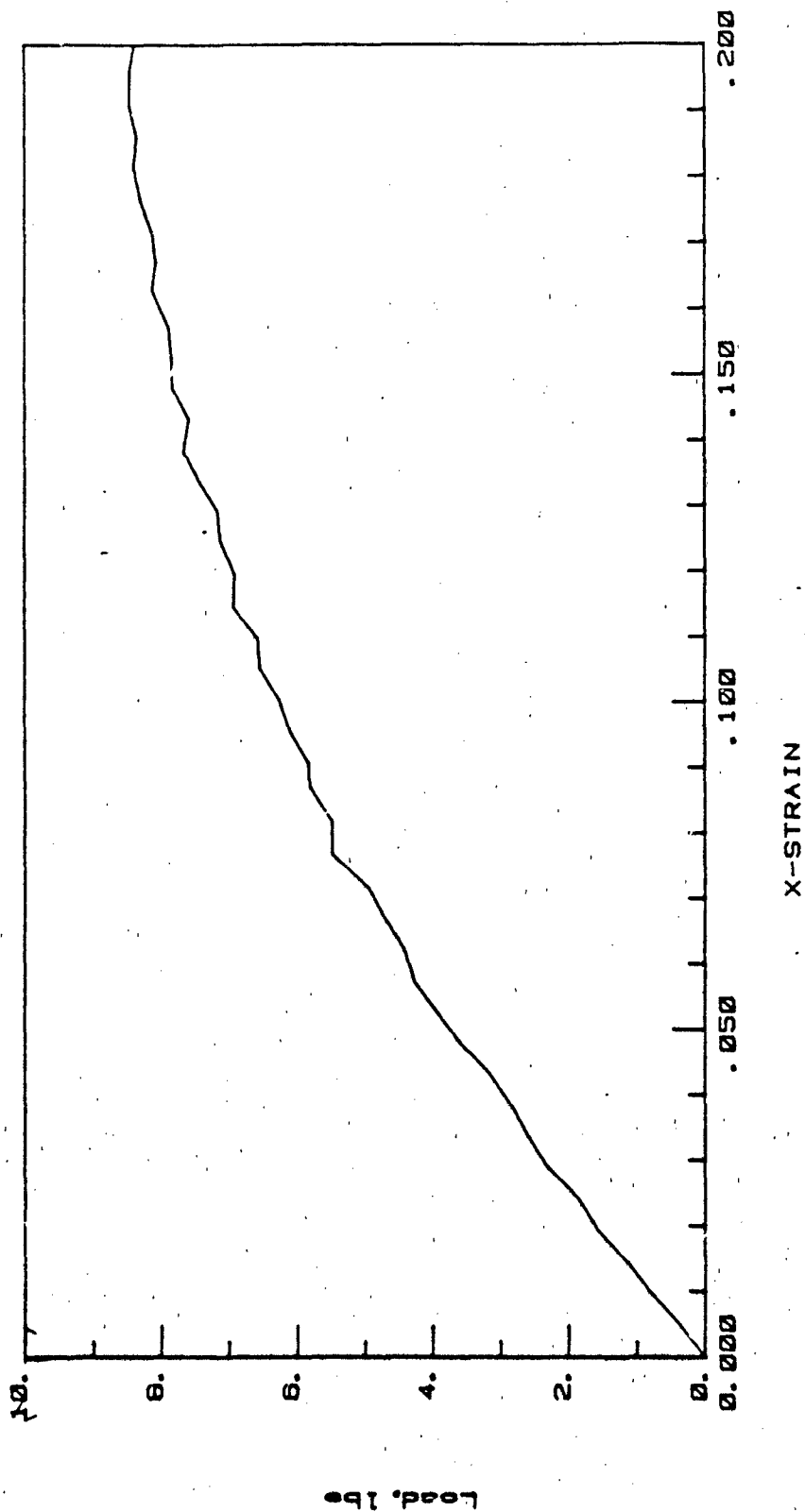
20 NOV. 1984

LMSC-F035789

ULTRASONIC DATA FOR BLX-9

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROPELLANT BLX-9 1.05H .75W .277T A110284



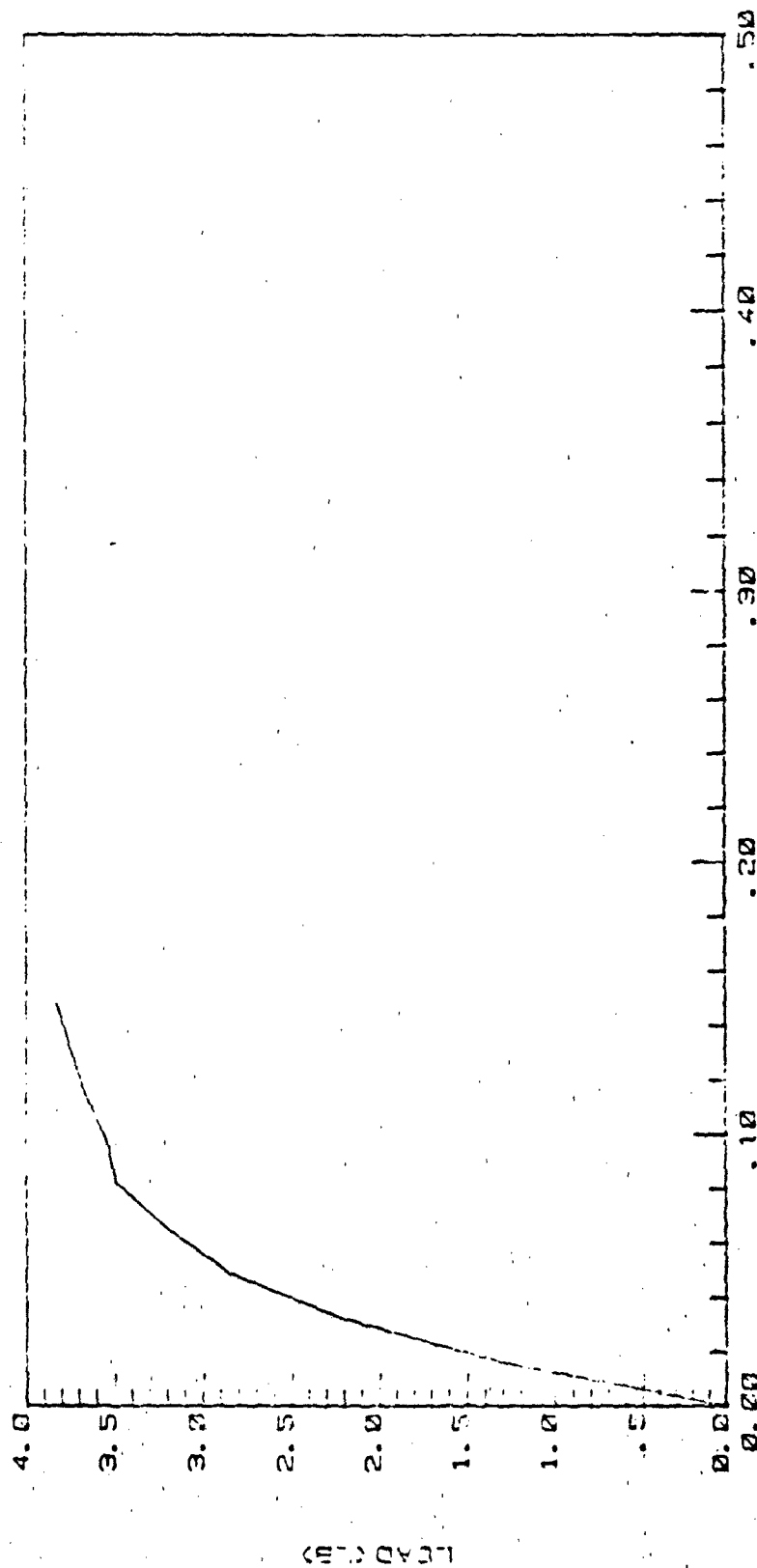
LMSC-F035789

30 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLY-- 9

— 889114

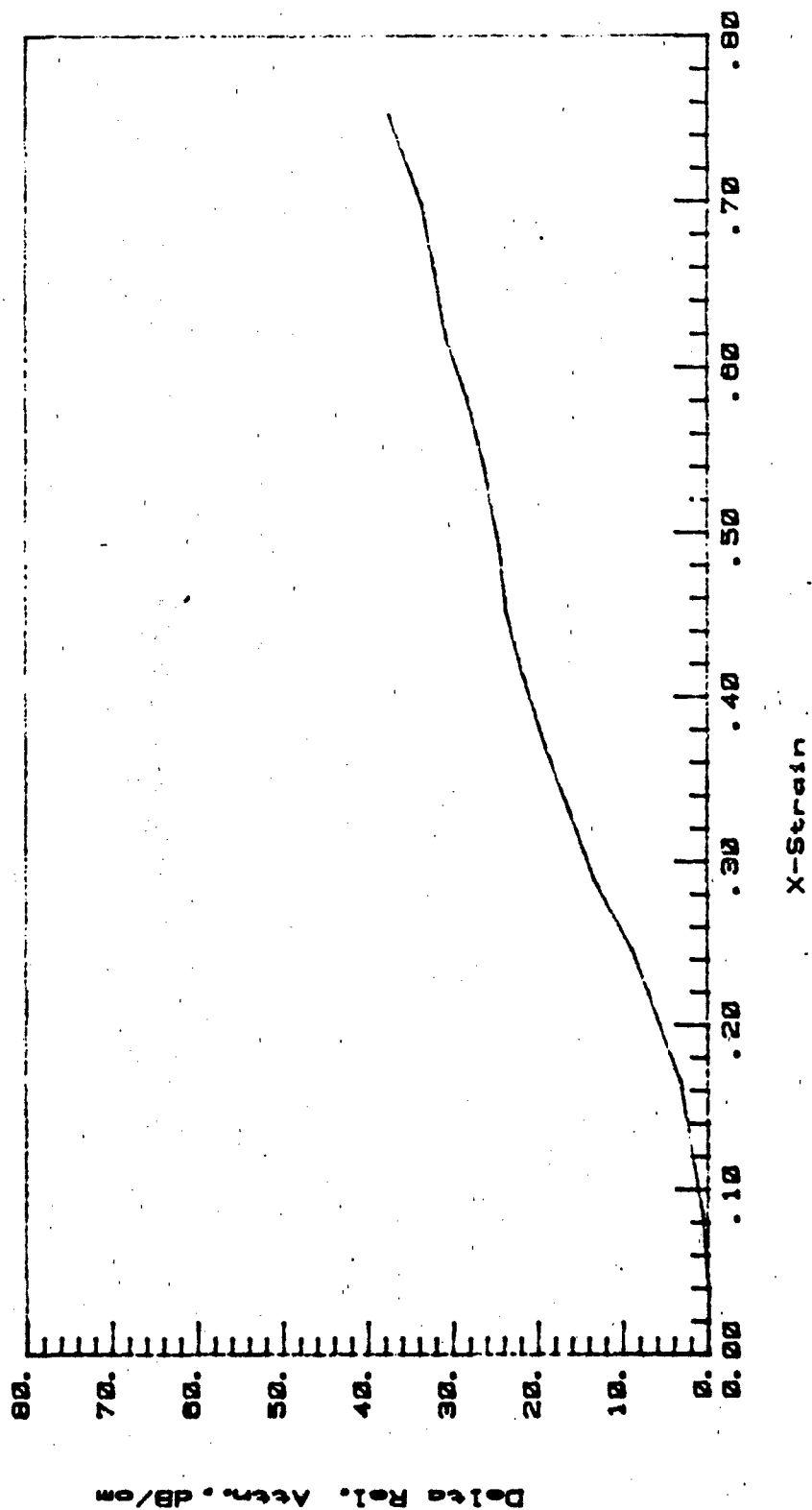


LMSC-F035789

9 OCT. 1964

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-9 #001184B 1.22H X.575WX .230T 9-12-84

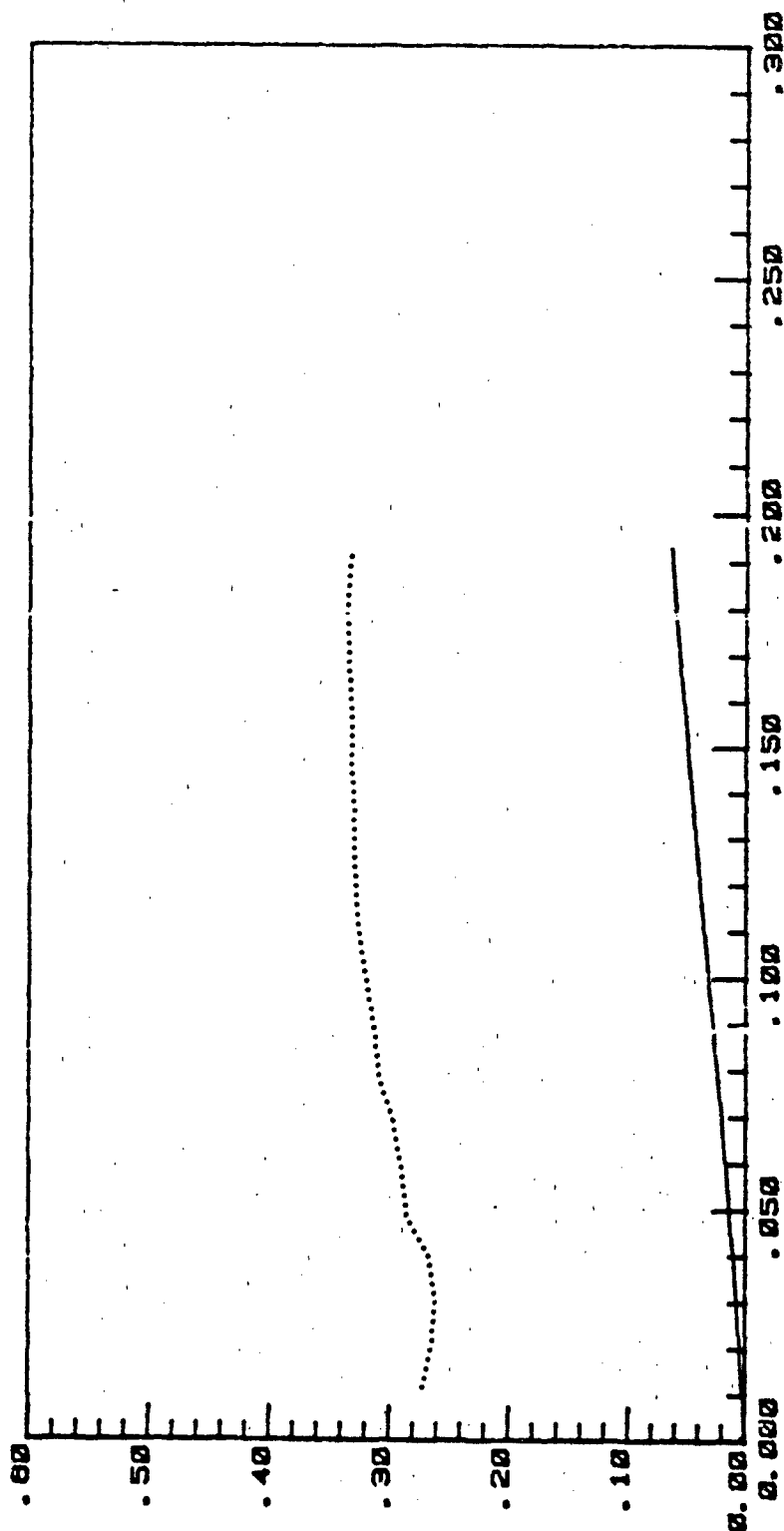


9 OCT. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-0 #A110284 1.05H X.750 X .277T 11-02-84

..... RATIO 2 ——— Z-STRAIN



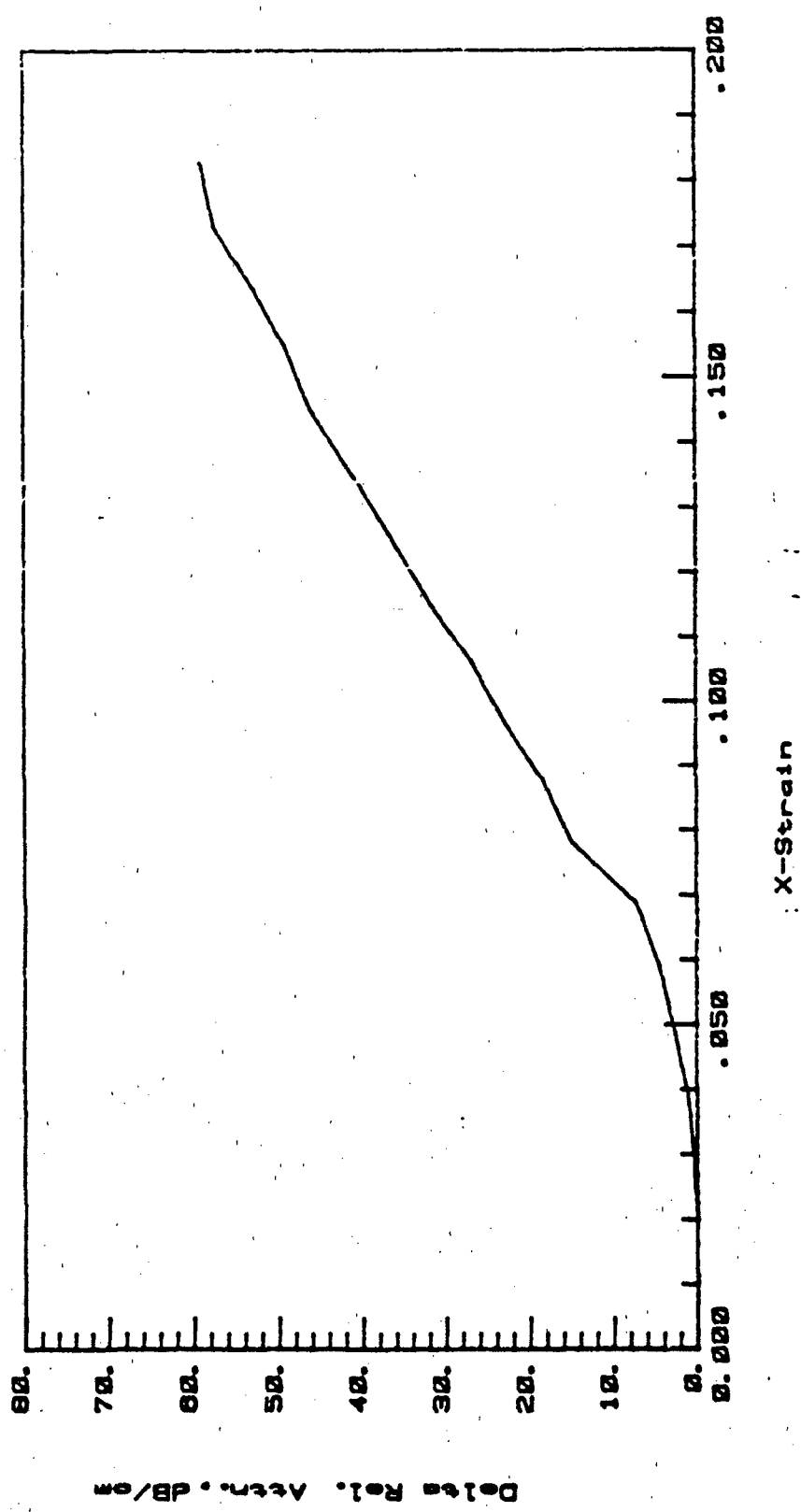
X-STRAIN

• NOV.. 1984

LMSC-F035789

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-0 #A110204 1.05H X.750 X .277T 11-02-84



