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TECHNICAL REPORT SL-86-41

MECHANICAL PROPERTIES OF ANTELOPE LAKE SOILS

by

Stephen A. Akers

Structures Laboratory

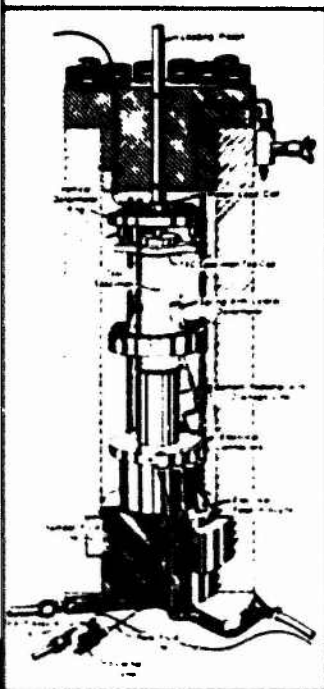
DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631



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Final Report

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<p>This report documents a mechanical property investigation conducted for Sandia National Laboratories, Livermore (SNLL) on undisturbed soil specimens obtained from a site at Antelope Lake within Tonopah Test Range near Tonopah, Nevada. The purposes of the investigation were to experimentally determine the mechanical responses of the Antelope Lake specimens and to provide representative material properties to SNLL. The completed laboratory test program obtained mechanical property data from 6 static unconfined compression tests and 12 static triaxial compression tests. In addition, composition property data in the form of water content, density, void ratio, etc., were obtained for the materials investigated.</p> <p>The failure strengths of materials at the Antelope Lake site were found to be dependent upon the initial degree of saturation of the test specimens and the magnitude of the</p> <p style="text-align: right;">(Continued) ←</p>					
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19. ABSTRACT (Continued).

→ applied mean normal stress. Clays from Layers 1 and 3 became fully saturated at a mean normal stress of about 14 MPa and achieved a Mises limiting strength of 5.3 MPa. The silts and silty sands in Layer 2 became fully saturated at about 3.4 MPa mean normal stress and achieved a 2.5 MPa Mises limit. *Keywords: Soil mechanics; soil tests.*

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PREFACE

The Geomechanics Division (GD), Structures Laboratory (SL), of the US Army Engineer Waterways Experiment Station (WES) was funded by Sandia National Laboratories Livermore (SNLL) to conduct a series of static mechanical property tests on undisturbed soil specimens obtained from a site at Antelope Lake, Tonapah Test Range, Tonapah, Nevada. This research work was conducted during the period September 1985 through December 1985 and was funded under SNLL Purchase Order No. 92-0766, dated 23 January 1985.

The laboratory testing was performed by Messrs. James L. McCaskill and Richard G. Cooper, GD. Instrumentation support was provided by Messrs. A. Leroy Peeples and John K. Rhodes, Instrumentation Services Division. This report was prepared by Mr. Stephen A. Akers, GD, under the general direction of Dr. J. G. Jackson, Jr., Chief, GD, and Mr. J. Q. Ehrgott, Chief, Operations Group, GD.

COL Allen F. Grum, USA, was the Director of WES during this investigation; COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is the WES Technical Director. Mr. Bryant Mather is Chief, SL.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
degrees (angle)	0.01745329	radians
feet	0.3048	meters
gallons (US liquid)	3.785412	cubic decimeters (liters)
inches	25.4	millimeters
kips (force)	4.448222	kilonewtons
kips (force) per square inch	6.894757	megapascals
megatons (nuclear equivalent of TNT)	4.184	petajoules
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter

MECHANICAL PROPERTIES OF ANTELOPE LAKE SOILS

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

At the request of Sandia National Laboratories Livermore (SNLL), the Geomechanics Division (GD) of the US Army Engineer Waterways Experiment Station (WES) performed a mechanical property investigation on undisturbed soil samples obtained from a site at Antelope Lake, which is within the Tonapah Test Range near Tonapah, Nevada. The purpose of the investigation was to experimentally determine the mechanical responses (strength and compressibility) of these soils. These data would be used by WES to deduce representative material properties that, in turn, would be used by SNLL in assessments of Antelope Lake as a suitable site for proposed Davis gun tests.

A laboratory test program was designed to obtain the data that were necessary to develop representative material properties. The completed test matrix consisted of 6 static unconfined compression (UC) tests and 12 static triaxial compression (TX) tests.

1.2 PURPOSE AND SCOPE

The purpose of this report is to document the test results obtained and the material property recommendations developed for the Antelope Lake soils. Soil descriptions and laboratory test procedures used in determining the soil's mechanical properties are presented in Chapter 2. Chapter 3 presents comparative plots of the data and results from the data analyses. This information is summarized in Chapter 4.



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CHAPTER 2

LABORATORY TESTS

2.1 COMPLETED TEST MATRIX

Six UC tests and 12 TX tests were conducted in this test program in order to discern the shear related strengths and stress-strain responses of Antelope Lake soils. Isotropic compression (IC) tests were conducted for the purpose of applying a designated static confining pressure to each TX test specimen prior to shear loading. Four levels of confining pressure (between about 0 and 48 MPa) were applied to the specimens, and the specimens were tested assuming three in situ layers (as described in Section 2.2). All of the tests were conducted in the SECO/DHT, a high-pressure static and dynamic triaxial test device (Reference 1).

All of the laboratory tests were numbered sequentially. The test number and the prefix "SNL" were used as test and specimen identifiers, e.g., SNL-10 was the tenth test conducted in the test program.

2.2 CLASSIFICATION AND COMPOSITION PROPERTIES

The laboratory test program was designed under the assumption that the Antelope Lake site could be characterized by three different material property layers to a depth of 15.2 meters (50 feet). The assumed first layer extended from 0 to 4.6 meters (0 to 15 feet), the assumed second layer extended from 4.6 to 9.2 meters (15 to 30 feet), and the assumed third layer extended from 12.2 to 15.2 meters (40 to 50 feet). No core was obtained between 9.2 and 12.2 meters (30 to 40 feet). The available specimens were divided into three groups based upon this initial layering scheme, and the specimens in each group were tested at four different levels of confining pressure. Upon completion of the material property tests, some of the posttest specimens and a few untested sections of core were selected at depth intervals of approximately 1.5 meters (5 feet) and sent to the WES Geotechnical Laboratory so that composition and physical property tests could be performed. In order to ensure that sufficient material would be available for the shear tests, these composition property samples were selected after the completion of the mechanical property tests.

Eight composition property samples were obtained from the available core. These samples were tested to obtain information such as particle size

gradation, specific gravity of solids, and Atterberg limits (presented in Plates 1-8). In addition, initial wet density and posttest water content values were determined from each test specimen. Knowing these values and a value for the specific gravity of solids, composition properties such as volume of voids, degree of saturation, etc., were calculated. These calculated values are listed in Table 2.1 along with the test number, the corresponding data plate number, and the type of test conducted. The data are grouped by the layers discussed later in Section 3.1.

These composition data simplified the process of understanding the measured specimen behavior. For example, specimens that had a high initial degree of saturation were expected to reach lockup (achieve full saturation) during the application of significant levels of confining pressure. Knowing that the specimens were fully saturated made it possible to explain the low shear strengths measured at the higher confining pressures.

2.3 SPECIMEN PREPARATION

The samples sent to WES were of nominal 7.2-cm (2.85-inch) diameter and of random lengths varying from 0.30 to 0.43 meters (1 to 1.4 feet). In the field, each sample was covered with aluminum foil, placed in a cardboard tube, and sealed with wax. Each sample tube was identified by boring number and depth. At WES, specimens were cut from these cores using a diamond saw with a special jig to secure the samples during the cutting operation. After the cutting process, the specimens were frozen for a minimum period of 24 hours, after which, the cardboard, wax, and foil were removed, and the specimen was prepared for testing. By freezing the specimens, the potential for disturbance of the specimens during the setup process was minimized. After specimen height, diameter, and weight measurements were recorded, two rubber membranes were placed on the specimen. The outer membrane was covered with a synthetic rubber; this coating protected the membrane from the deteriorating effects of the hydraulic oil used to laterally confine/pressurize the test specimens. All tests were conducted in an undrained manner, i.e., no pore fluids (air or water) were allowed to drain from the membrane-enclosed specimen. A posttest water content value was obtained for each specimen with the exception of those contaminated by oil due to membrane leakage during the test.

Sections of core that were too short to test were measured and weighed in order to calculate a value of wet density. A water content was also obtained

for these pieces, and several of these sections were used for classification purposes.

2.4 IC TESTS

The IC tests were conducted as the confining pressure application phase of the TX tests. The data obtained during IC loading provide a measure of the bulk compressibility of the material under a cylindrical state of stress. During an IC test, a uniform fluid loading was applied to the specimen, and the resulting deformations were measured at the specimen's top and midheight. Four channels of data were recorded, i.e., two axial displacements, one radial displacement, and confining pressure. From these measurements, one can calculate axial strain (typically taken as the average of the two vertical deformeters divided by the original height), radial strain, mean normal stress, and volumetric strain. The effects of membrane deformations were assumed insignificant in the calculation of radial strain.

Volumetric strains were calculated from deformer measurements by assuming both a uniform-cylinder and a truncated-cone deformed specimen shape (Reference 2). The uniform-cylinder approximation assumes that the specimen deforms as a right circular cylinder. The truncated-cone approximation assumes that the current diameter is measured at the specimen's midheight and that the diameter changes linearly to the original pretest diameter at the ends of the specimen. For most soils, the uniform-shape assumption approximates the volumetric strains more accurately during IC loading and at small axial strains during shear. The truncated-cone assumption approximates the volumetric strains more accurately during shear at larger axial strains, e.g., >7-8 percent. The "true" volumetric strains are typically somewhere between these two calculated values.