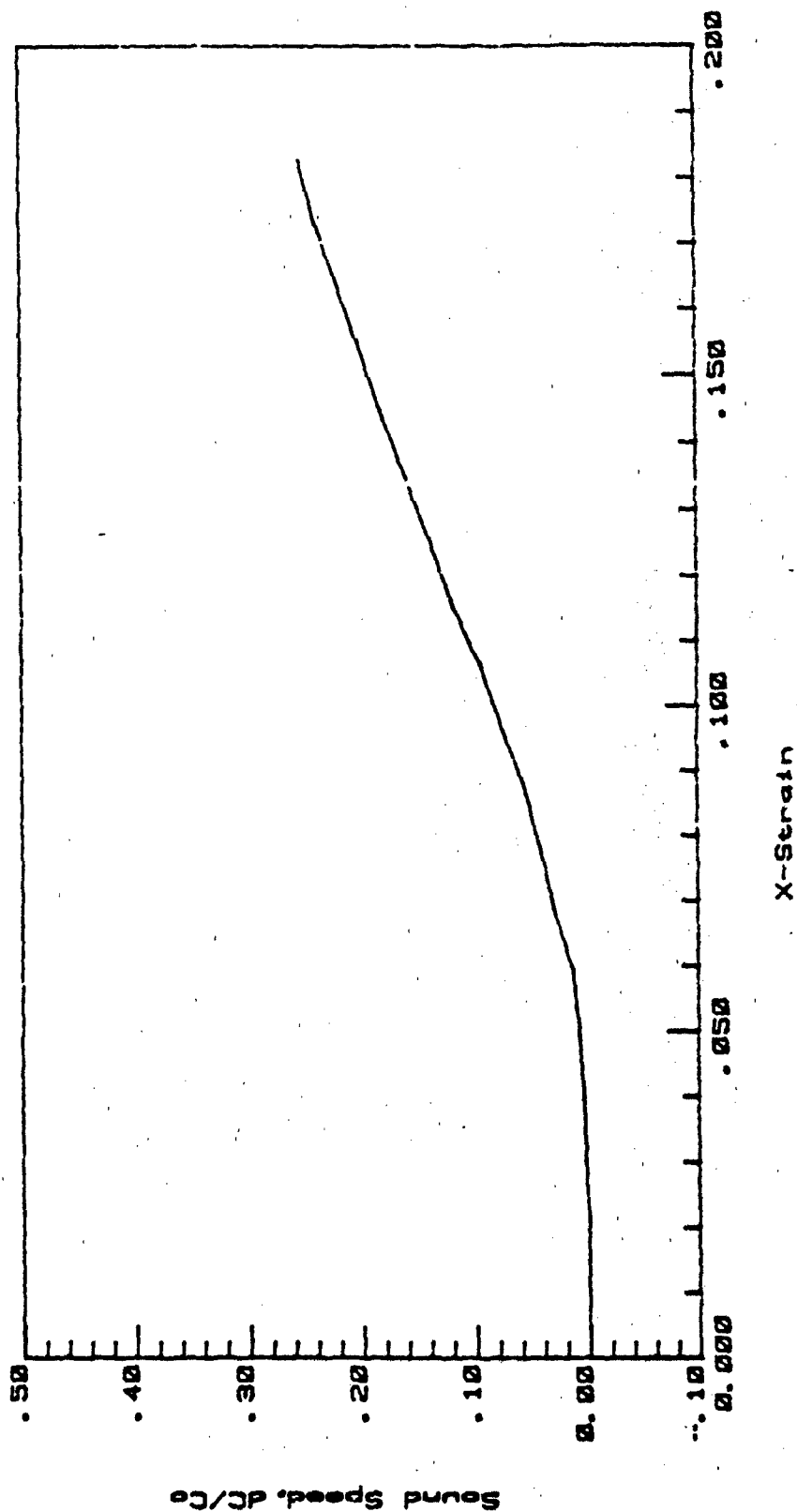
LMSC-F035789

NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #A110284 1.05H X.750 X .277T 11-02-84

AI-31

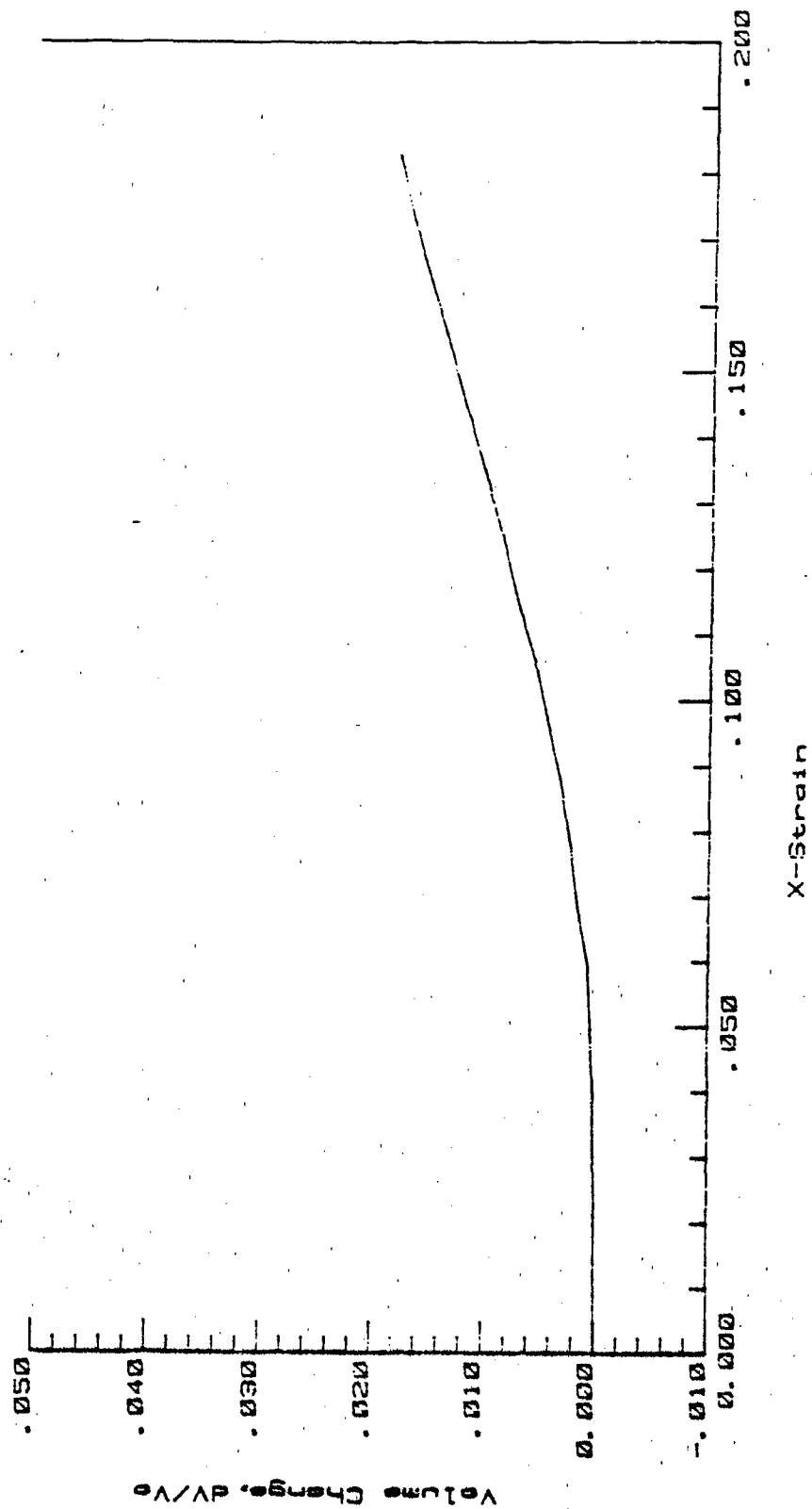


LMSC-F035789

• NOV., 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-9 #A110284 1.0EH X.750 X .277T 11-02-84



AI-32

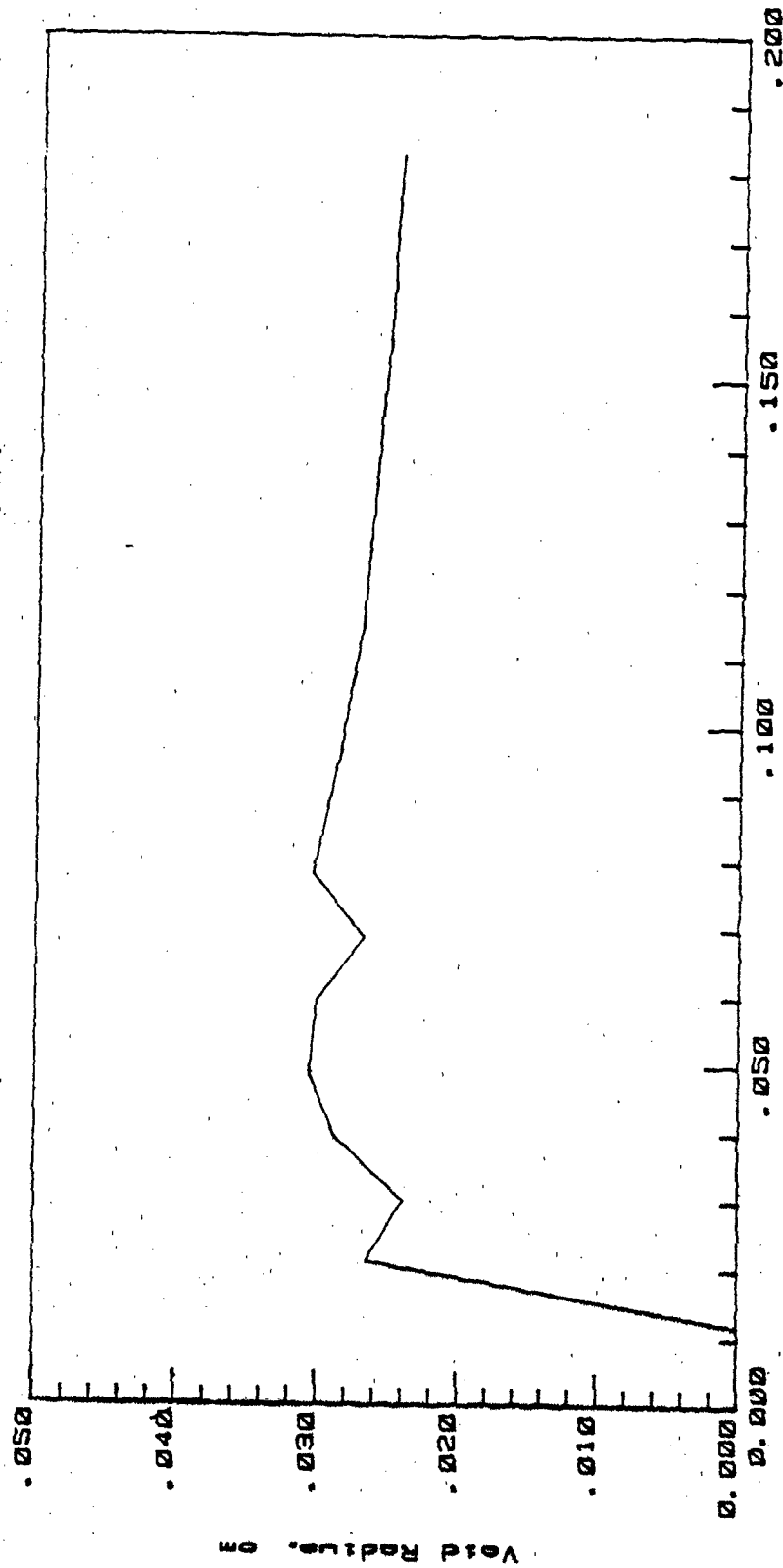
LMSC-F035789

12 NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-9 #A110284 1.05H X.750 X .277T 11-02-84

(FIXED POISSON'S RATIO OF .48 USED)



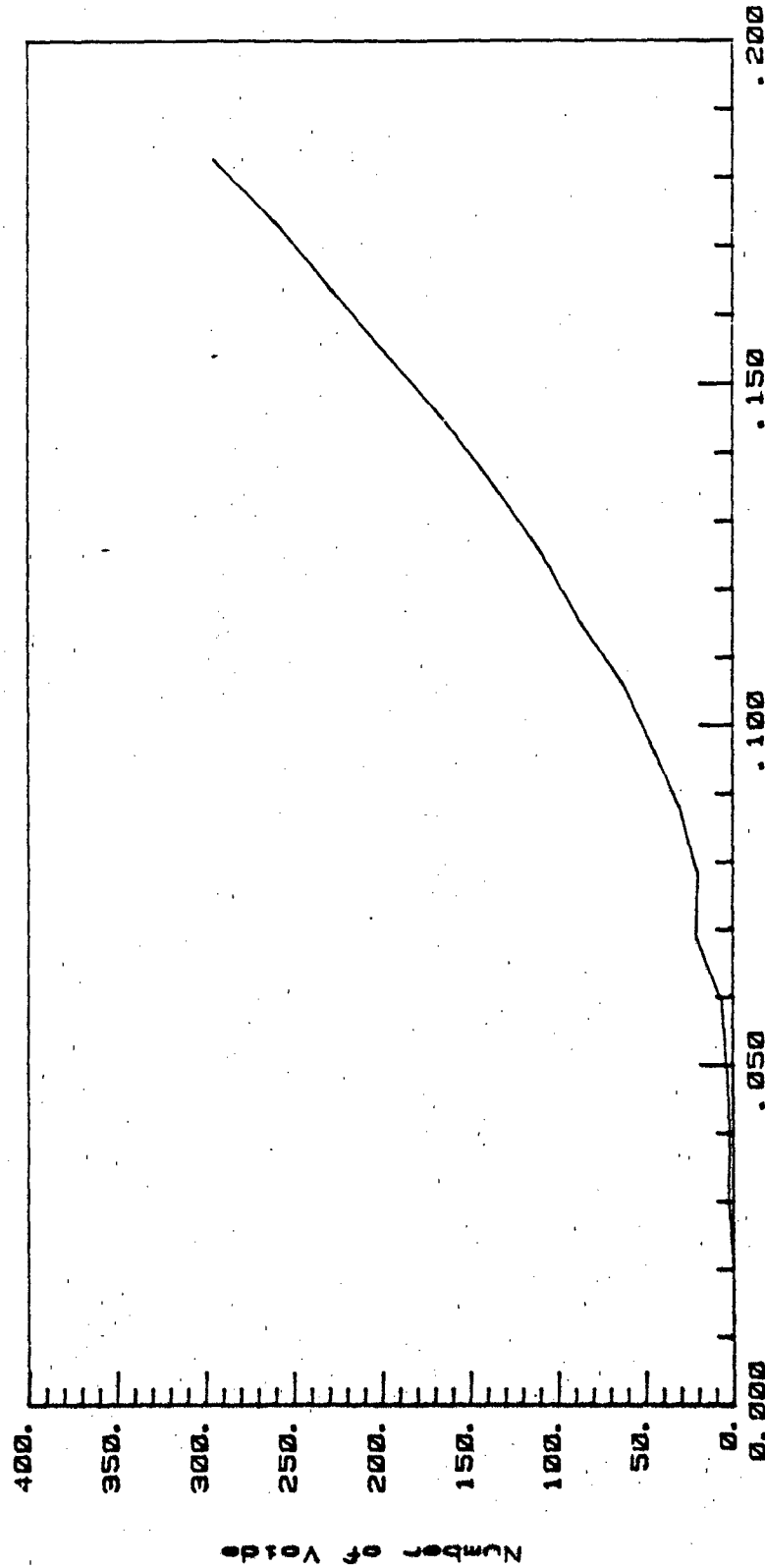
X-Strain

28 NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-8 #A110284 1.05H X.750 X .277T 11-02-84

(FIXED POISSON'S RATIO OF .48 USED)