2.5 UC AND TX TESTS

Reference 3 describes typical test procedures used in conducting laboratory TX tests. After the confining pressure was applied to the specimen, the axial load was applied by a piston until specimen failure was achieved. Failure was defined as the value of peak principal stress difference or the value at 15-percent axial strain during shear, whichever occurred first (Reference 3). Six channels of data were recorded during the TX tests, i.e., the same four channels monitored during the IC loading plus the output from one load cell and an external linear potentiometer.

A UC test is simply a TX test conducted at zero confining pressure. However, in this test program, a 0.14-MPa confining pressure was imposed upon the test specimens in order to ensure that the rubber membranes remained in contact with the specimen's sides. Thus, the lateral deformer would measure specimen deformations and not bulges in the rubber membranes.

The results of each successful shear test are presented on Plates 9-25. The stress and strain data were plotted on four-corner plots, which present the data as (a) principal stress difference versus mean normal stress, (b) principal stress difference versus both principal strain difference and axial strain, (c) volumetric strain versus principal strain difference, and (d) volumetric strain versus mean normal stress. All stresses and strains were plotted from a pretest zero stress-zero strain state; thus, all plots include the stresses and strains that resulted from application of confining pressure or IC loading.

The six UC tests are presented on Plates 9-14. Despite the variations in composition properties, the failure strengths of all the UC tests were very similar. In most of these tests, a peak or constant value of principal stress difference was obtained prior to achieving 15 percent axial strain. Note in these data plates the variation between the cone and uniform volumetric strain calculations during shear loading. These differences indicate that the specimens were developing large radial strains after reaching 4 to 5 percent axial strain during shear.

The TX tests were conducted at three different levels of confining pressure, i.e., 6.9, 27.6, and 48.3 MPa. At least one specimen from each of the three designated layers was tested at each confining pressure. Three additional TX tests were conducted because of questionable or inconsistent data. At the end of the test program, 12 TX tests were completed. Their data are presented on Plates 15-25 and are grouped by soil layer starting with Layer 1.

Specific problems or notes about particular tests are described here. In three tests (SNL01, 02, and 10), the loading piston came into contact with the specimen between two scans of the data acquisition system. Therefore, the initial loading was estimated and is drawn as dashed lines on the stress-strain curves in Plates 15, 17, and 22, respectively. Instrumentation problems that developed during test SNL07 precluded the collection of meaningful data; therefore, no test results are presented. The remaining data are

considered to be representative of the in situ material's behavior under triaxial loading conditions.

Due to the large deformations encountered in some tests, the isotropic compression loading response could not be measured over the entire IC stress range. For example, volumetric strain data could only be obtained while the vertical deformeters were in their calibrated range. The final axial and radial strains during isotropic compression loading were obtained for each TX test when the loading piston was placed in contact with the specimen. The phase of each test during which the vertical deformeters were out of range has been identified on each data plate.

Table 2.1. Composition properties of Antelope Lake soil specimens.

Test No.	Plate No.	Type of Test	Avg. Depth m	Depth, ft		Water Content w, %	Wet Density Y, g/cc	Dry Density Y _d , g/cc	Specific Gravity of Solids	Void Ratio	Degree of Saturation S, %	Volume of	
				Top	Bottom							Air V _a , %	Solids V _s , %
- LAYER 1 -													
SML01	15	TX	0.59	1.7	2.2	--	1.578	--	2.70	--	--	--	--
SML02	17	TX	0.74	2.2	2.7	--	1.638	--	2.70	--	--	--	--
SML03	16	TX	0.97	2.9	3.4	24.0	1.777	1.433	2.70	0.884	73.3	12.5	53.1
SML04	18	TX	1.13	3.4	4.0	23.0	1.795	1.460	2.70	0.850	73.0	12.4	54.1
SML14	9	UC	2.72	8.7	9.2	23.3	1.985	1.610	2.70	0.677	92.9	2.9	59.6
SML15	10	UC	2.87	9.2	9.7	23.2	2.005	1.628	2.70	0.659	95.0	2.0	60.3
SML16	19	TX	3.58	11.5	12.0	18.4	2.034	1.719	2.70	0.571	86.8	4.8	63.7
SML17	11	UC	5.36	17.3	17.8	23.4	1.974	1.600	2.70	0.687	91.8	3.3	59.3
SML18	12	UC	5.51	17.8	18.3	22.9	1.944	1.582	2.70	0.707	87.4	5.2	58.6
- LAYER 2 -													
SML10	22	TX	6.75	21.9	22.4	23.8	1.879	1.518	2.70	0.778	82.4	7.7	56.2
SML11	20	TX	6.91	22.4	22.9	22.4	1.895	1.549	2.70	0.743	81.2	8.0	57.4
SML09	21	TX	7.67	24.9	25.4	23.6	1.754	1.419	2.70	0.902	70.6	14.0	52.6
- LAYER 3 -													
SML05	23	TX	12.73	41.5	42.0	25.7	1.916	1.524	2.67	0.752	91.3	3.7	57.1
SML06	24	TX	13.04	42.5	43.0	--	1.978	--	2.67	--	--	--	--
SML07	--	TX	13.46	43.9	44.4	27.2	1.900	1.494	2.67	0.787	92.1	3.5	56.0
SML12	13	UC	13.61	44.4	44.9	26.4	1.899	1.502	2.67	0.777	90.7	4.1	56.3
SML13	14	UC	13.90	45.4	45.9	26.2	1.868	1.480	2.67	0.804	87.1	5.8	55.4
SML08	25	TX	14.06	45.9	46.4	--	1.885	--	2.67	--	--	--	--

CHAPTER 3

DATA ANALYSIS

3.1 REVISED SITE PROFILE

Upon completion of the composition and mechanical property tests, the assumed site profile (see Section 2.2) was modified. The site can indeed be characterized by three layers; however, the interface between Layers 1 and 2 should be placed at a depth of approximately 6.4 meters (21 feet) instead of the assumed depth of 4.6 meters (Figure 3.1). The top layer of material at the site is composed predominantly of clays, which were classified as CL by the Unified Soil Classification System (USCS, Reference 4). This layer had in situ water content values of 18 to 24 percent and a value of specific gravity of 2.70. The materials in the top 2 meters of Layer 1 were characterized by lower densities and lower degrees of saturation than the underlying Layer 1 materials. The Layer 1 materials below 2 meters had nominal dry densities of 1.63 g/cm^3 and degrees of saturation of 85 to 95 percent. The materials in Layer 2 contained greater amounts of silt than encountered in Layer 1 (as indicated by the USCS classification of ML) and had lower values of dry density (mean value of 1.50 g/cm^3 versus about 1.60 g/cm^3 for Layer 1). Layer 2 appeared to grade into a silty sand at a depth of approximately 8.5 meters (28 feet) as indicated by the gradation curve of a sample from that depth (see Plate 6). Unfortunately, no samples were recovered between depths of 9.1 and 12.2 meters (30-40 feet); therefore, it is impossible to determine the actual extent of the silty sand layer. It must be assumed that the interface between Layers 2 and 3 occurs within this depth range. The materials in Layer 3 were classified as CL by the USCS. This layer had values of water content of between 24 and 29 percent, had dry density values of about 1.50 g/cm^3 , and had degrees of saturation that ranged from 87 to 92 percent.

3.2 ISOTROPIC COMPRESSION RESPONSE

As mentioned earlier, no IC tests were planned in the original test matrix. The isotropic compression test data obtained during the application of the static confining pressure prior to TX shear were thought to be sufficient to discern the material's IC loading response. Test results illustrating the volumetric response of the materials from each of the three layers are presented in Figures 3.2 to 3.4.

The magnitude of the calculated volumetric strains was a function of the assumed deformational shape of the specimen (see Section 2.4). Figure 3.5 illustrates the differences in the two calculated values of volumetric strain for test number SNL08. Under isotropic compression loading conditions, the uniform-cylinder shape assumption is usually the better method for approximating the volumetric strains; therefore, the recommended IC response was based upon these calculations. Figure 3.6 presents the representative IC response curves for the three layers at the Antelope Lake site.

3.3 TRIAXIAL SHEAR STRENGTH AND STRESS-STRAIN RESPONSE

An analysis of all the TX test data indicates that the peak shear strength of the soils at the Antelope Lake site is dependent upon the magnitude of the applied mean normal stress and the specimen's initial degree of saturation. If the applied mean stress is of sufficient magnitude to close the air voids and thus produce a fully saturated test specimen, then the shear strength will be constant under the same initial conditions at higher pressures. In other words, once the specimens are fully saturated, the application of additional total mean normal stress does not significantly increase the effective confining stress on the material; thus, no increase in failure strength is achieved. A Mises-type failure envelope is appropriate to model this portion of the failure surface for such materials.

In general, the Antelope Lake soils reached a fully saturated state at mean normal stress levels of approximately 14 MPa for Layers 1 and 3 and 3.4 MPa for Layer 2. The three layers at the Antelope Lake site were discerned to have two different failure envelopes (Figure 3.7). The failure envelopes for soils in Layers 1 and 3 were the same. The materials in Layer 2, which contained greater amounts of silt, had a Mises limit (2.5 MPa) that was approximately half that of the materials from Layers 1 and 3 (5.3 MPa).

Two of the specimens tested (SNL01 and 02) were obtained from the top two meters of Layer 1. These specimens did not reach a state of full saturation during the application of confining pressure and had failure strengths that were much greater than the deeper specimens. The materials in this upper section of Layer 1 were not characterized as a separate material property layer.

Figures 3.8 to 3.12 present the stress-strain curves from the shear tests grouped by material property layer. These stress-strain responses exhibited

significant variability; however, this is typical of the response of undisturbed materials from dry lake beds. Because of this variability, the representative stress-strain response curves for the three material property layers (Figures 3.13 and 3.14) do not necessarily match the stress-strain curve of a particular test. Once the material has reached a state of full saturation, the stress-strain response will change little as mean normal stress increases.

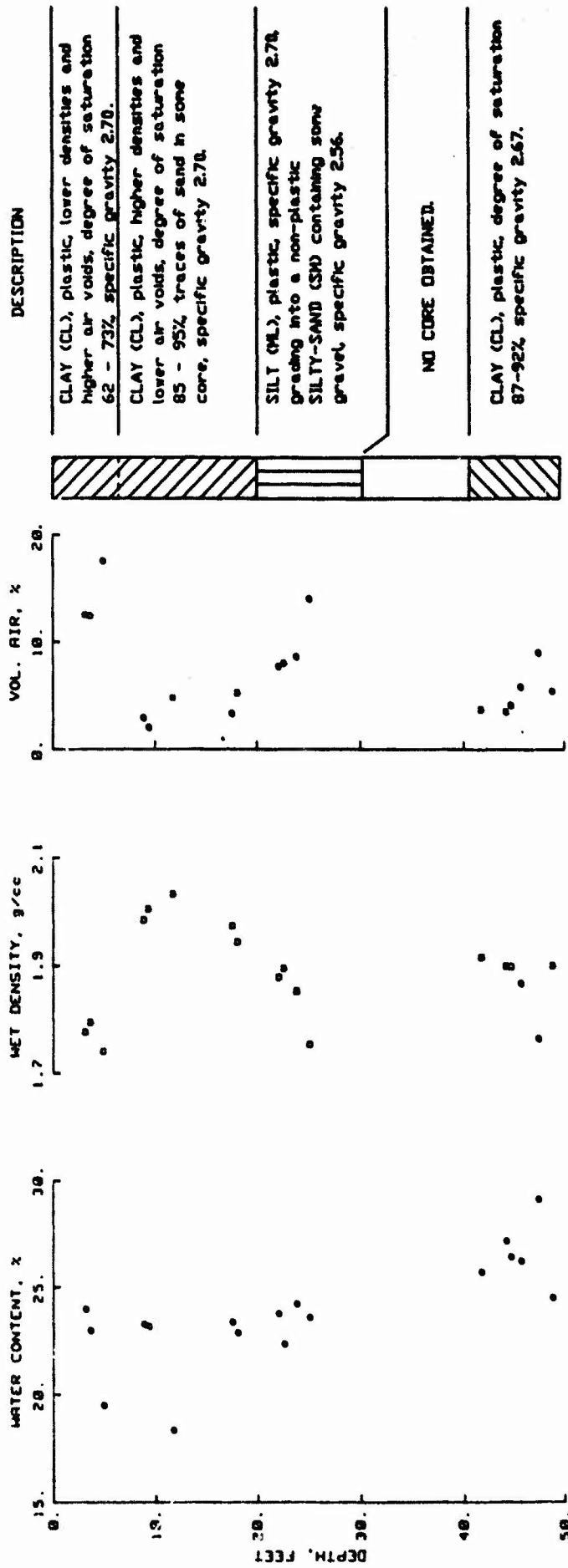


Figure 3.1. Antelope Lake site profile and selected composition property data.

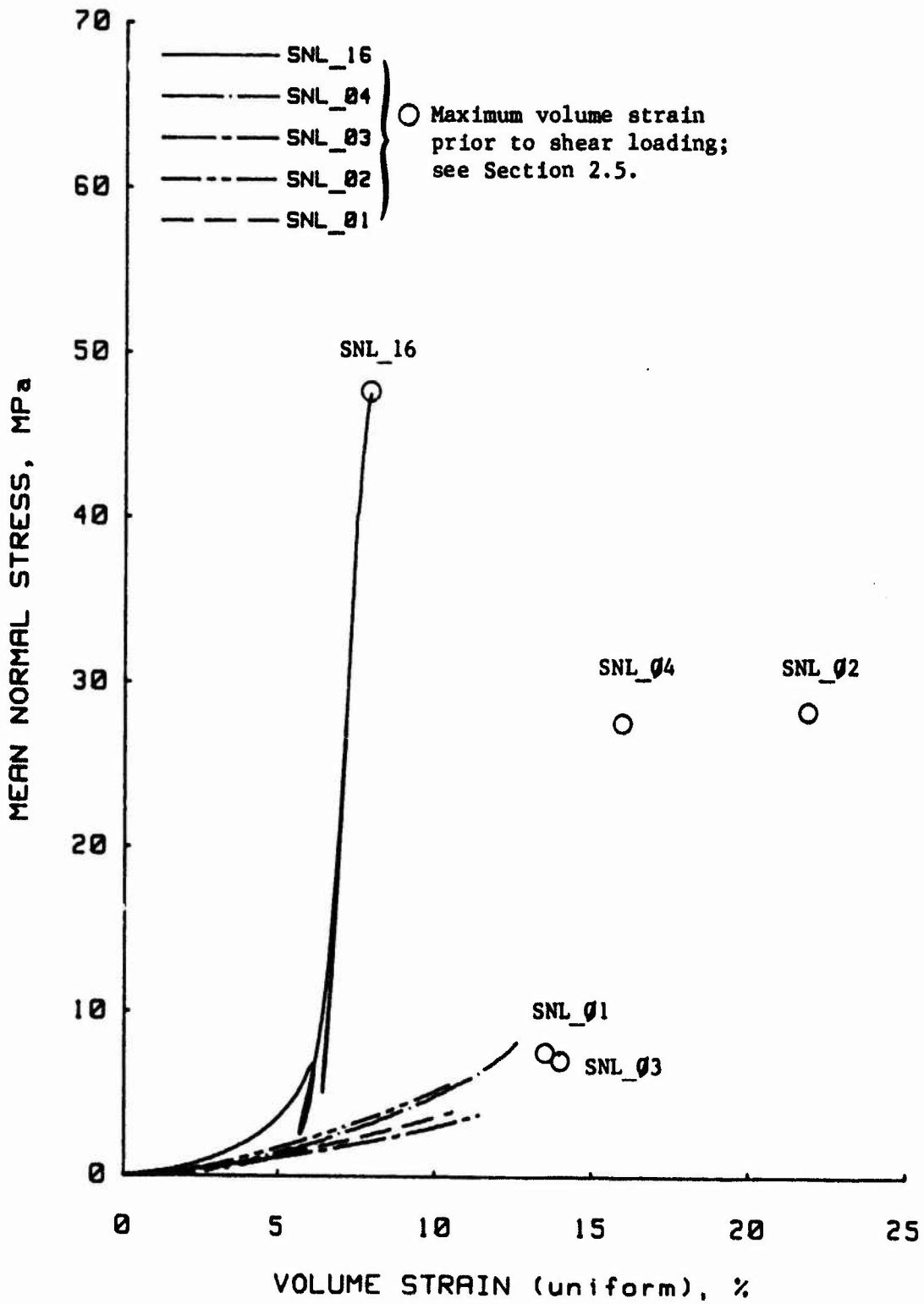


Figure 3.2. IC test results from Layer 1 specimens.

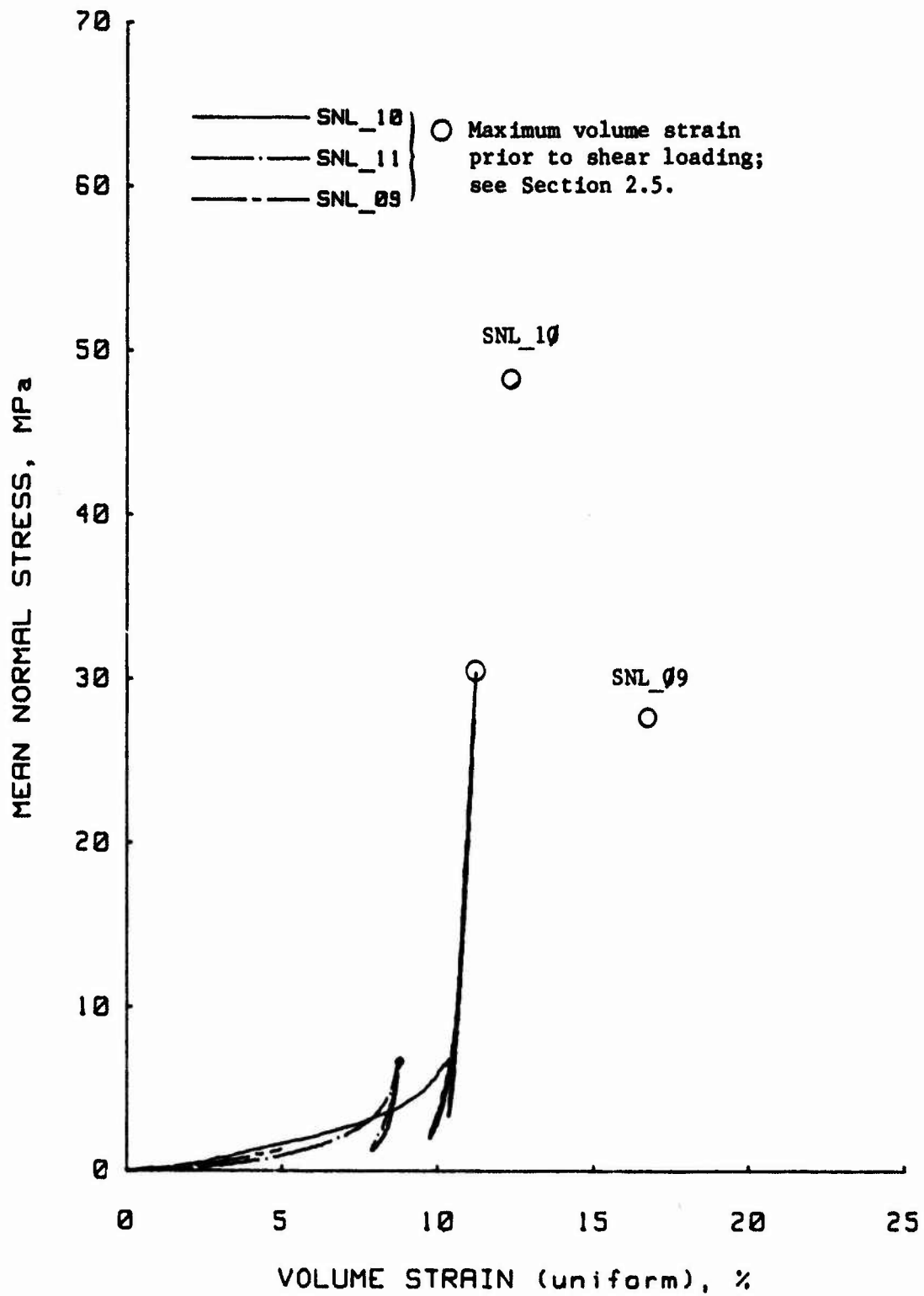


Figure 3.3. IC test results from Layer 2 specimens.