X-Strain

28 NOV.. 1984

AI-34

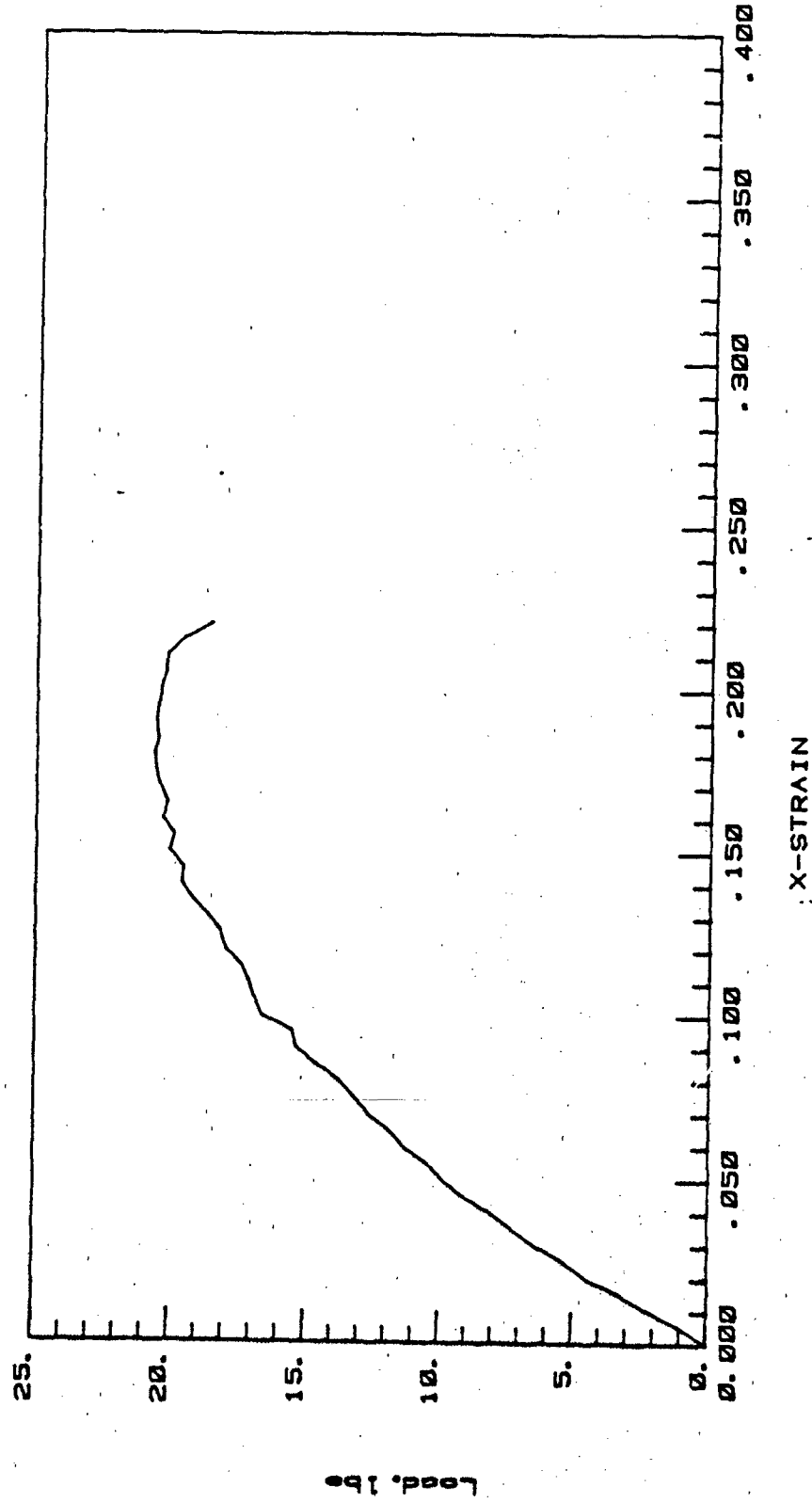
LMSC-F035789

ULTRASONIC DATA FOR BLX-11

A1-35

LOCKHEED MATERIALS ANALYSIS LABORATORY

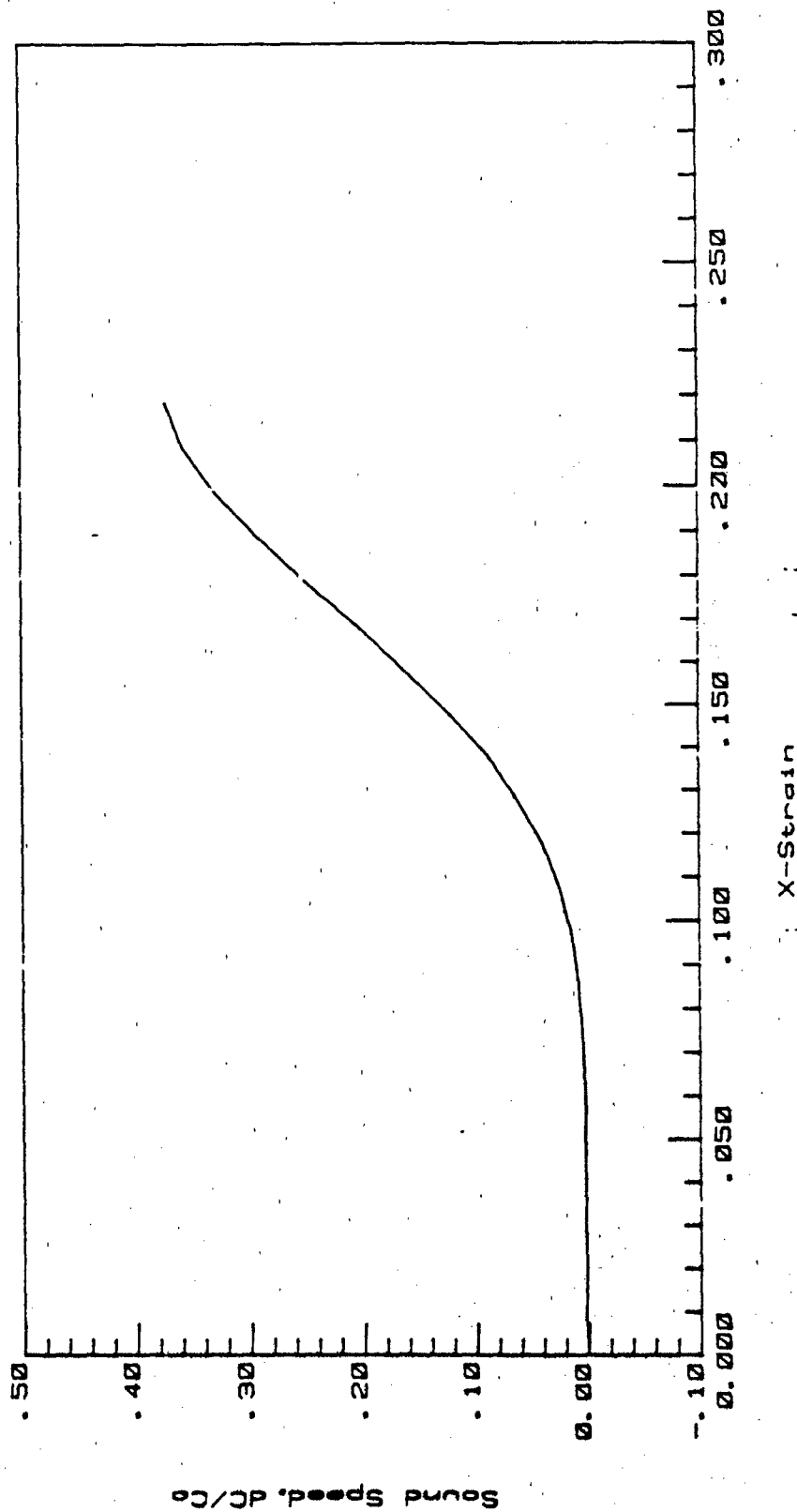
CHINA LAKE PROPELLANT BLX-11 1H 1W .268T A110584



30 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-11#A110584 1.005HX.1.00X .268T 11-05-84

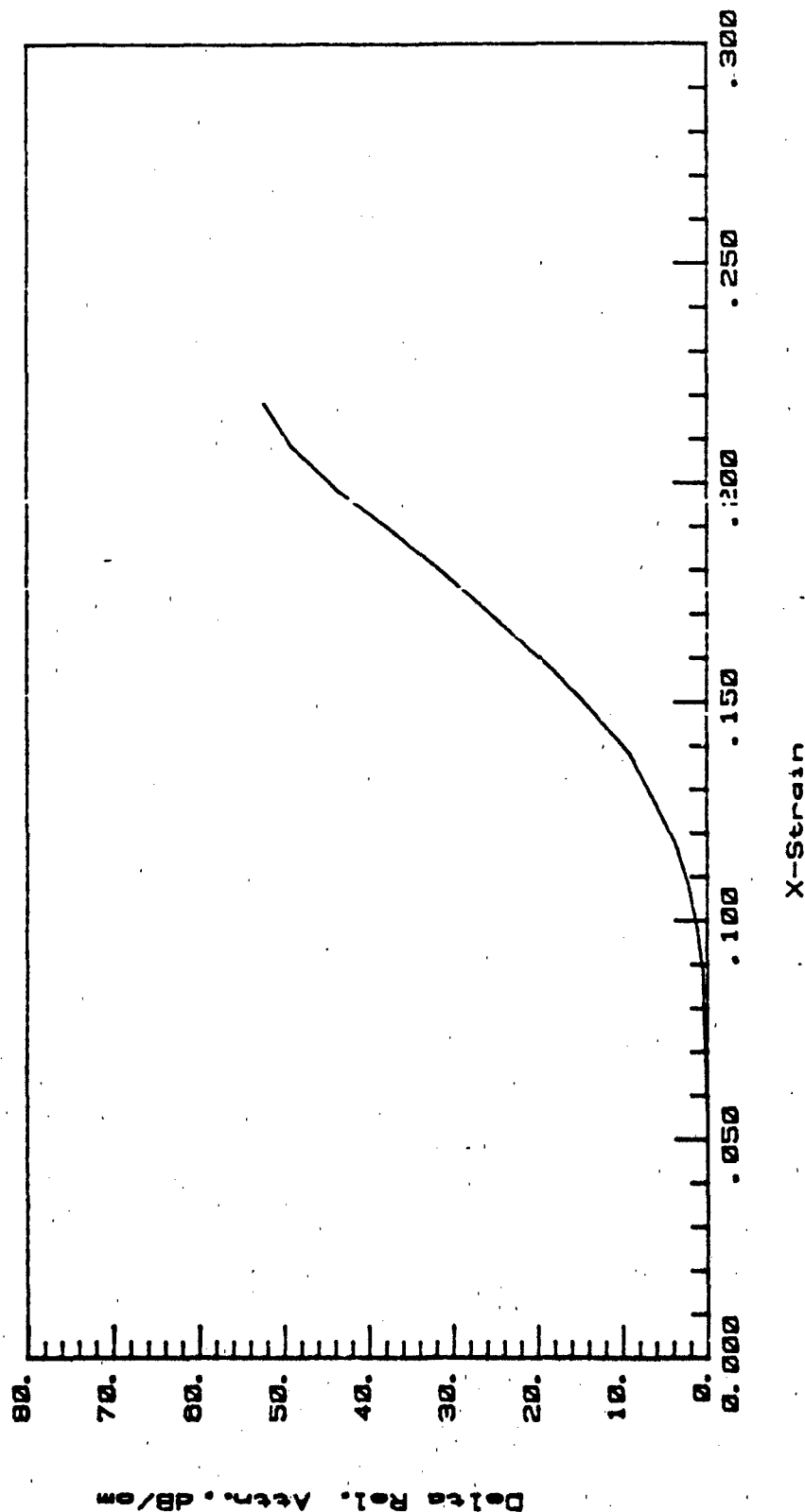


LMSC-F035789

9 NOV.. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-11#A110584 1.005HX.1.00X .268T 11-05-84



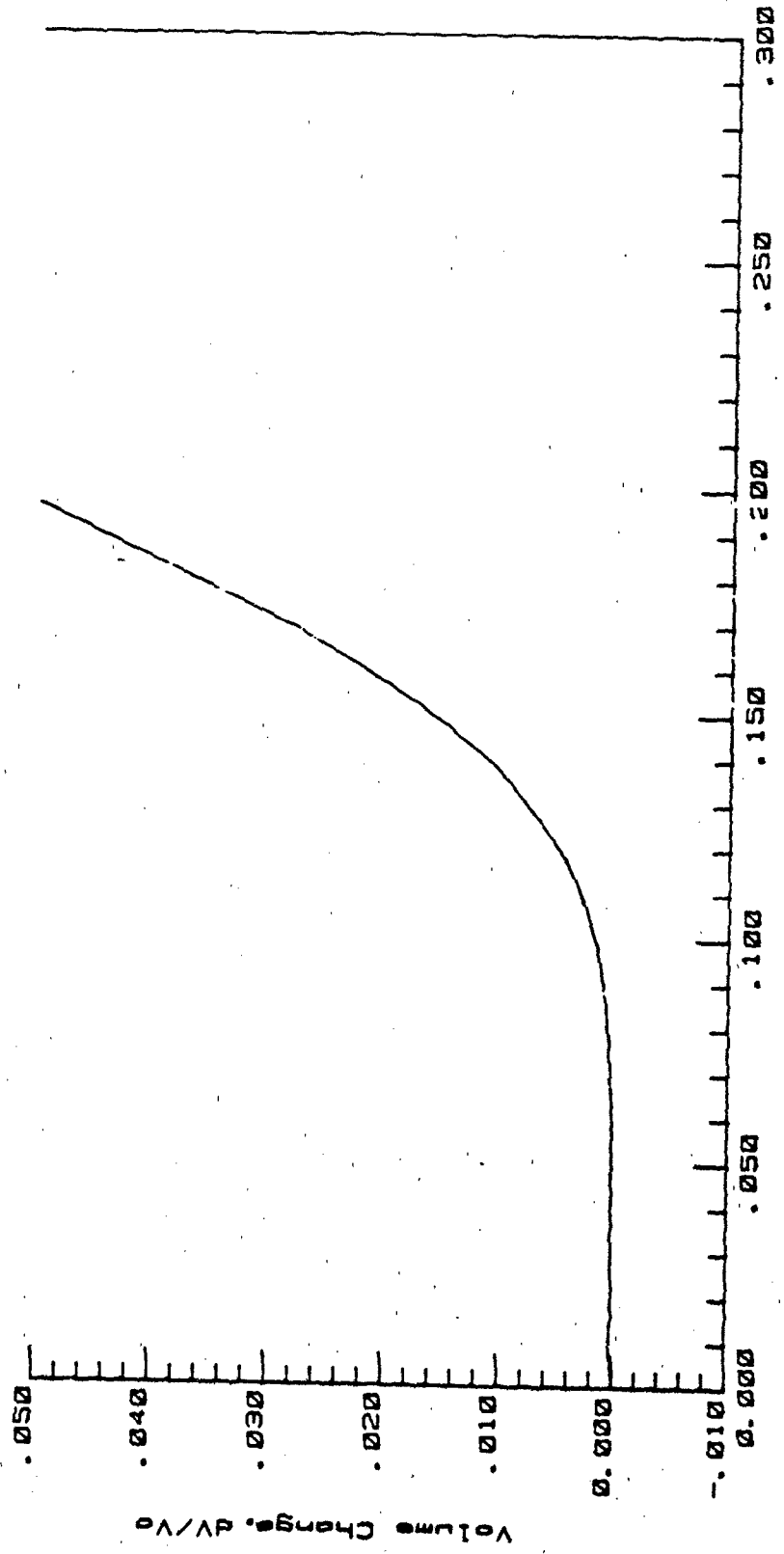
LMSC-F035789

7 NOV. 1984

AI-38

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-11W110584 1.00EHX.1.00X .268T 11-05-84