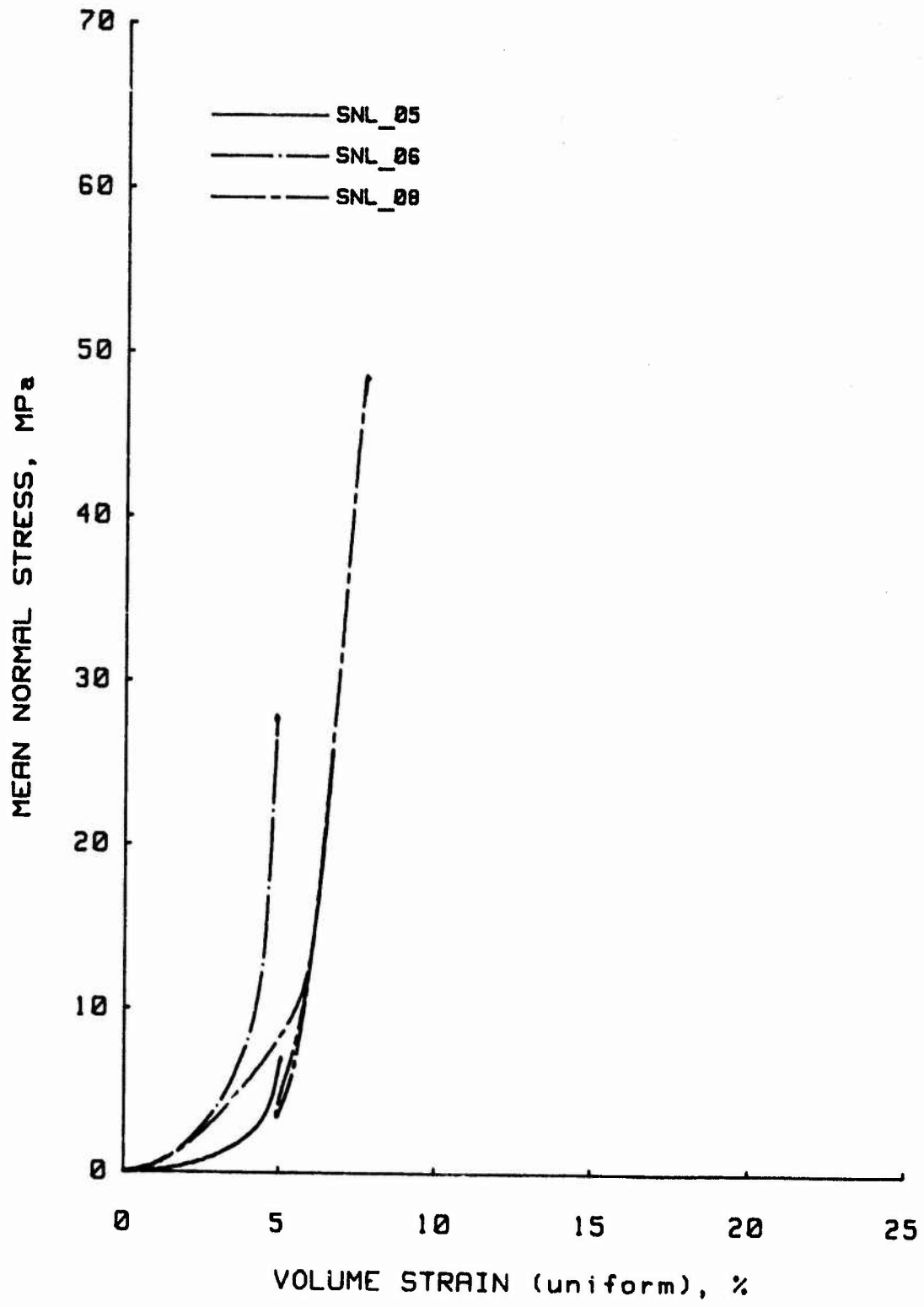


Figure 3.4. IC test results from Layer 3 specimens.

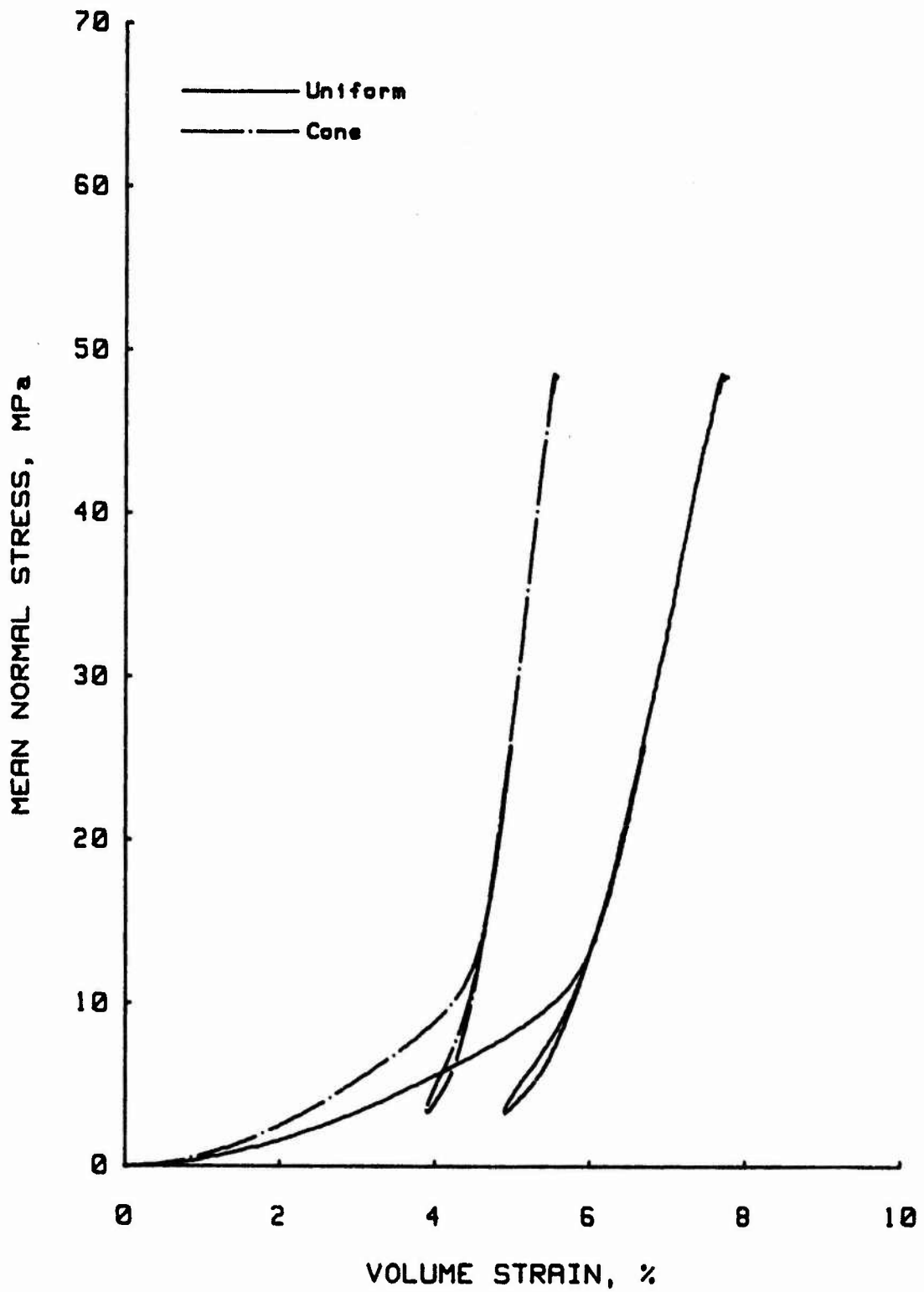


Figure 3.5. IC volumetric strains for Test SNL_08 calculated by the uniform-cylinder and truncated-cone assumed shapes.

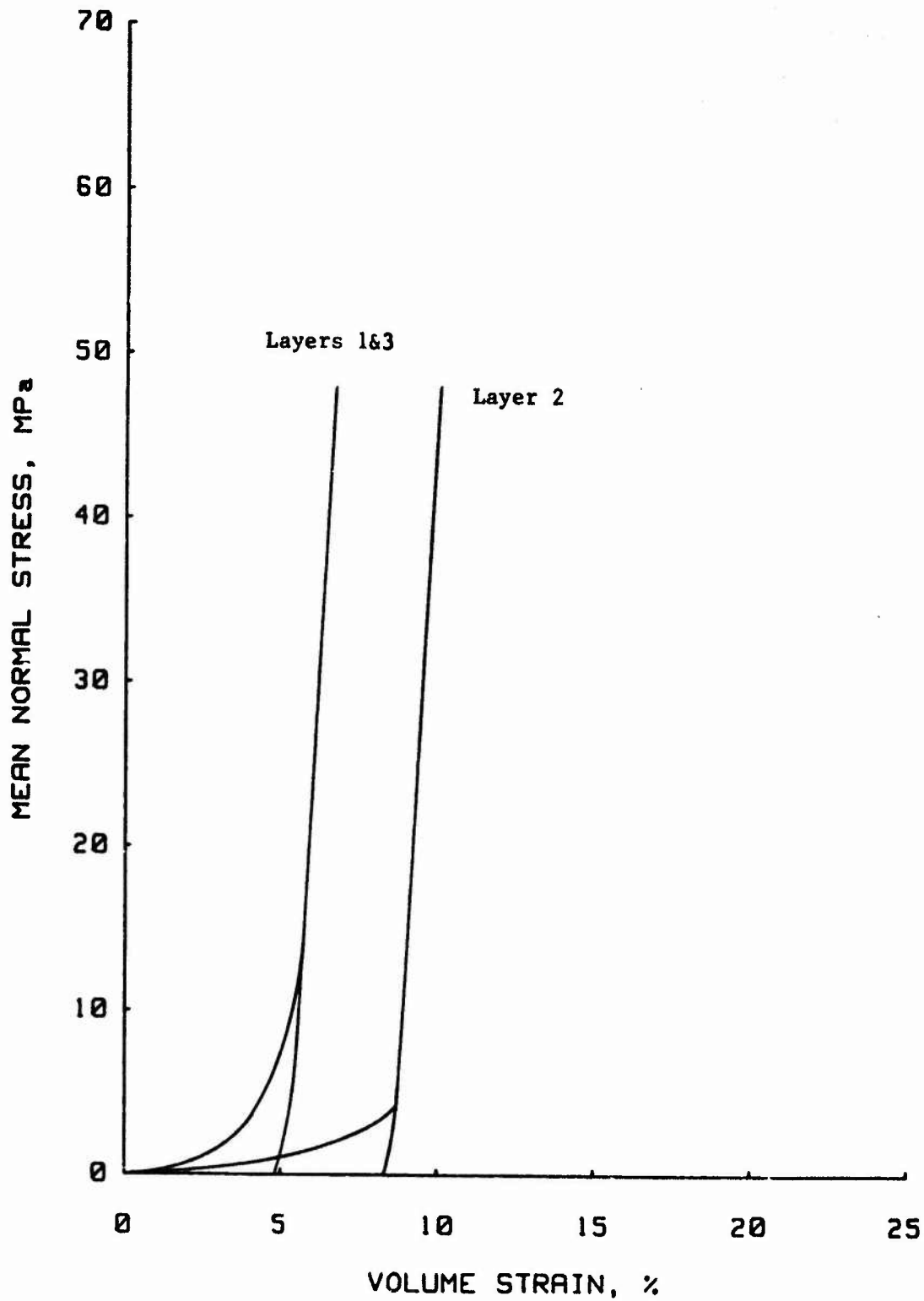
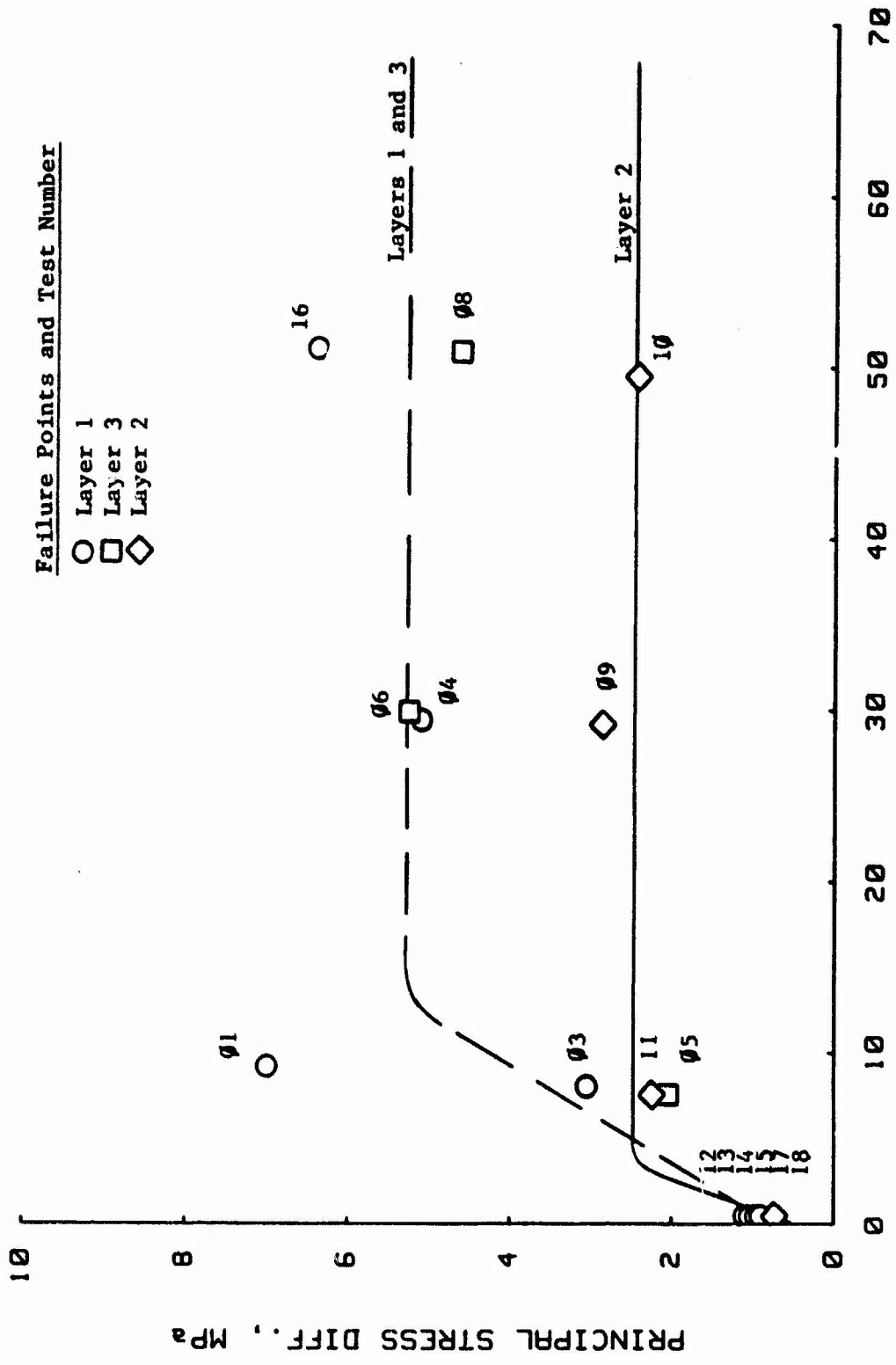


Figure 3.6. Representative IC response for Antelope Lake Layers 1, 2, and 3.



MEAN NORMAL STRESS, MPa

Figure 3.7. Failure envelopes for Antelope Lake soils.