X-Strain

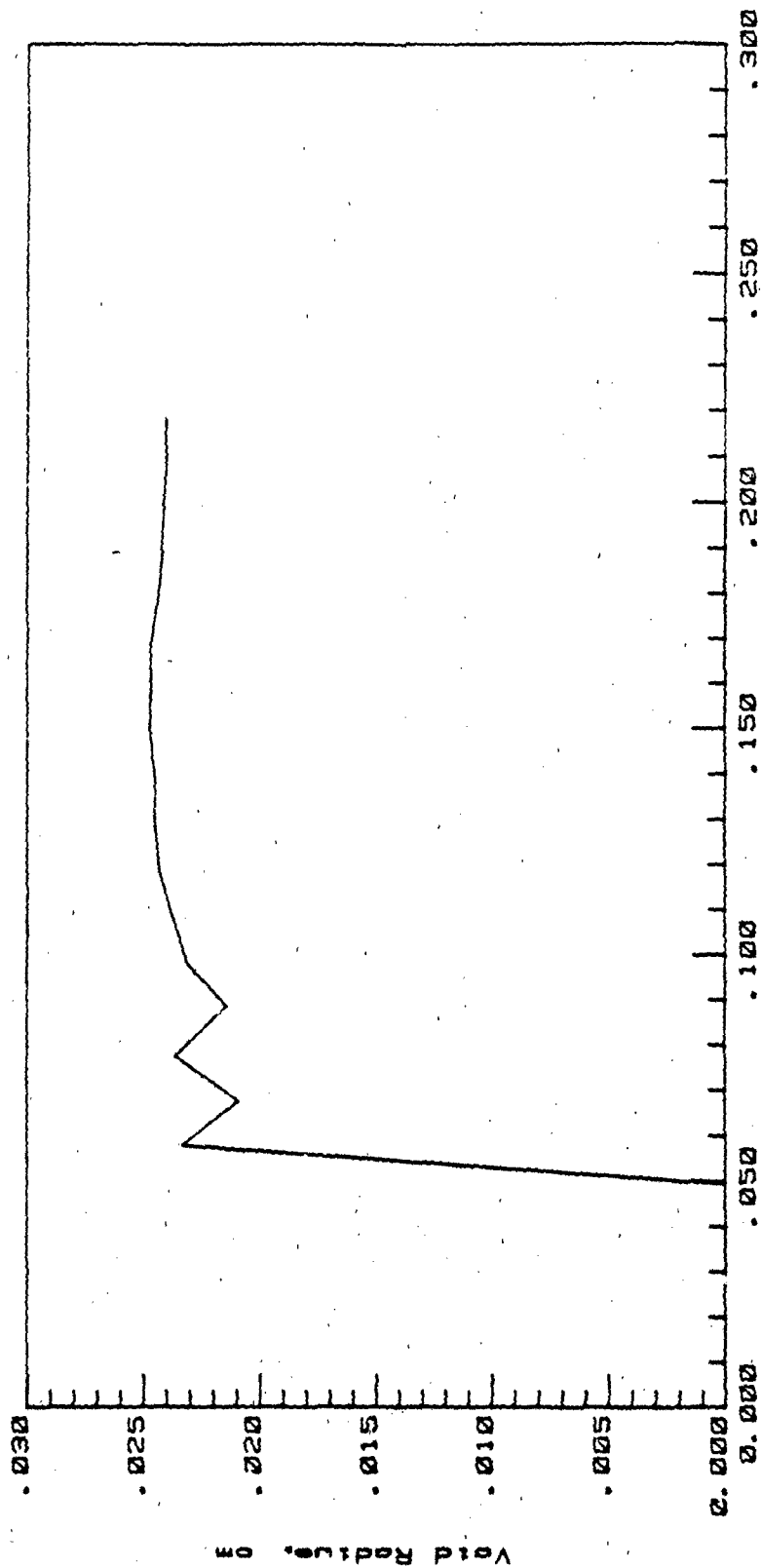
9 NOV. 1984

LMSC-F035789

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-11#A110584 1.005HX.1.00X.268T 11-05-84

(FIXED POISSON'S RATIO = .48)



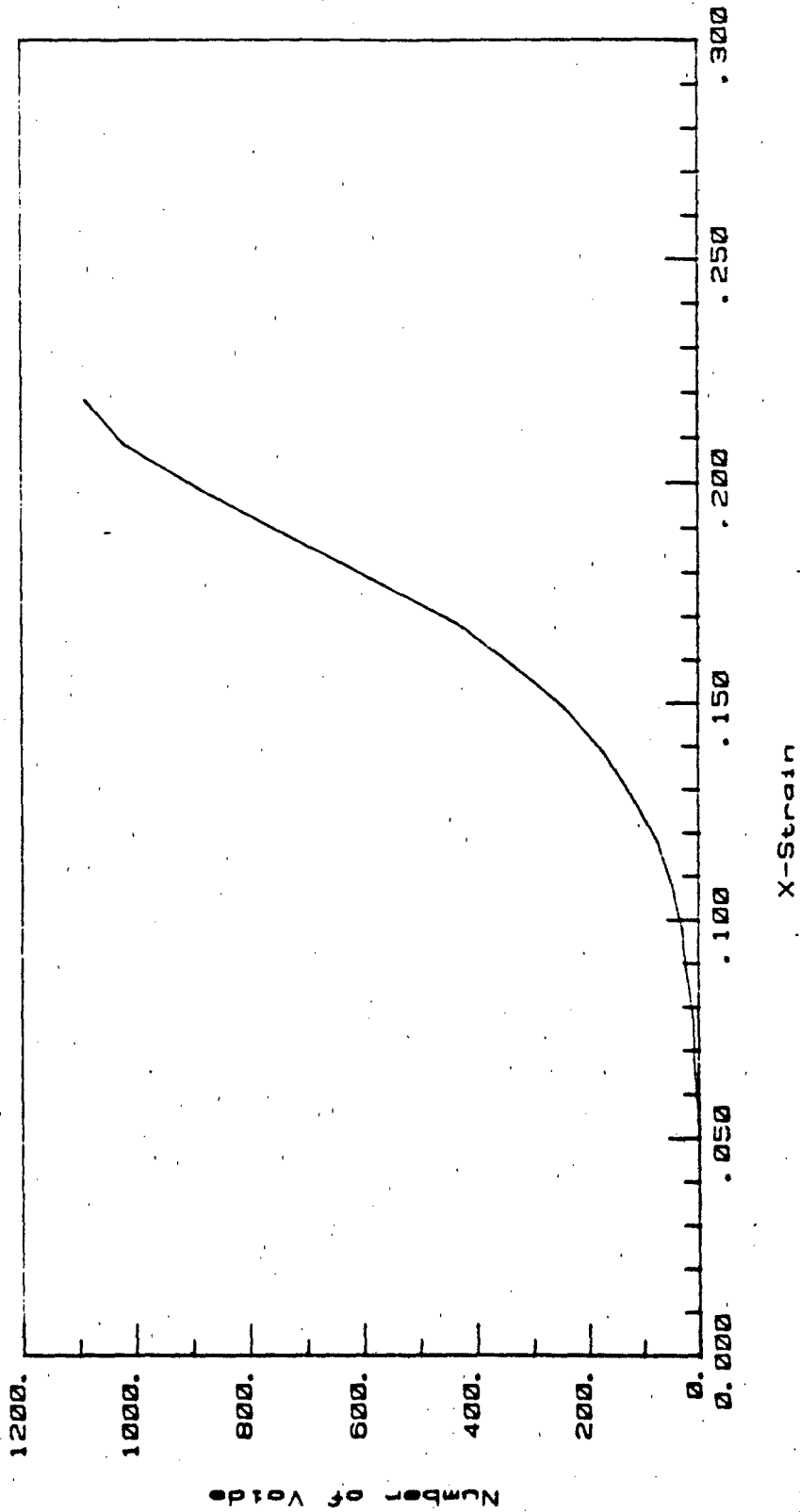
LMSC-F035789

28 NOV. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE PROP. BLX-11#A110584 1.005HX.1.00X .268T 11-05-84

(FIXED POISSON'S RATIO = .48)



LMSC-F035789

20 NOV. 1984

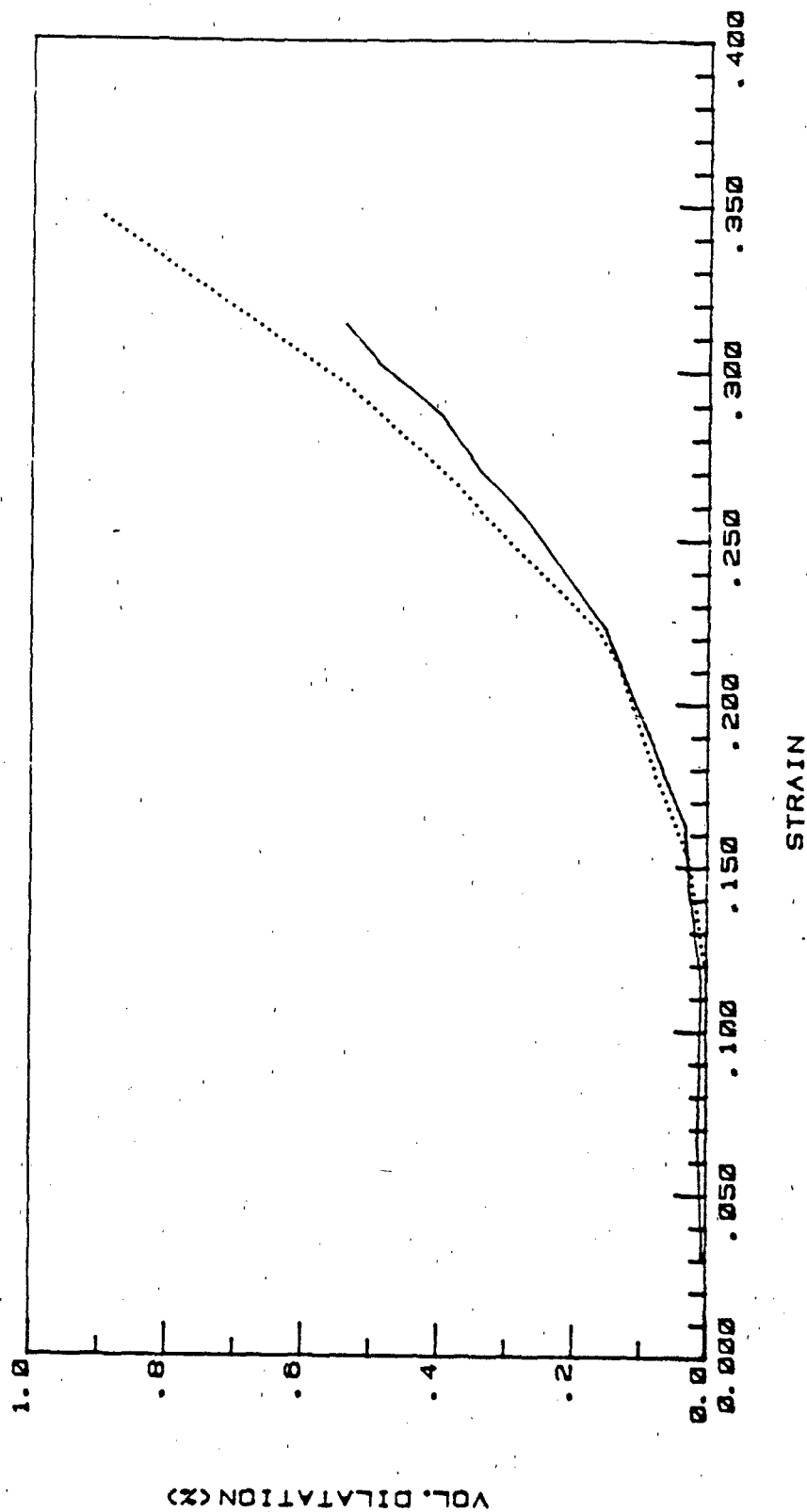
LMSC-F035789

DILATATION DATA FOR BLX-4, BLX-6,
BLX-8, BLX-9, AND BLX-11(3)

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE VOL. DILATATION FROM LETTER OF SEP. 10 1984