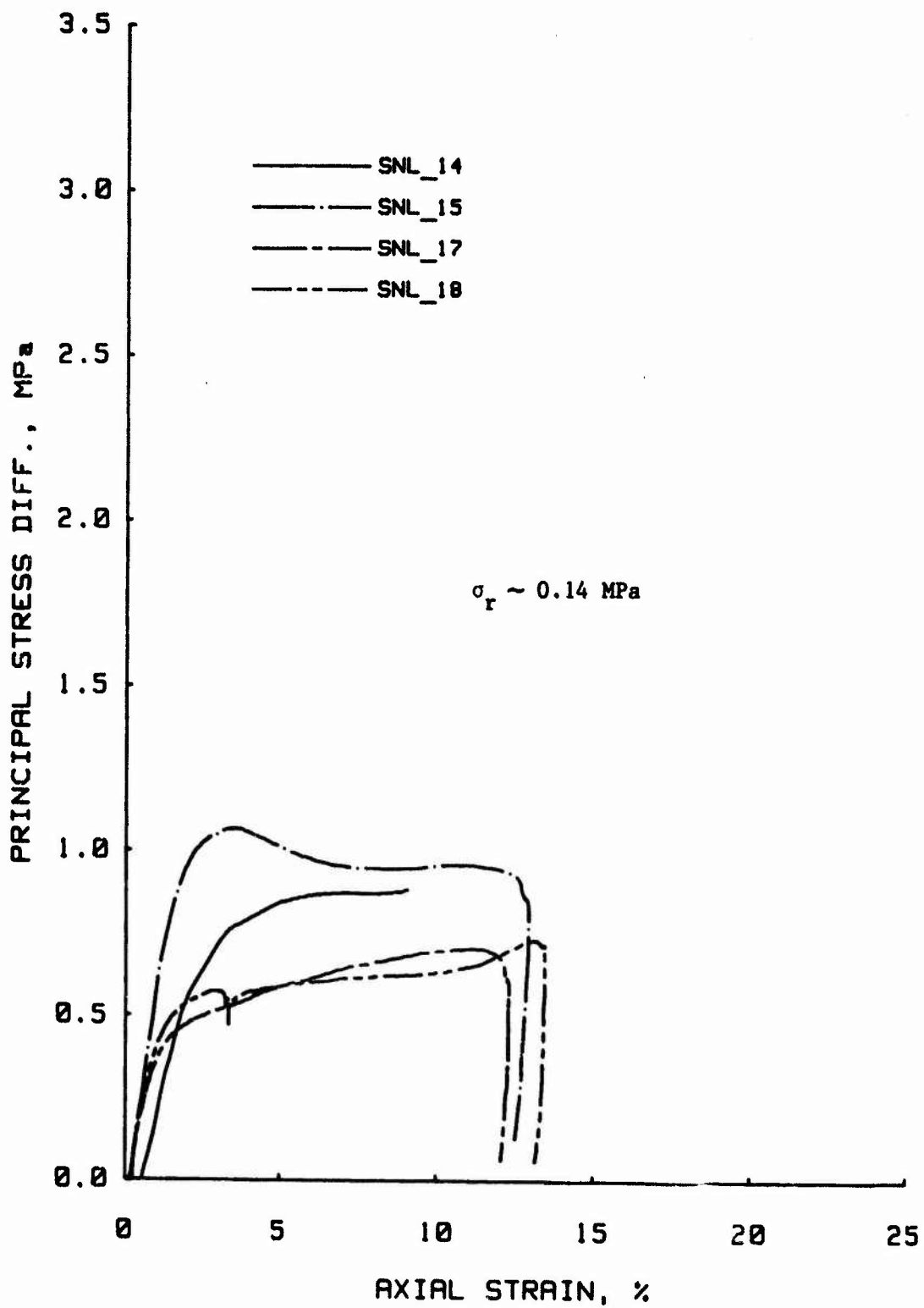


Figure 3.8. UC test results from Layer 1 specimens.

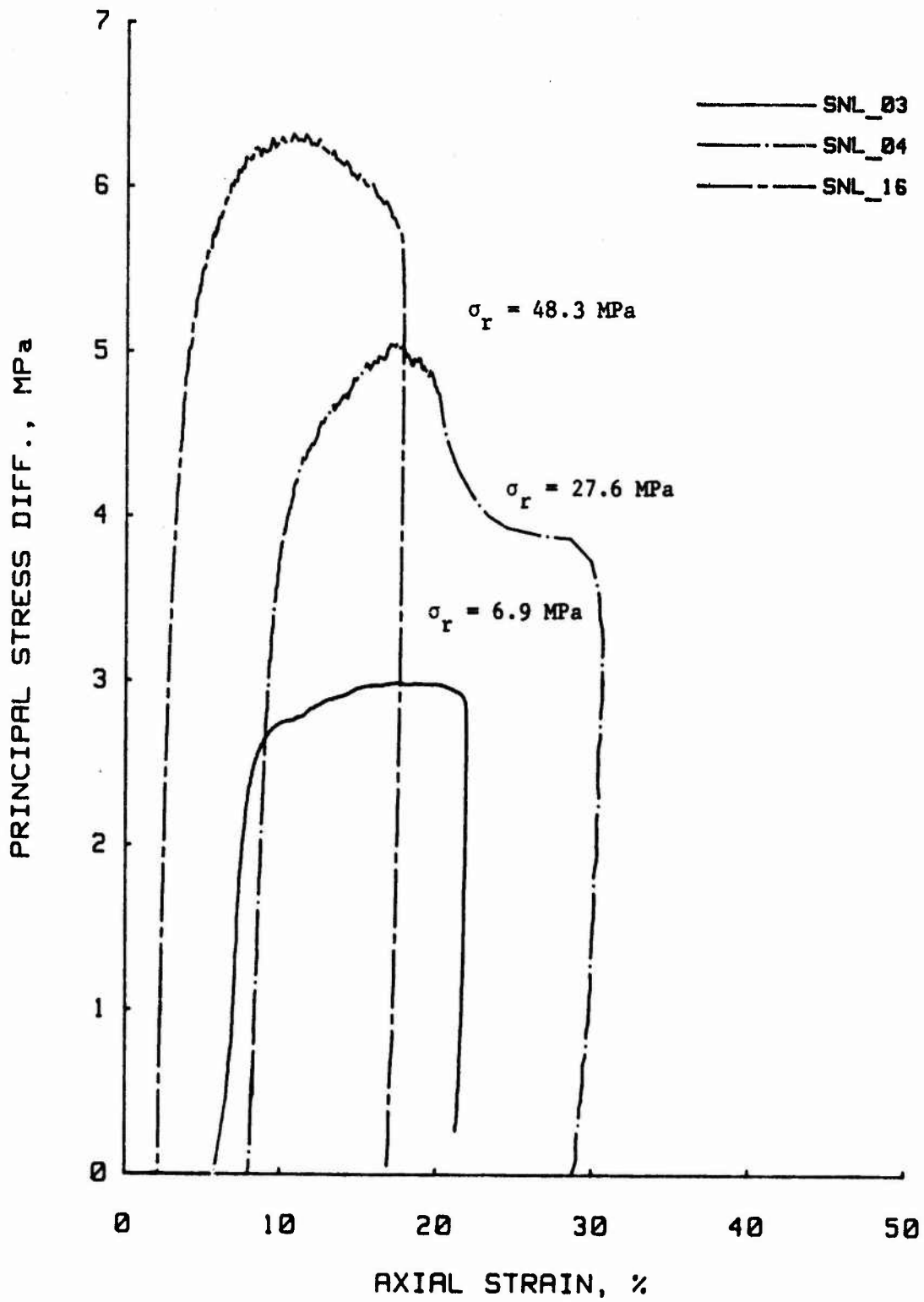


Figure 3.9. TX test results from Layer 1 specimens.

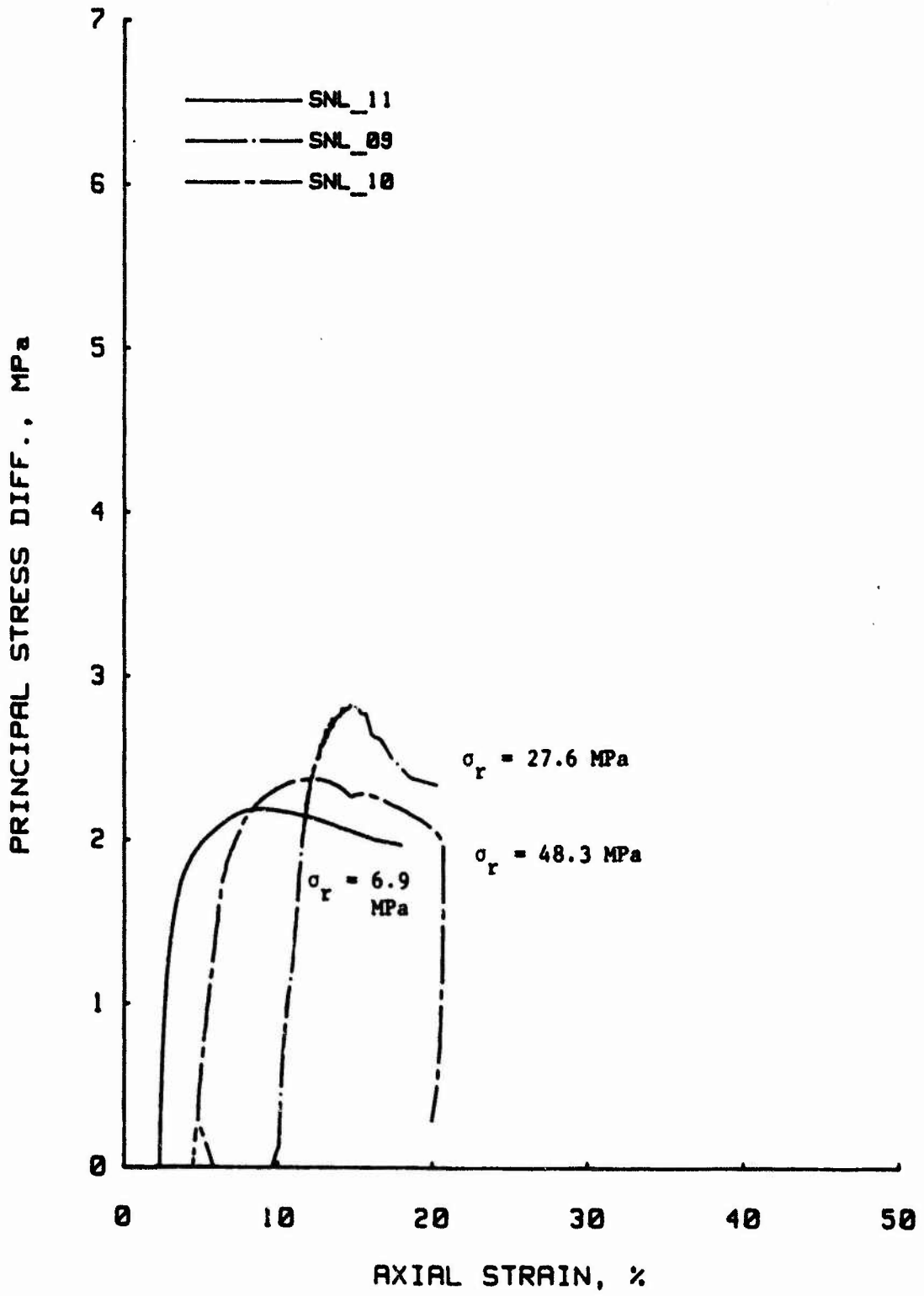


Figure 3.10. TX test results from Layer 2 specimens.

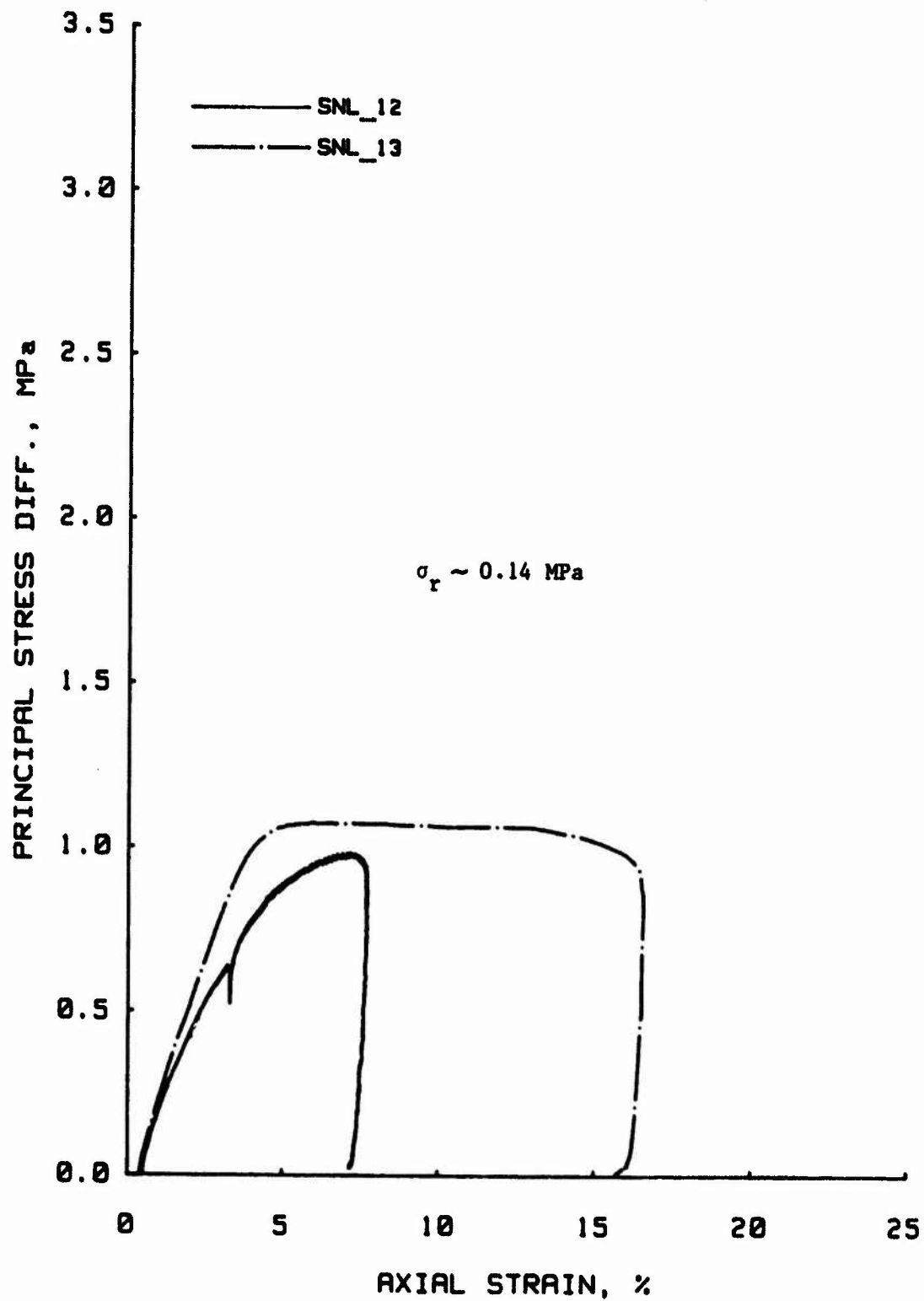


Figure 3.11. UC test results from Layer 3 specimens.

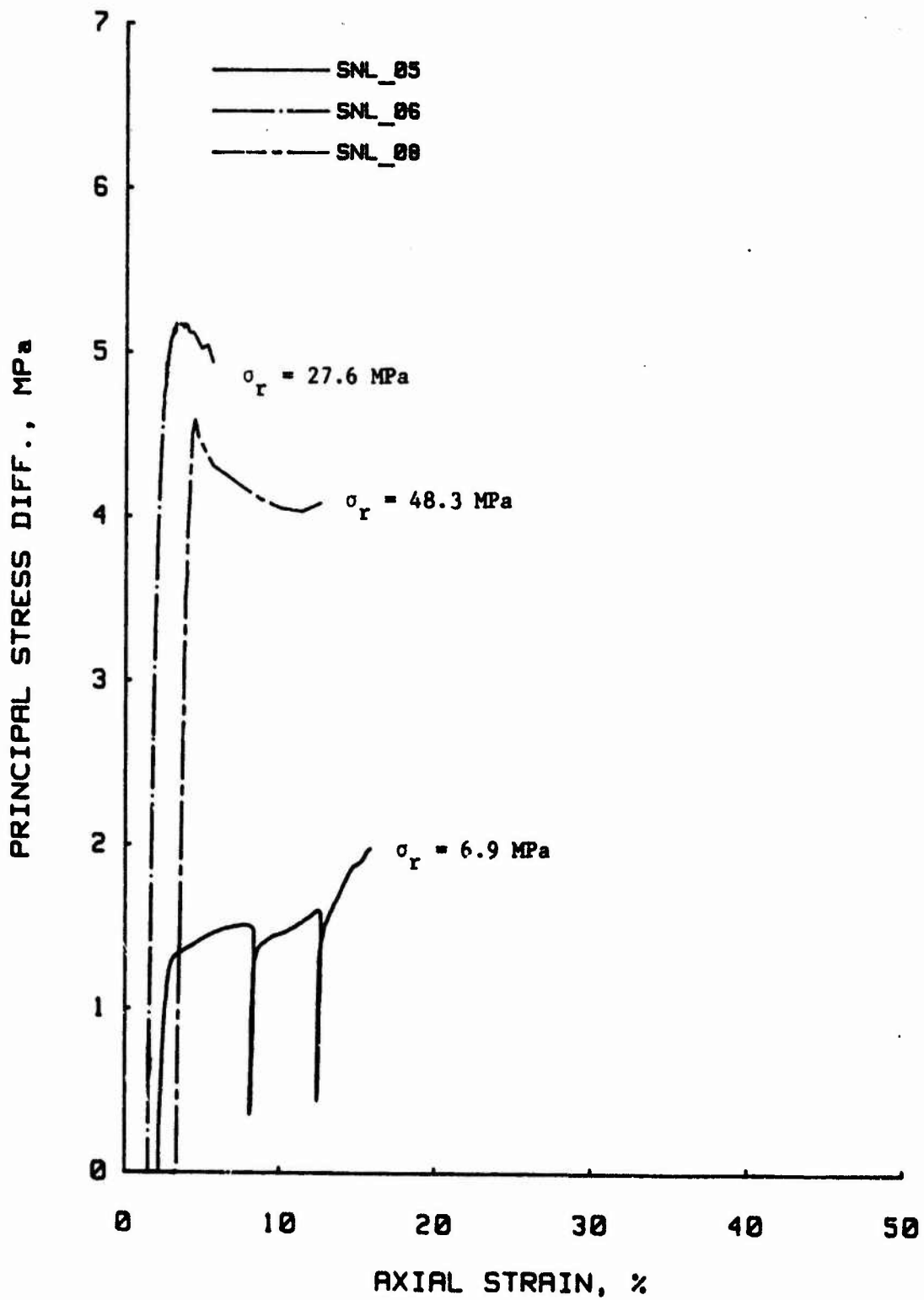


Figure 3.12. TX test results from Layer 3 specimens.