..... BLX492 — BLX493



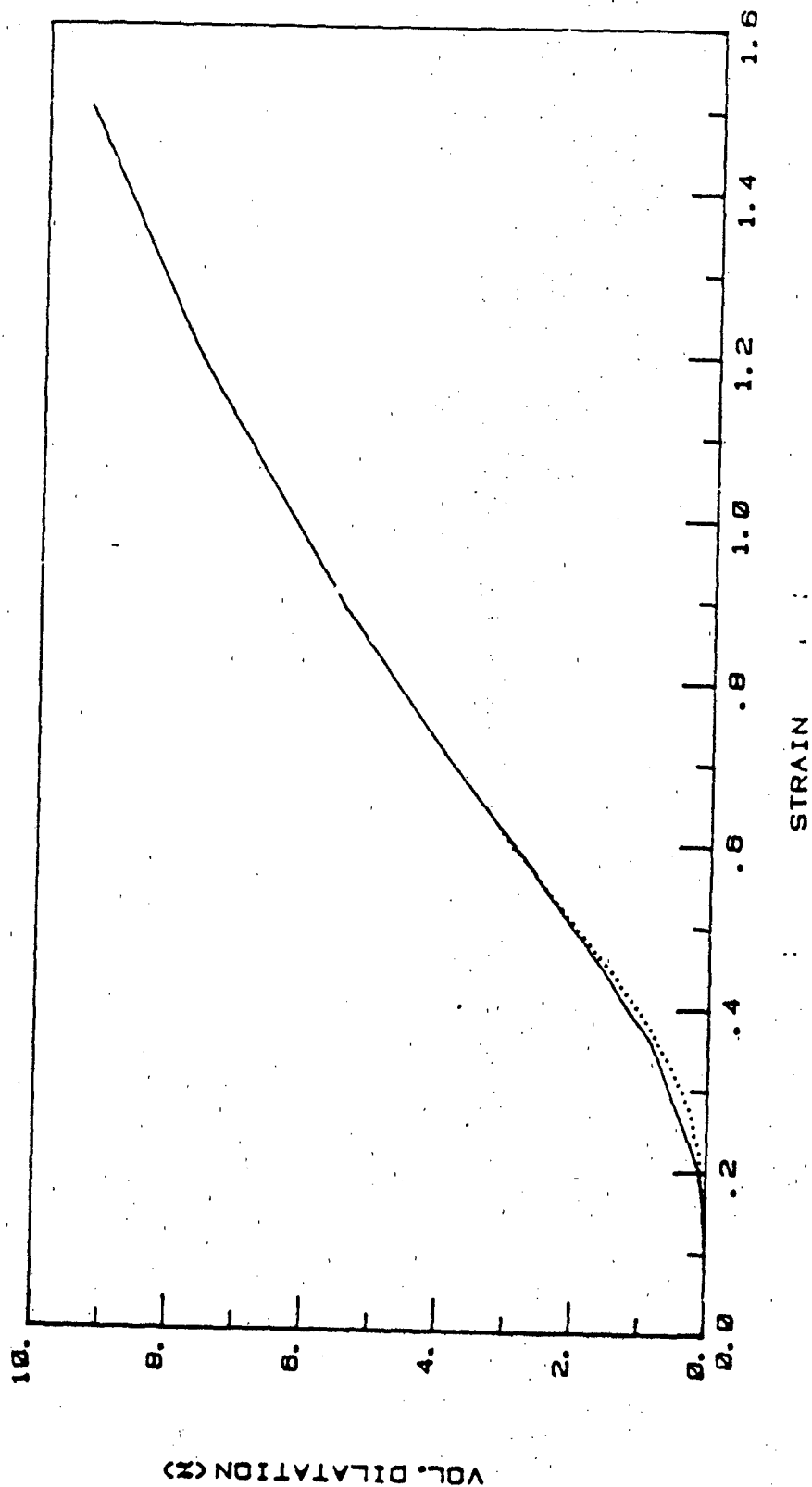
LMSC-F035789

8 OCT. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE VOL. DILATATION FROM LETTER OF SEP. 10 1984

..... BLX642 ——— BLX632



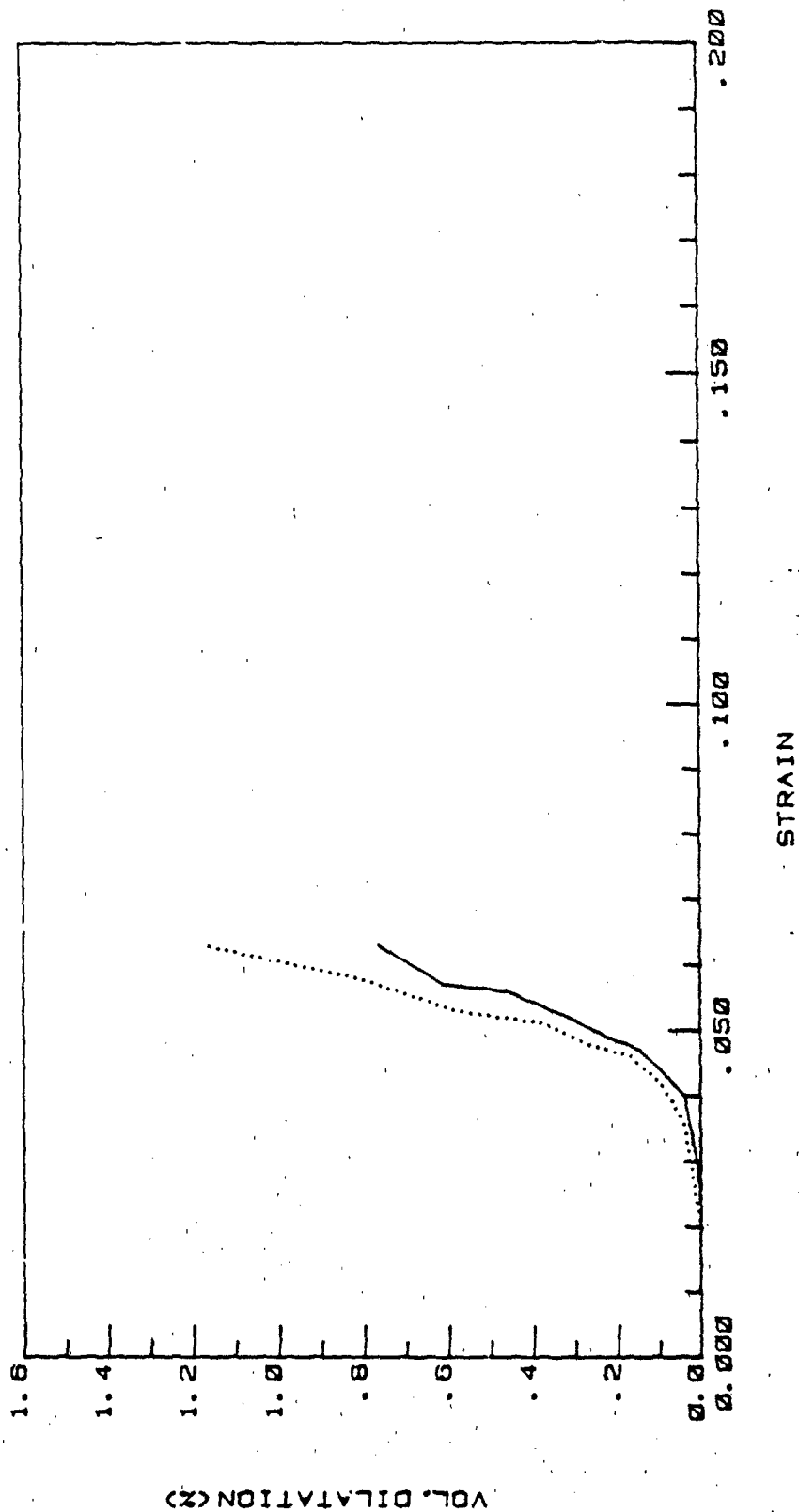
LMSC-F035789

8 OCT. 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE VOL. DILATATION FROM LETTER OF SEP. 10 1984

..... BLX872 ——— BLX871



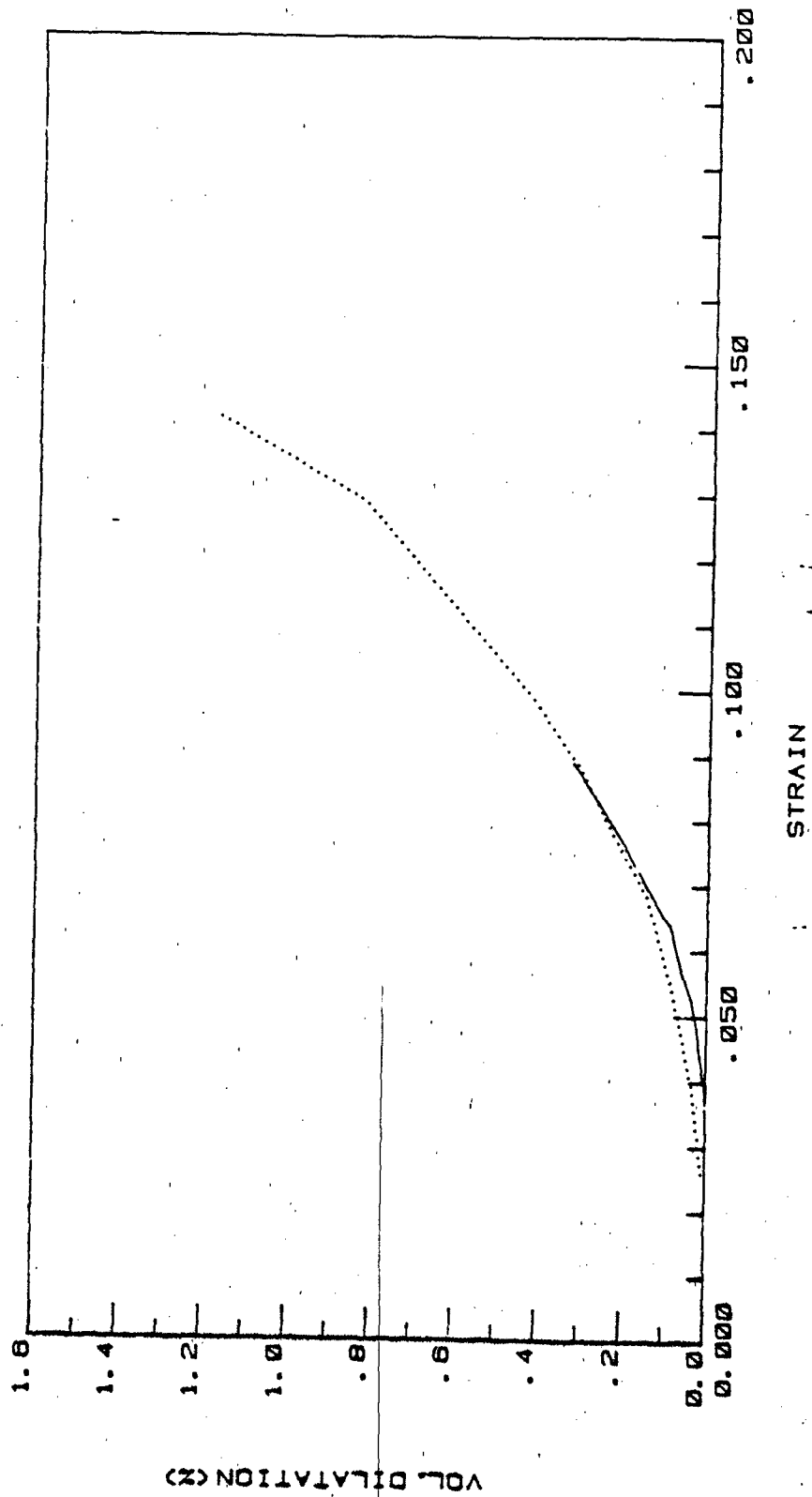
LMSC-F035789

8 OCT., 1984

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE VOL. DILATATION FROM LETTER OF SEP. 10 1984

..... BLX952 ——— BLX942

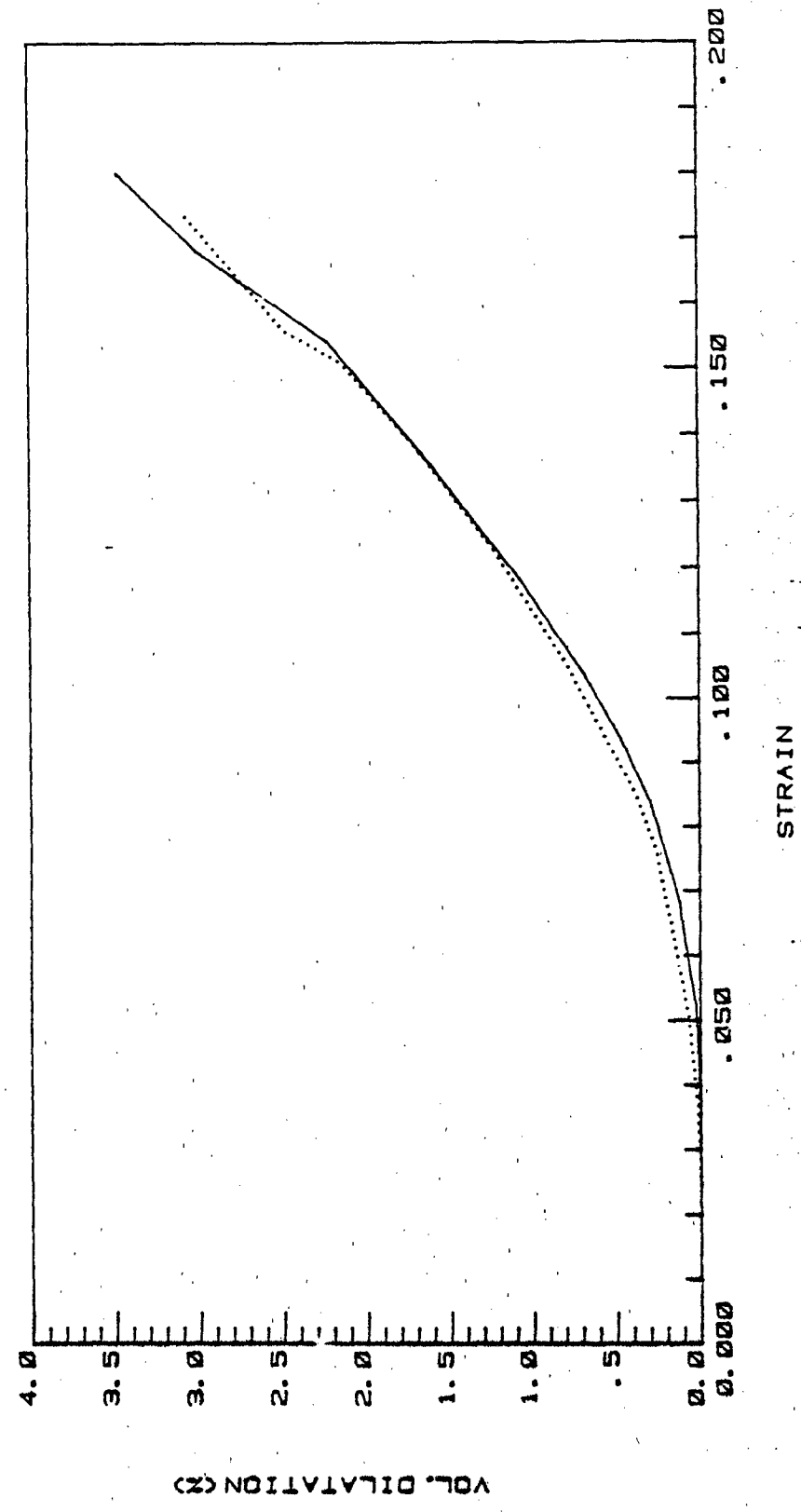


Al-46

LOCKHEED MATERIALS ANALYSIS LABORATORY

CHINA LAKE VOL. DILATATION FROM LETTER OF SEP. 10 1984

..... BLX322 — BLX352



AI-47

LMSC-F035789

8 OCT. 1984

RESULTS OF ULTRASONIC MEASUREMENTS OF
POISSON'S RATIO FOR 5 MATERIALS

<u>MATERIAL NUMBER</u>	<u>LONGITUDINAL WAVE SPEED (cm/sec) x 10⁻⁵</u>	<u>TRANSVERSE WAVE SPEED (cm/sec) x 10⁻⁴</u>	<u>POISSON'S RATIO $\frac{U_o}{-}$</u>
BLX-4	1.98	4.1	0.48
BLX-6	2.1	3.0	0.49
BLX-8	2.3	5.1	0.48
BLX-9	1.94	3.1	0.49
BLX-11	1.84	4.0	0.48

$$U_o = \frac{1 - 0.5r^2}{1 - r^2}$$

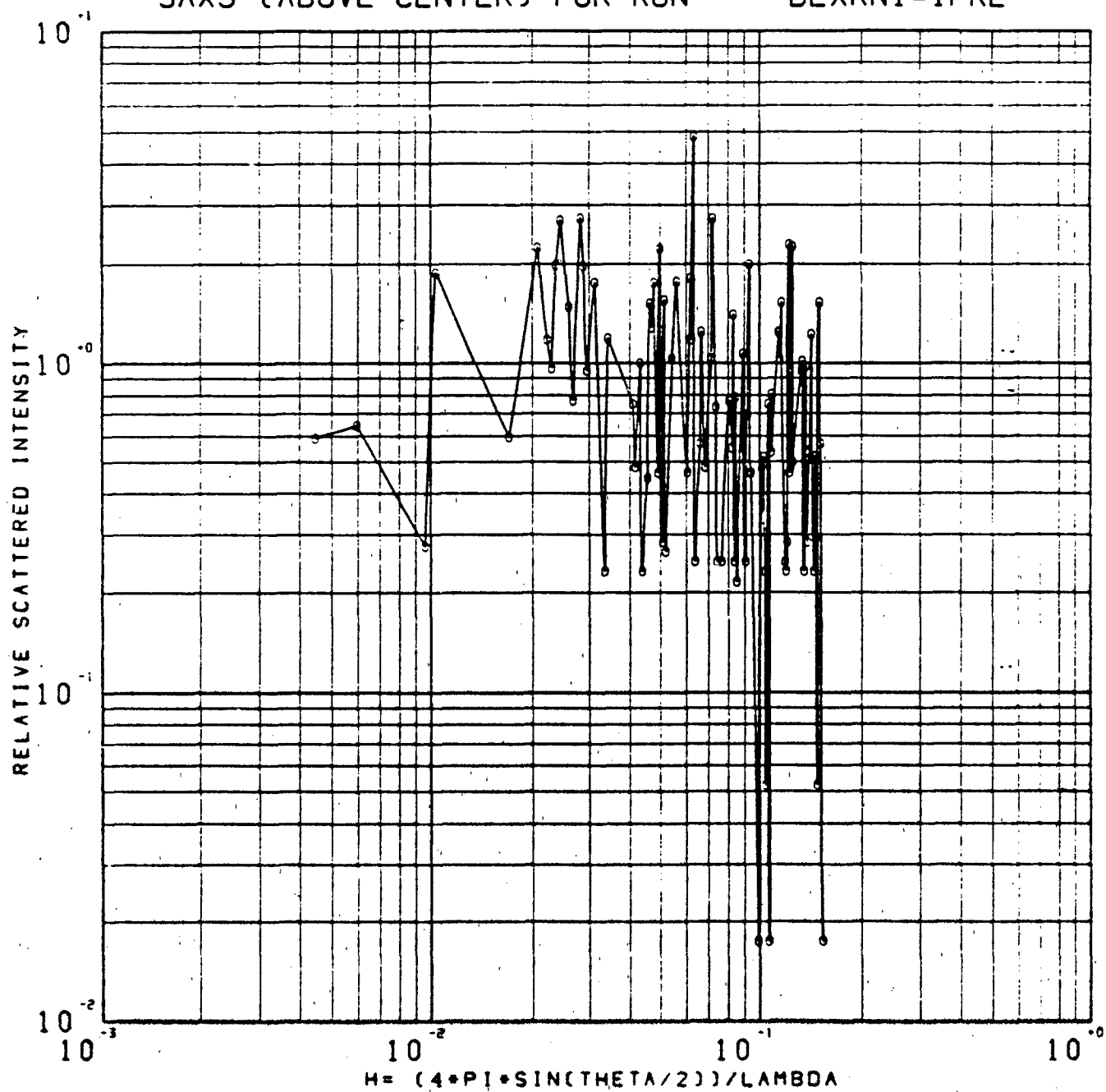
where $r = \frac{\text{shear wave speed}}{\text{longitudinal wave speed}}$

APPENDIX II
SAXS DATA FOR BLX-4

SAXS (ABOVE CENTER) FOR RUN

BLXRN1-1PRE

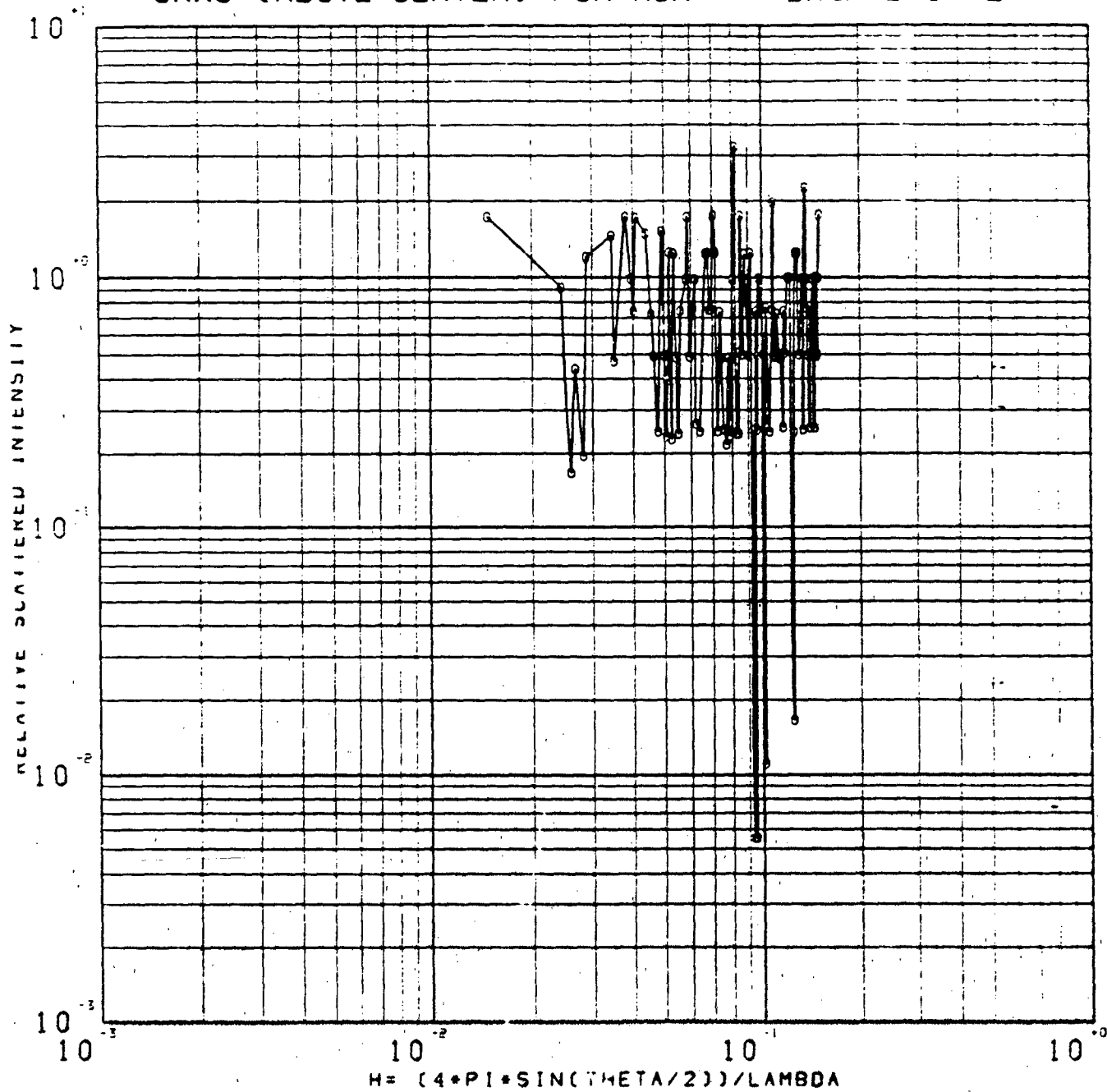
U1108/SC4020
0000 0002



SAXS (ABOVE CENTER) FOR RUN

BX4RN2-1PRE

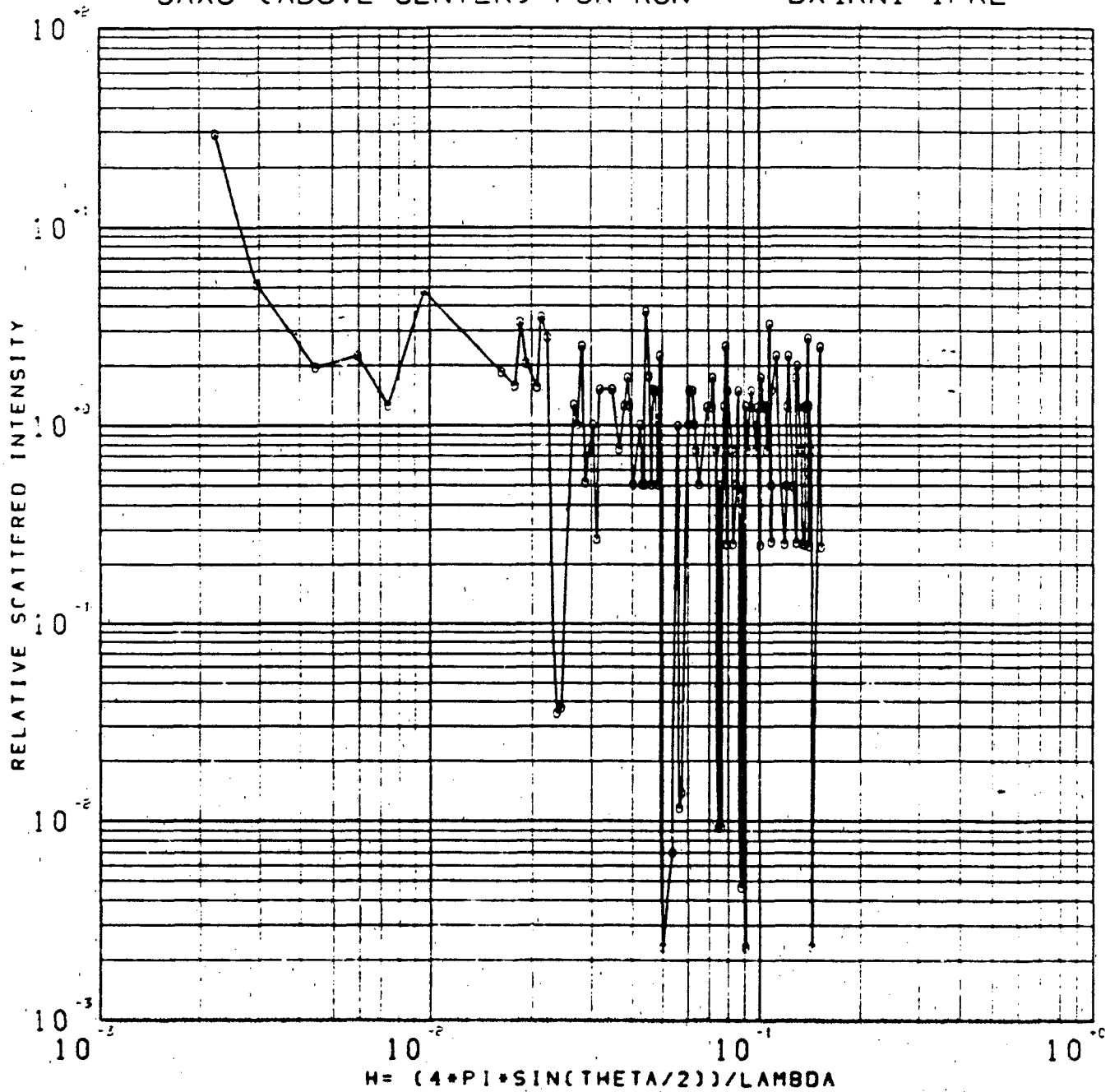
U1108/SC4020L
3000 C004



SAXS (ABOVE CENTER) FOR RUN

BX4RN1-1PRE

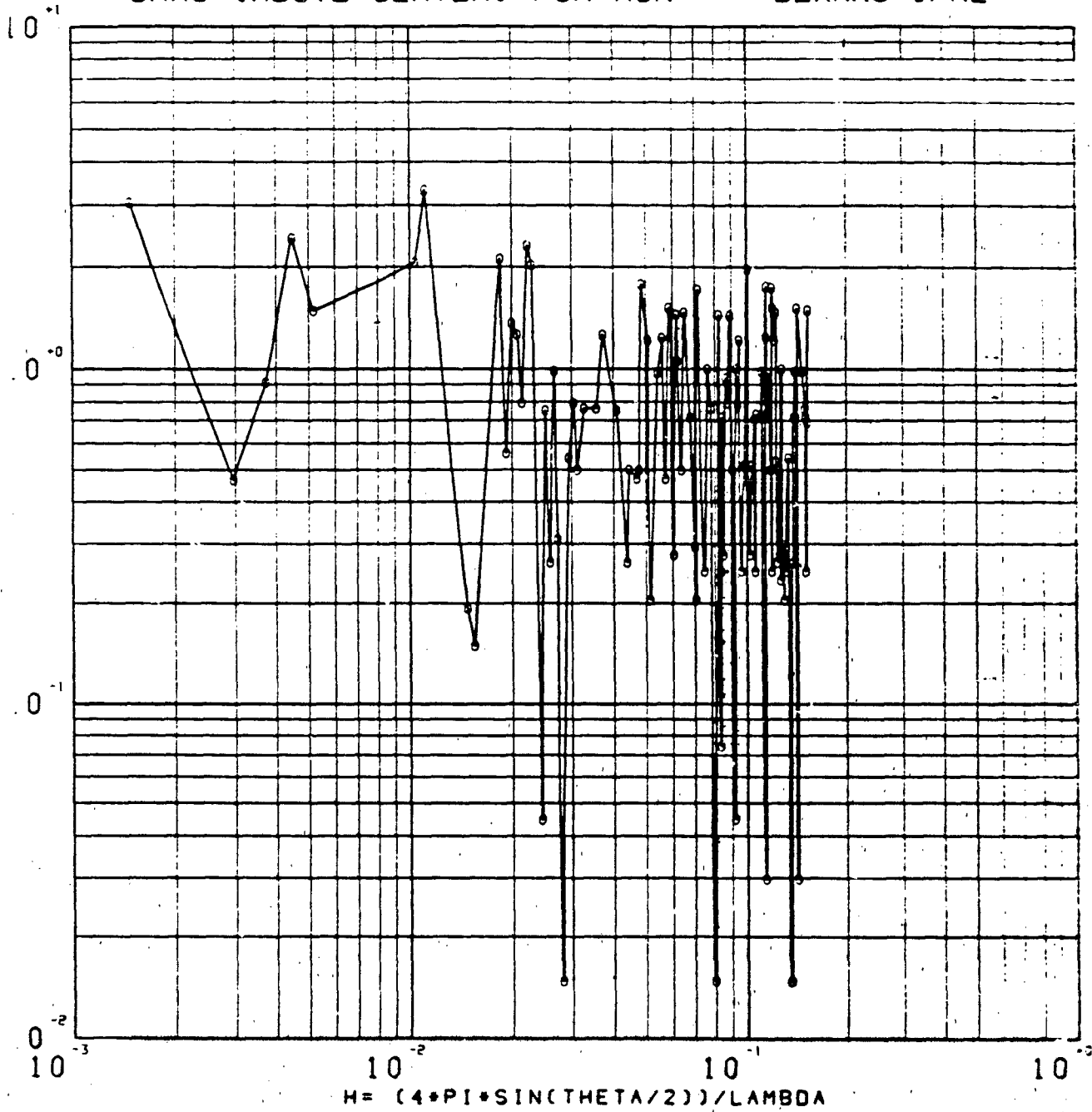
0110P/SC-020
000 0000



SAXS (ABOVE CENTER) FOR RUN

BLXRN5-1PRE

U1108/SC4020
0000 0010

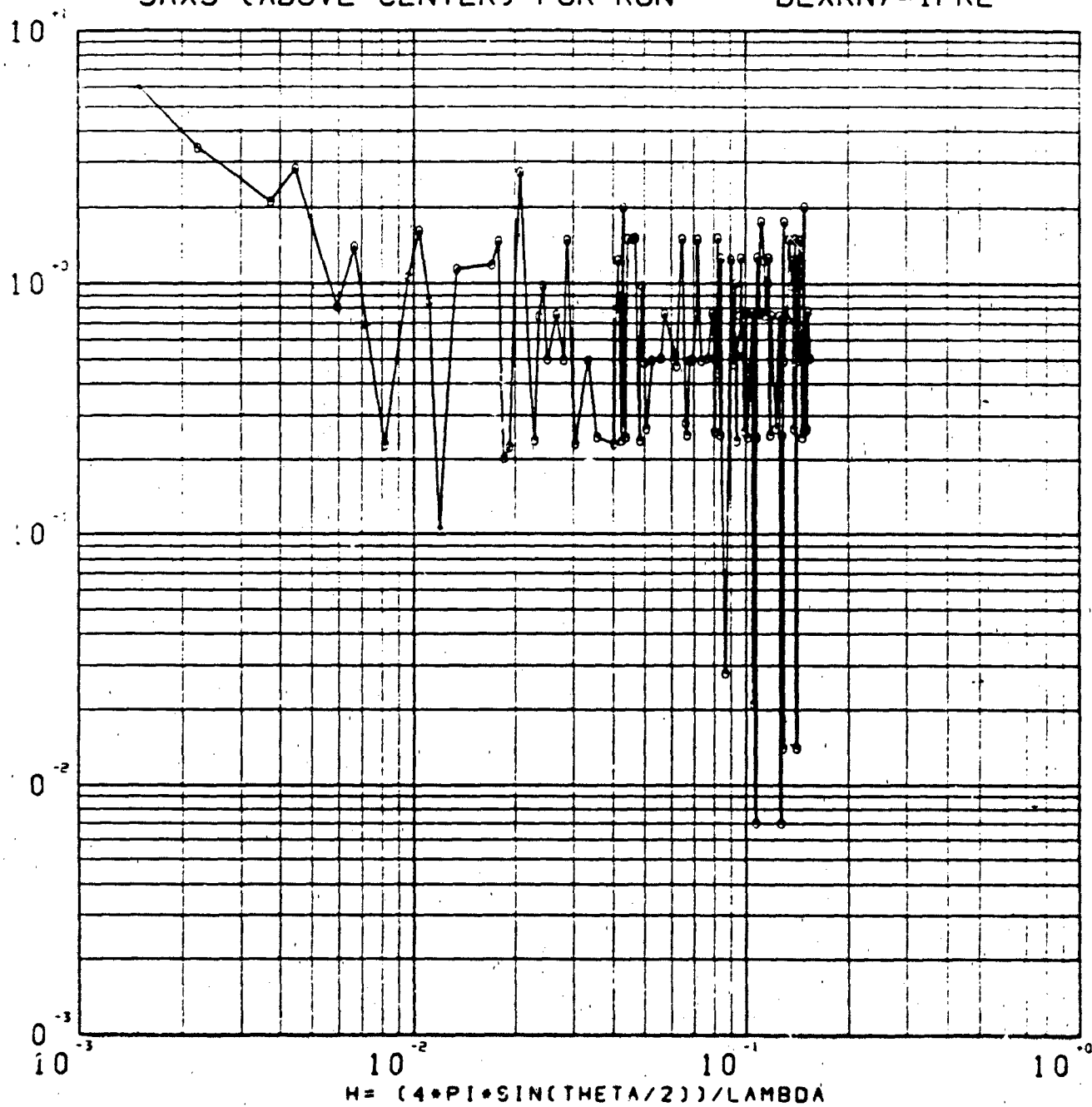


LMSC-F035789

SAXS (ABOVE CENTER) FOR RUN

BLXRN7-1PRE

U1108/SC4020
0000 0014

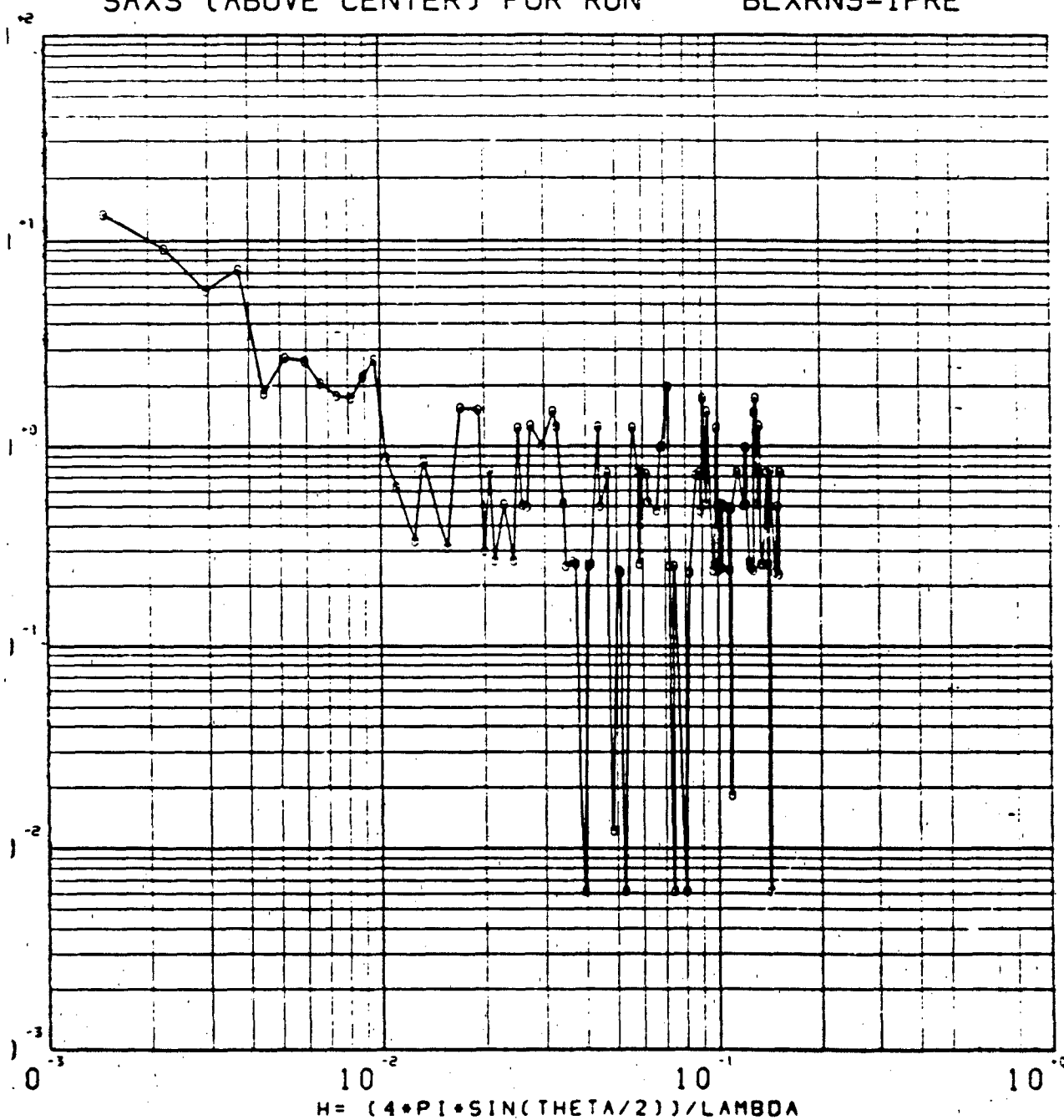


LMSC-F035789

SAXS (ABOVE CENTER) FOR RUN

BLXRN9-1PRE

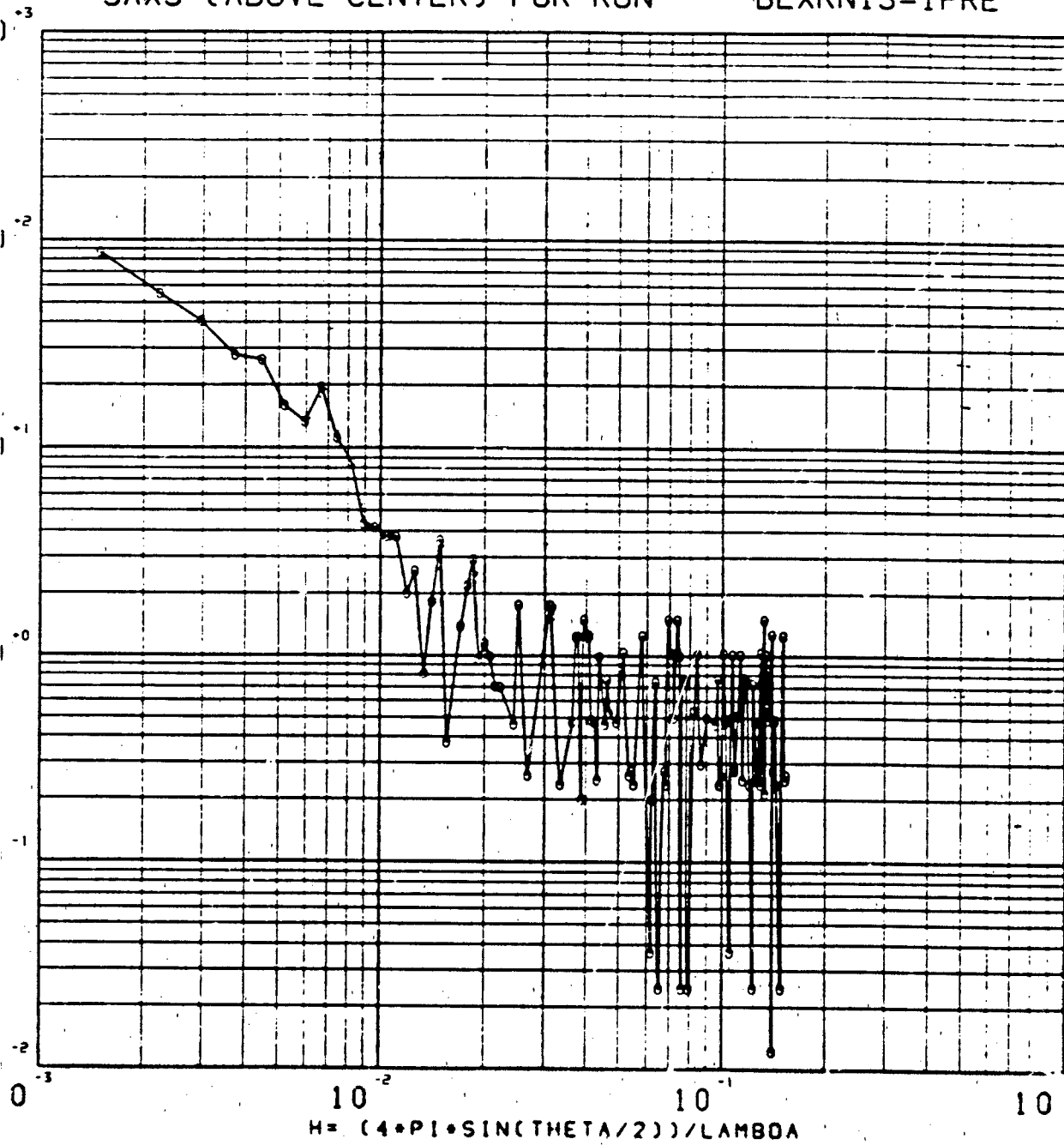
01108/SC4920-
0000 12:18



SAXS (ABOVE CENTER) FOR RUN

BLXRN13-1PRE

U1108/SC4020
2000 0027

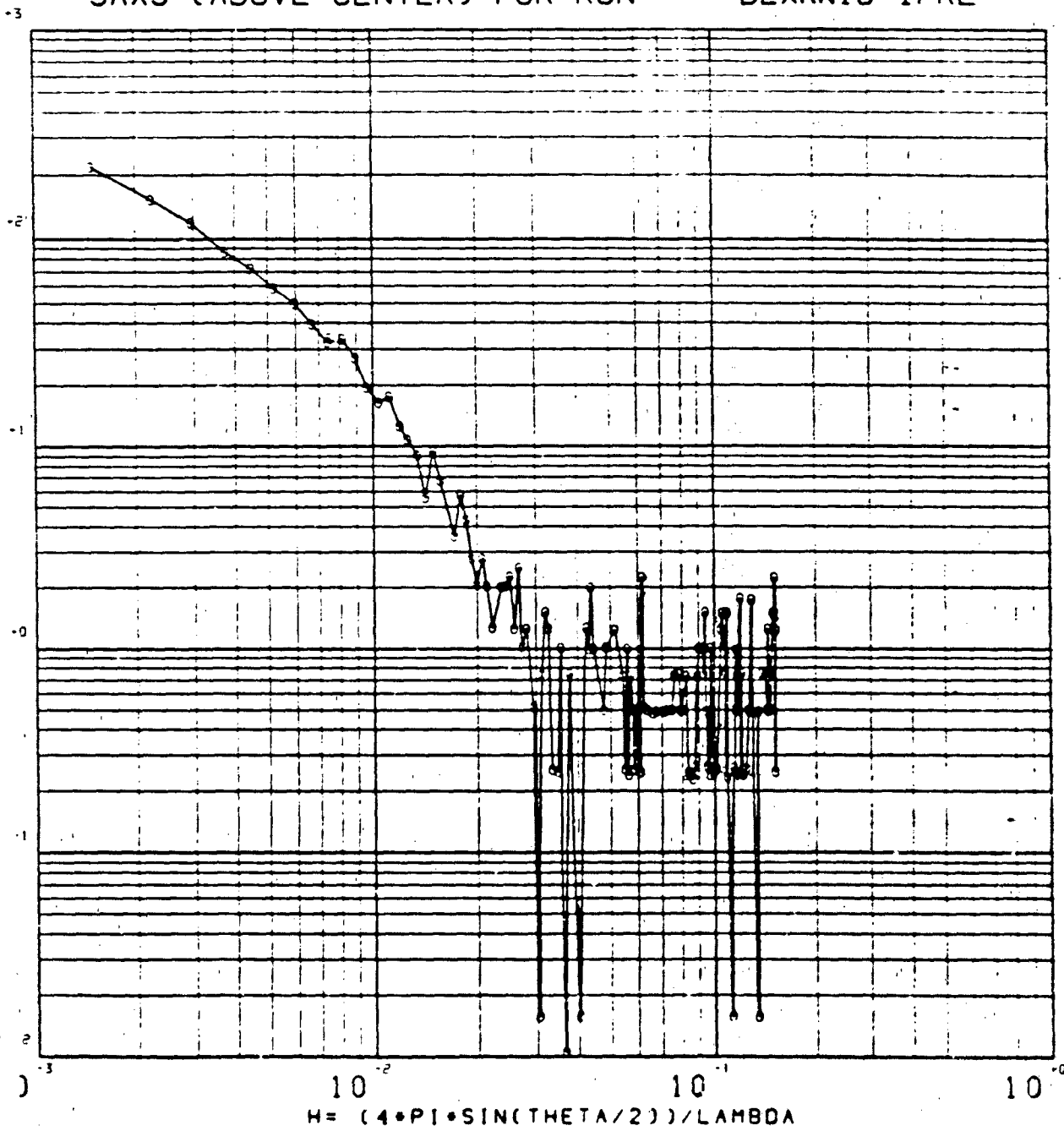


LMSC-F035789

SAXS (ABOVE CENTER) FOR RUN

BLXRN15-1PRE

01108/SC4020-
2000 0033

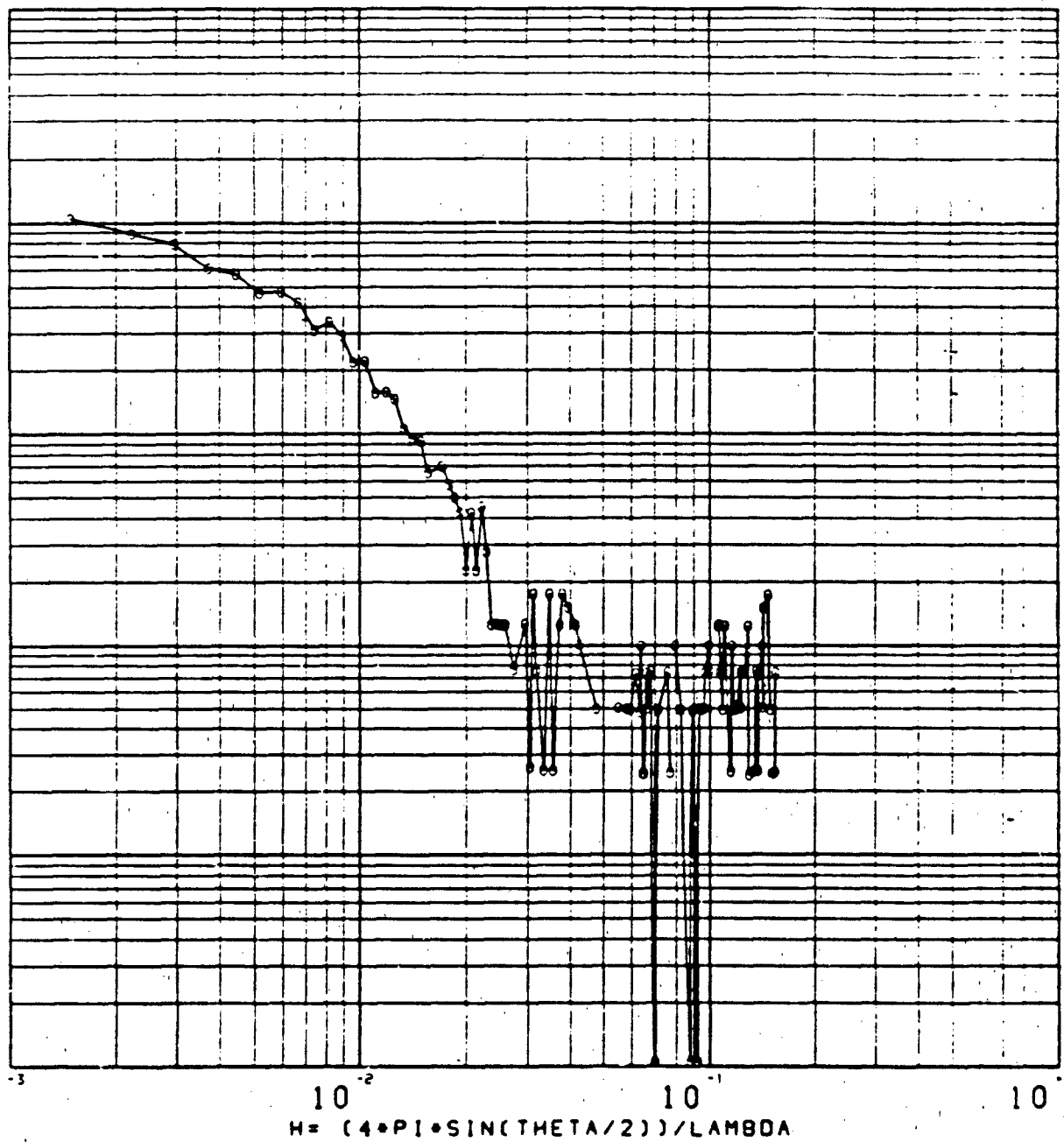


LMSC-F035789

SAXS (ABOVE CENTER) FOR RUN

BLXRN16-1PRE

0036



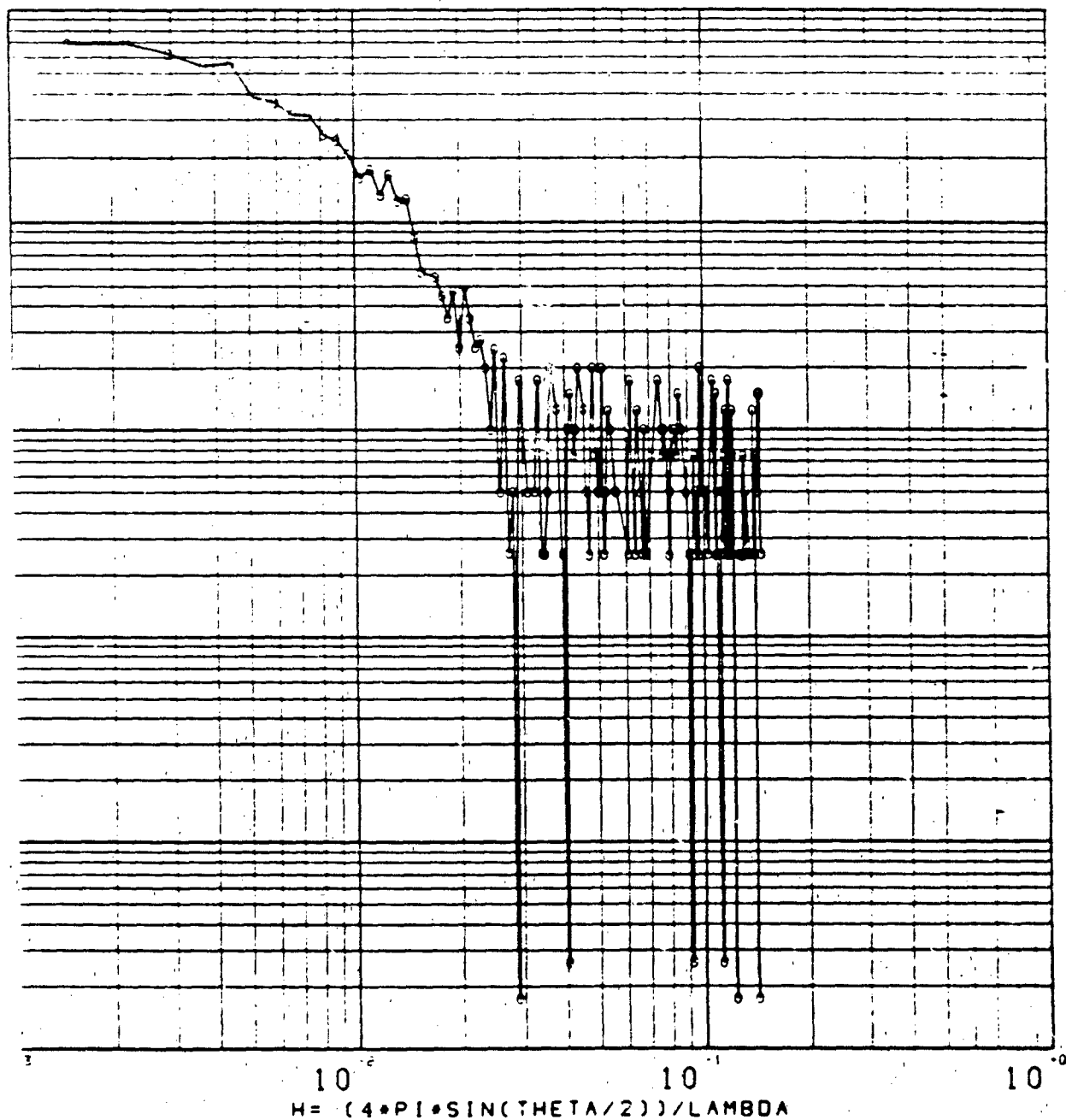
ALL-10

LMSC-F035789

SAXS (ABOVE CENTER) FOR RUN

BLXRN17-1PRE

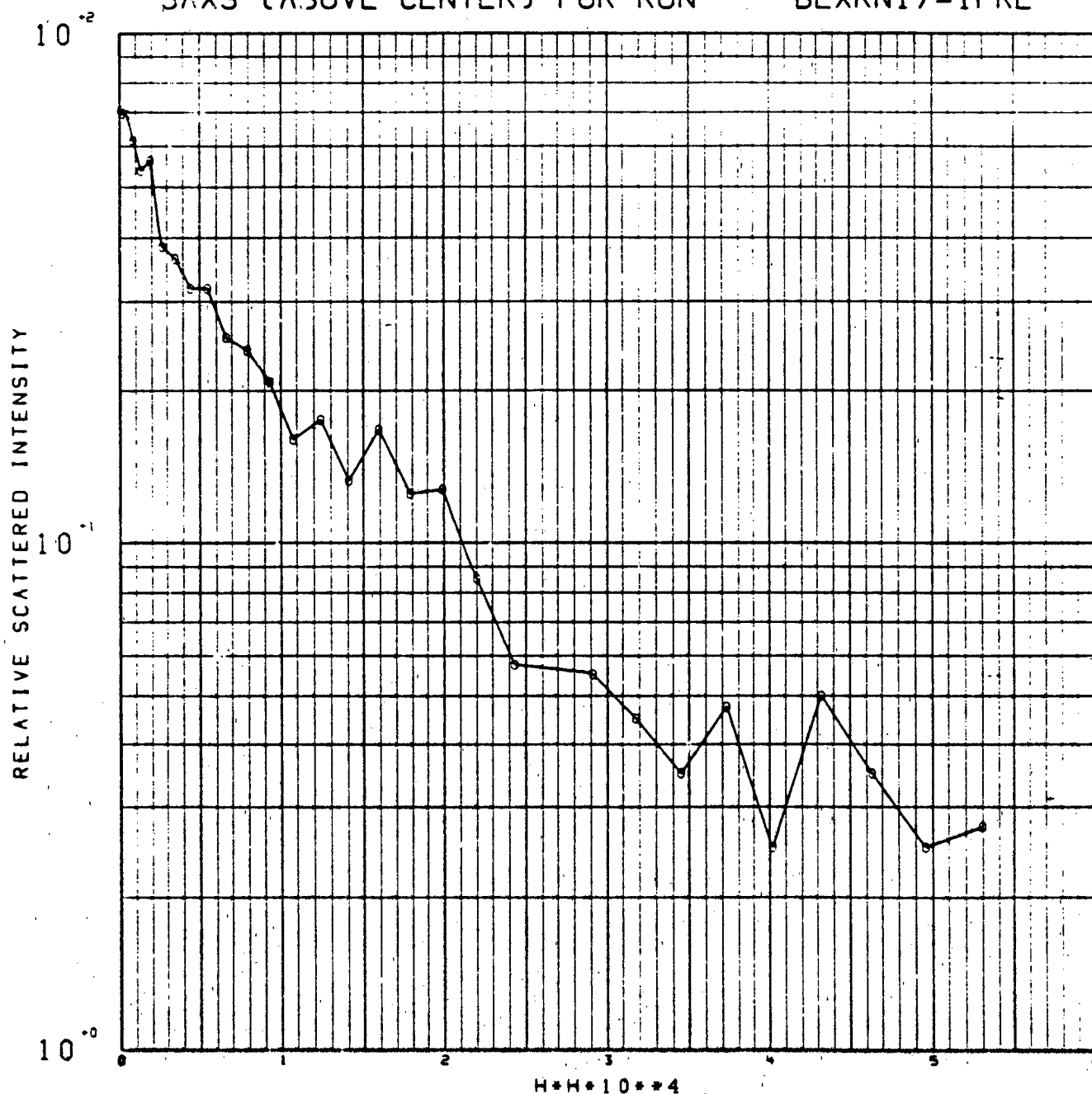
01108/SC4026L
0000 0039



SAXS (ABOVE CENTER) FOR RUN

BLXRN17-1PRE

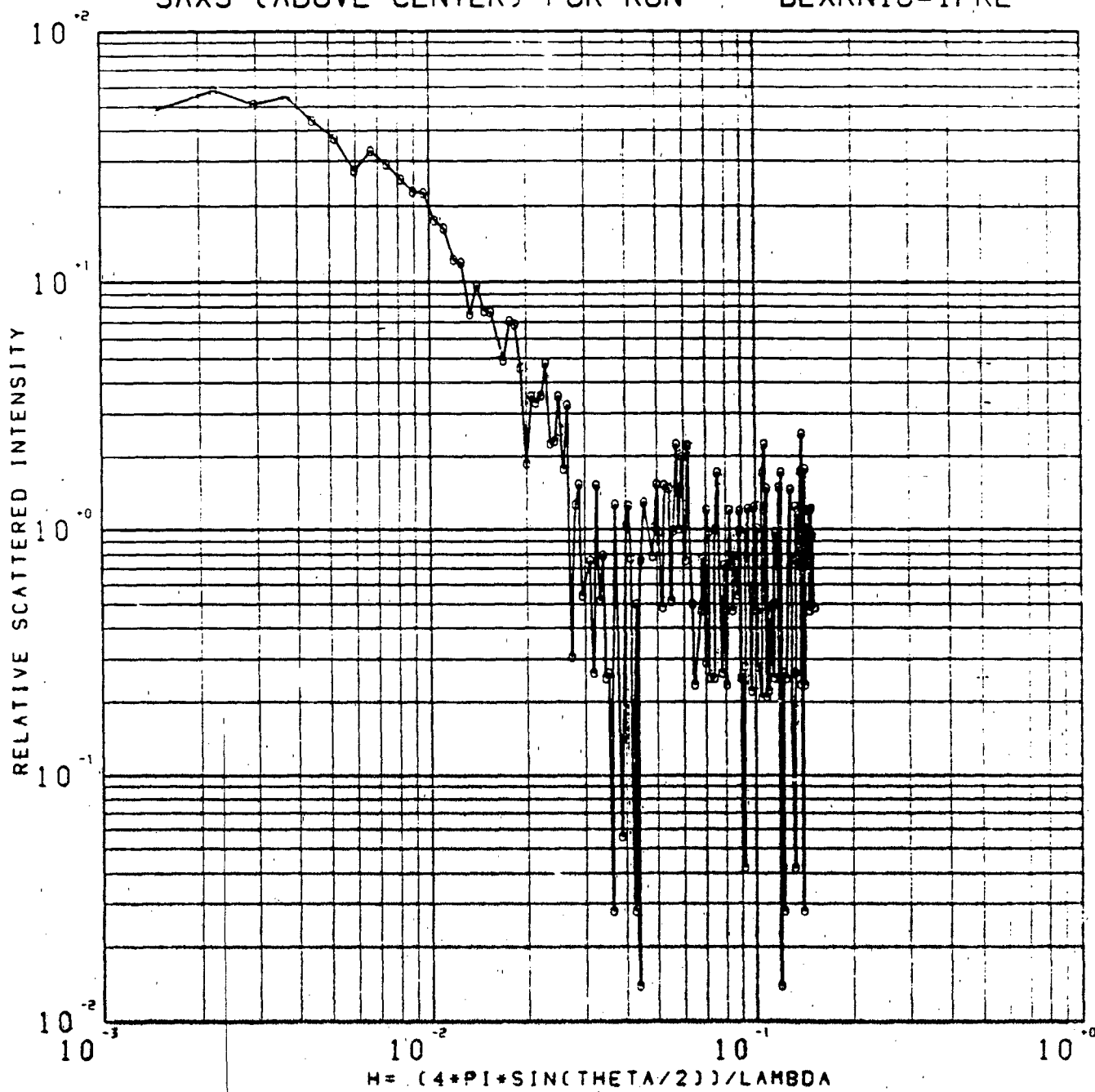
U1108/SC4020
2000 0040



SAXS (ABOVE CENTER) FOR RUN

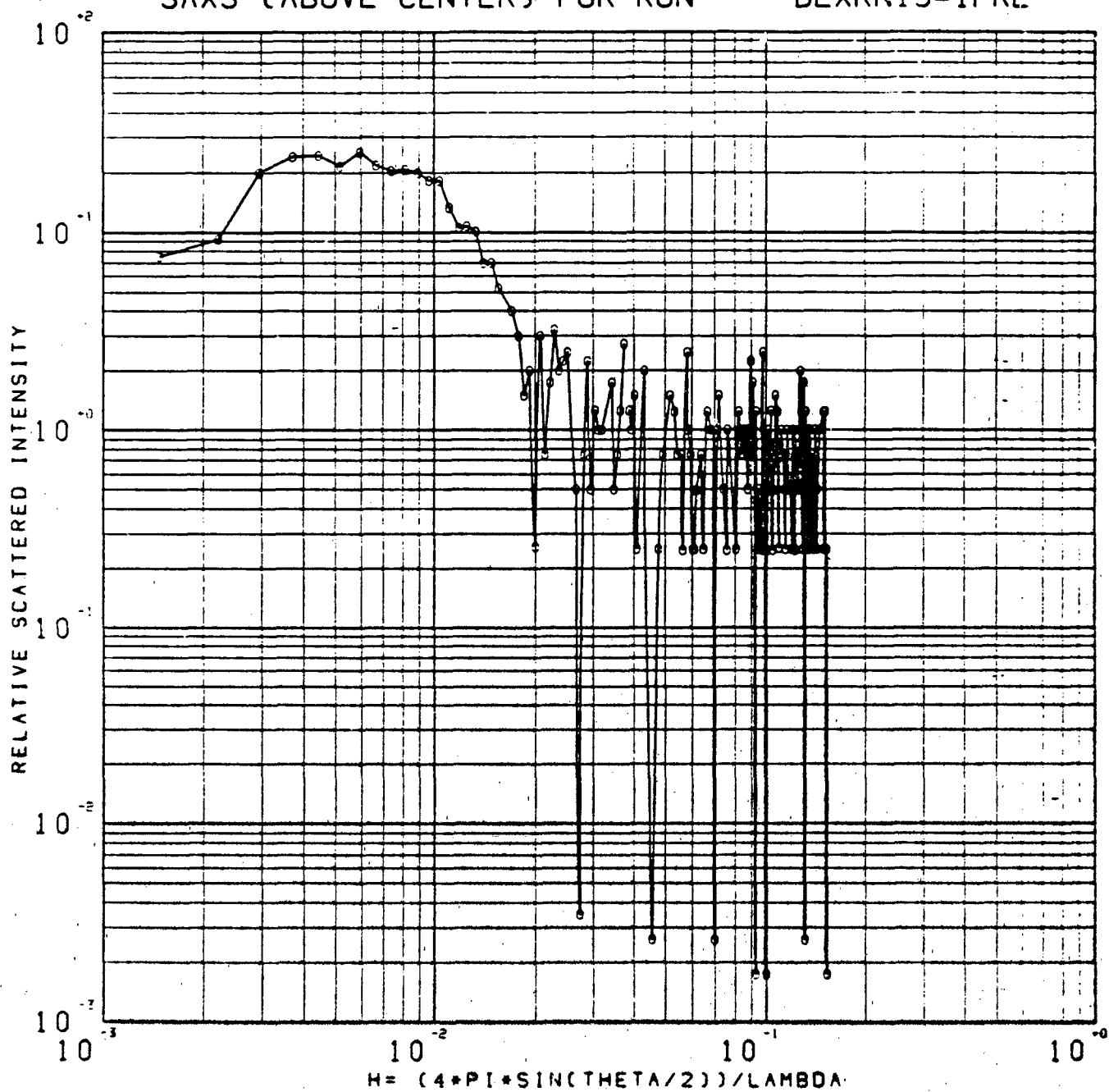
BLXRN18-1PRE

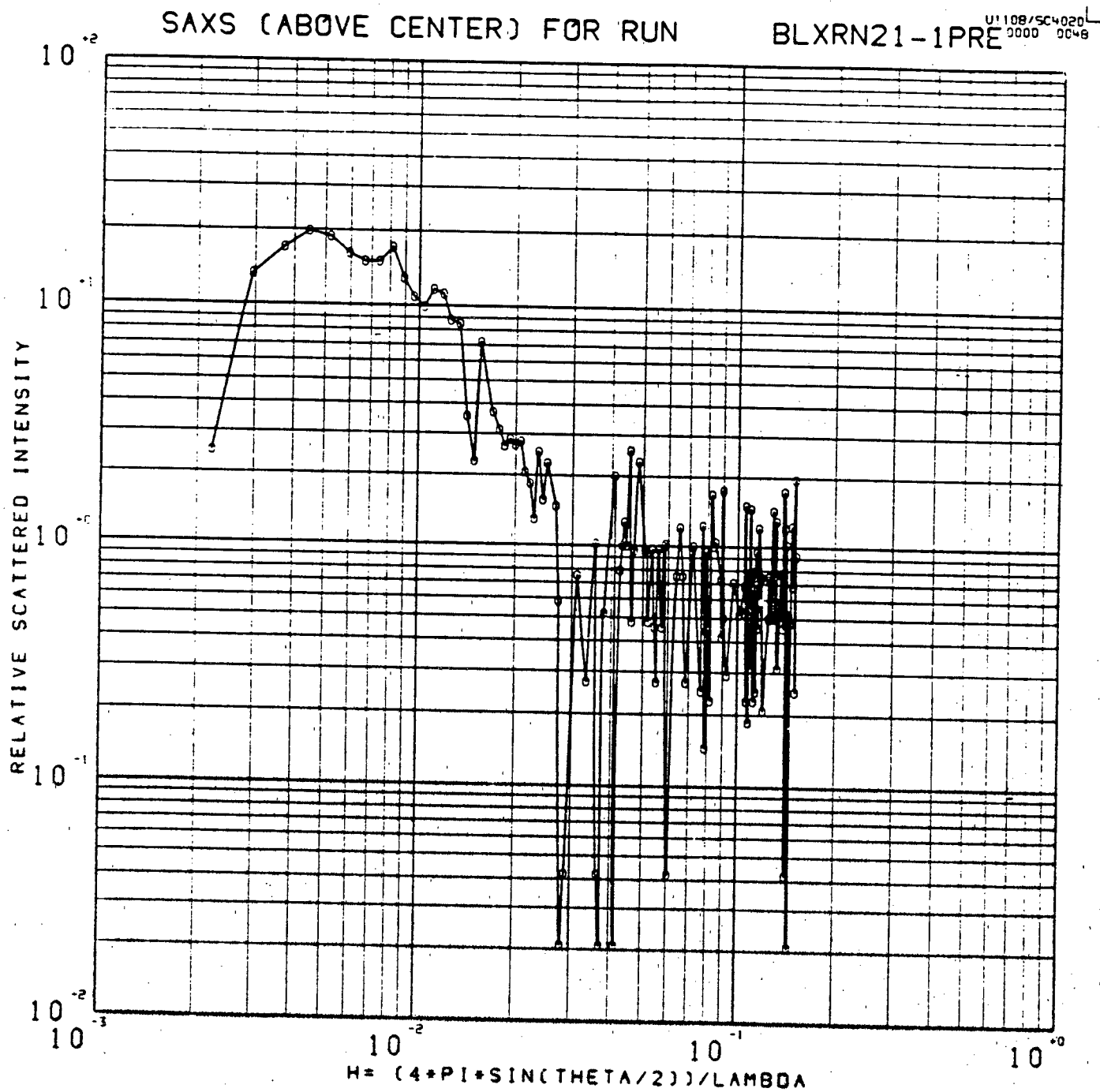
01108/SC4020
0000 0041



SAXS (ABOVE CENTER) FOR RUN

BLXRN19-1PRE 0000 0044





UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS None	
SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION / AVAILABILITY OF REPORT Unlimited	
DECLASSIFICATION / DOWNGRADING SCHEDULE			
PERFORMING ORGANIZATION REPORT NUMBER(S) IC/F035789		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
NAME OF PERFORMING ORGANIZATION Lockheed Missiles & Space Company, Inc.		6b. OFFICE SYMBOL (If applicable)	
ADDRESS (City, State, and ZIP Code) Palo Alto, CA 94304		7a. NAME OF MONITORING ORGANIZATION Office of Naval Research	
ADDRESS (City, State, and ZIP Code) Arlington, VA 22217		7b. ADDRESS (City, State, and ZIP Code) Arlington, VA 22217	
NAME OF FUNDING, SPONSORING ORGANIZATION Office of Naval Research		8b. OFFICE SYMBOL (If applicable) Code 432	
ADDRESS (City, State, and ZIP Code) Arlington, VA 22217		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-83-C-0271	
		10. SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO	PROJECT NO
		TASK NO	WORK UNIT ACCESSION NO.
TITLE (Include Security Classification) Binder-Filler Interaction in Energetic Polymers (Unclassified)			
PERSONAL AUTHOR(S) L. H. Martinson			
TYPE OF REPORT Final Technical	13b. TIME COVERED FROM 5/83 TO 12/84	14. DATE OF REPORT (Year, Month, Day) 1985, 3, 31	15. PAGE COUNT 94
SUPPLEMENTARY NOTATION			
COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	Energetic Polymers, ultrasonics, small angle x-ray scattering, dewetting	
ABSTRACT (Continue on reverse if necessary and identify by block number) This report is an account of ultrasonic and small angle x-ray scattering experiments in deformed energetic polymers. Vacuole number densities and sizes caused by deformation are estimated from ultrasonic and x-ray measurements. The influence of binders and plasticizers on vacuole formation are studied.			
DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
NAME OF RESPONSIBLE INDIVIDUAL L. H. Martinson		22b. TELEPHONE (Include Area Code) 415-349-5672	22c. OFFICE SYMBOL

FORM 1473, 84 MAR

83 APR edition may be used until exhausted.

All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED (U)

END

FILMED

8-85

DTIC