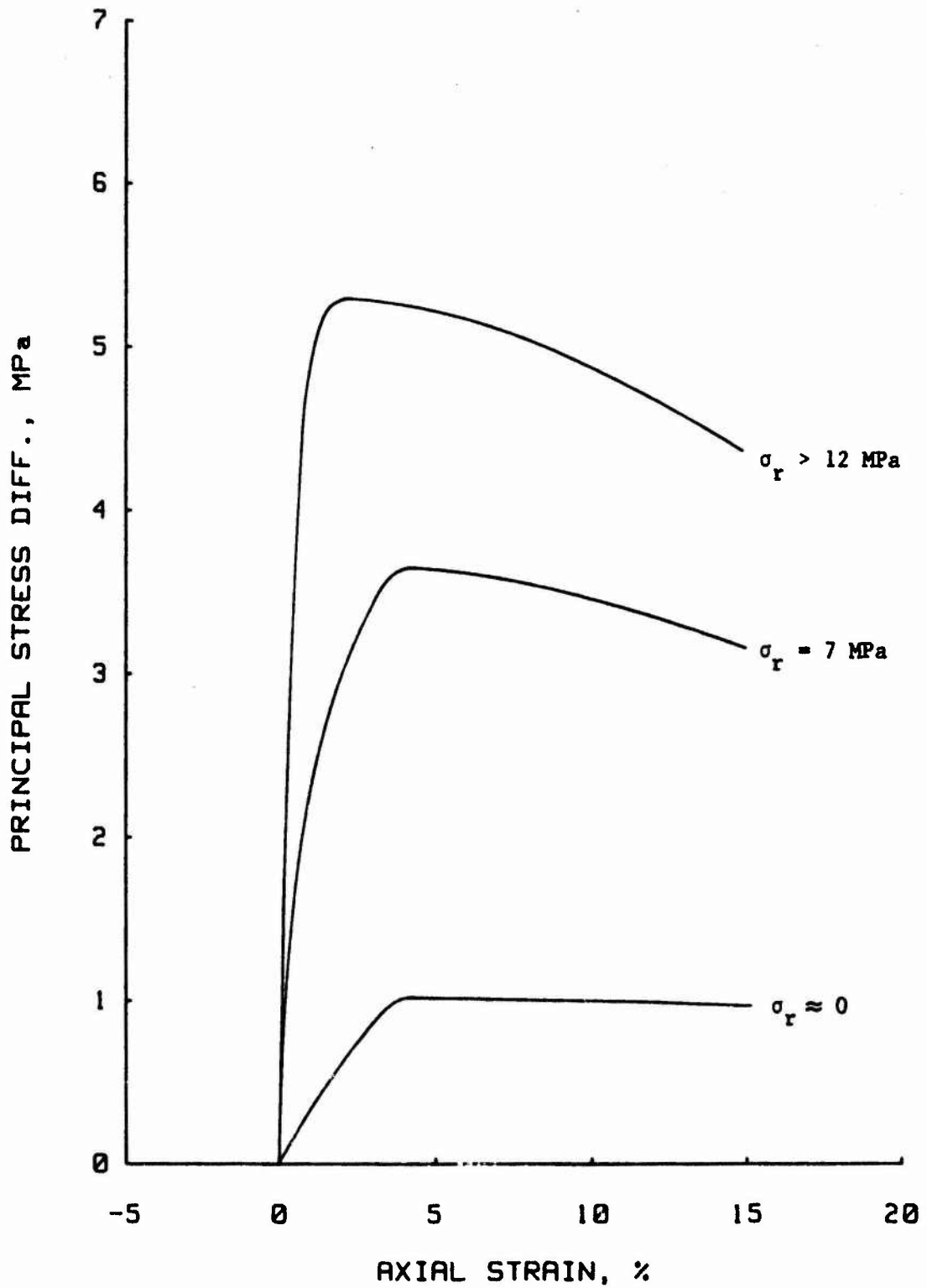


Figure 3.13. Representative UC and TX stress-strain responses for materials in Antelope Lake Layers 1 and 3.

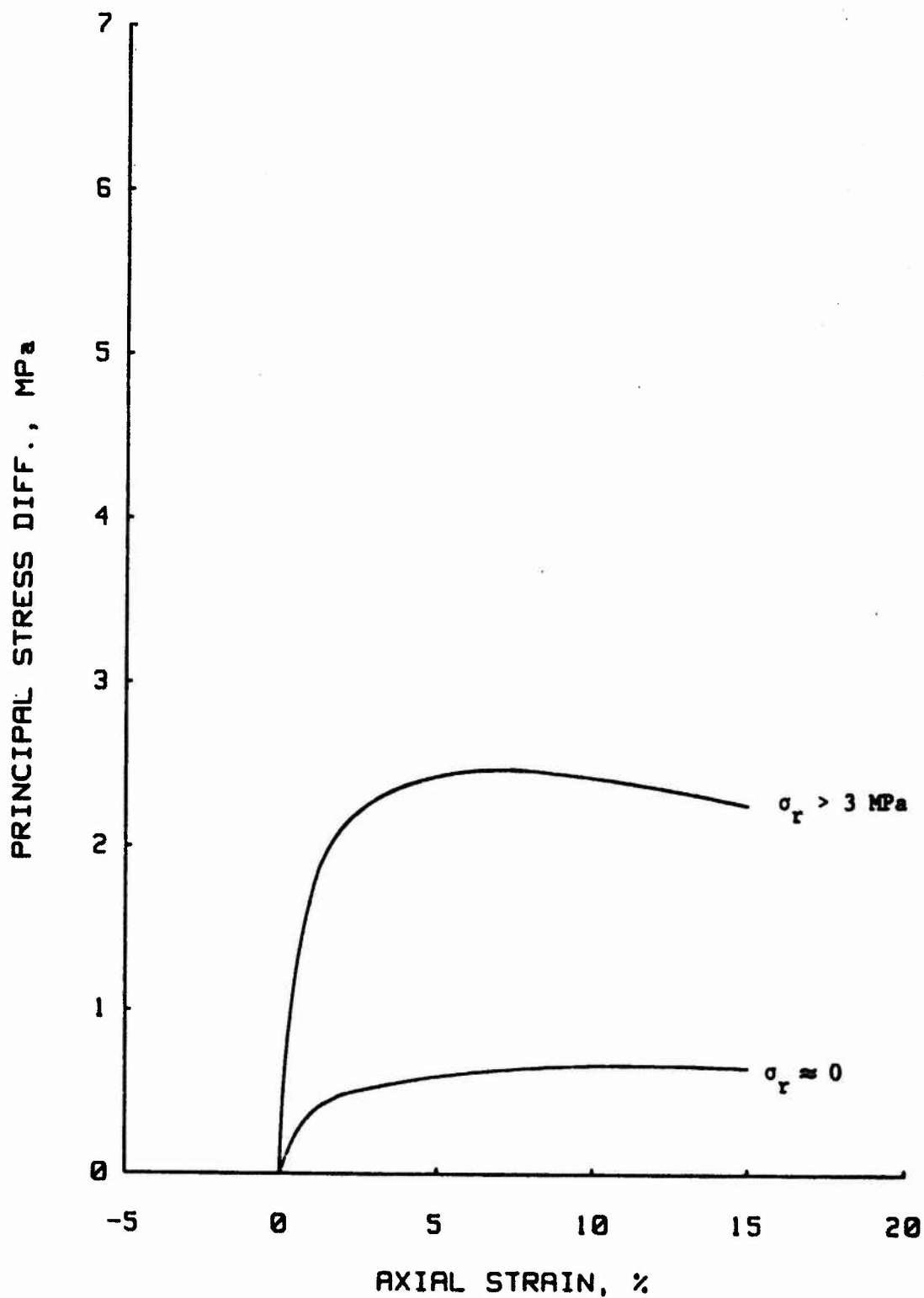


Figure 3.14. Representative UC and TX stress-strain responses for materials in Antelope Lake Layer 2.

CHAPTER 4

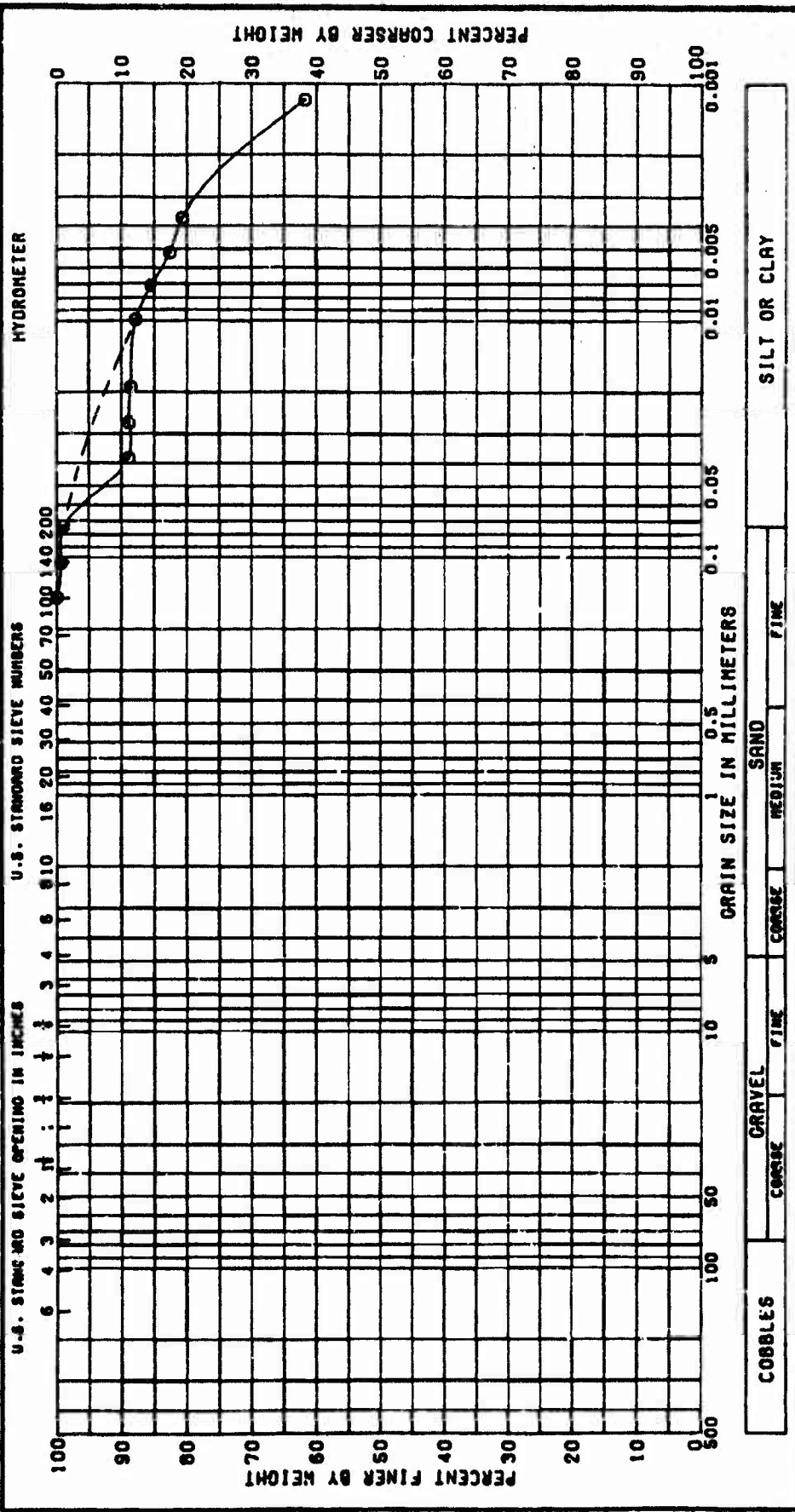
SUMMARY

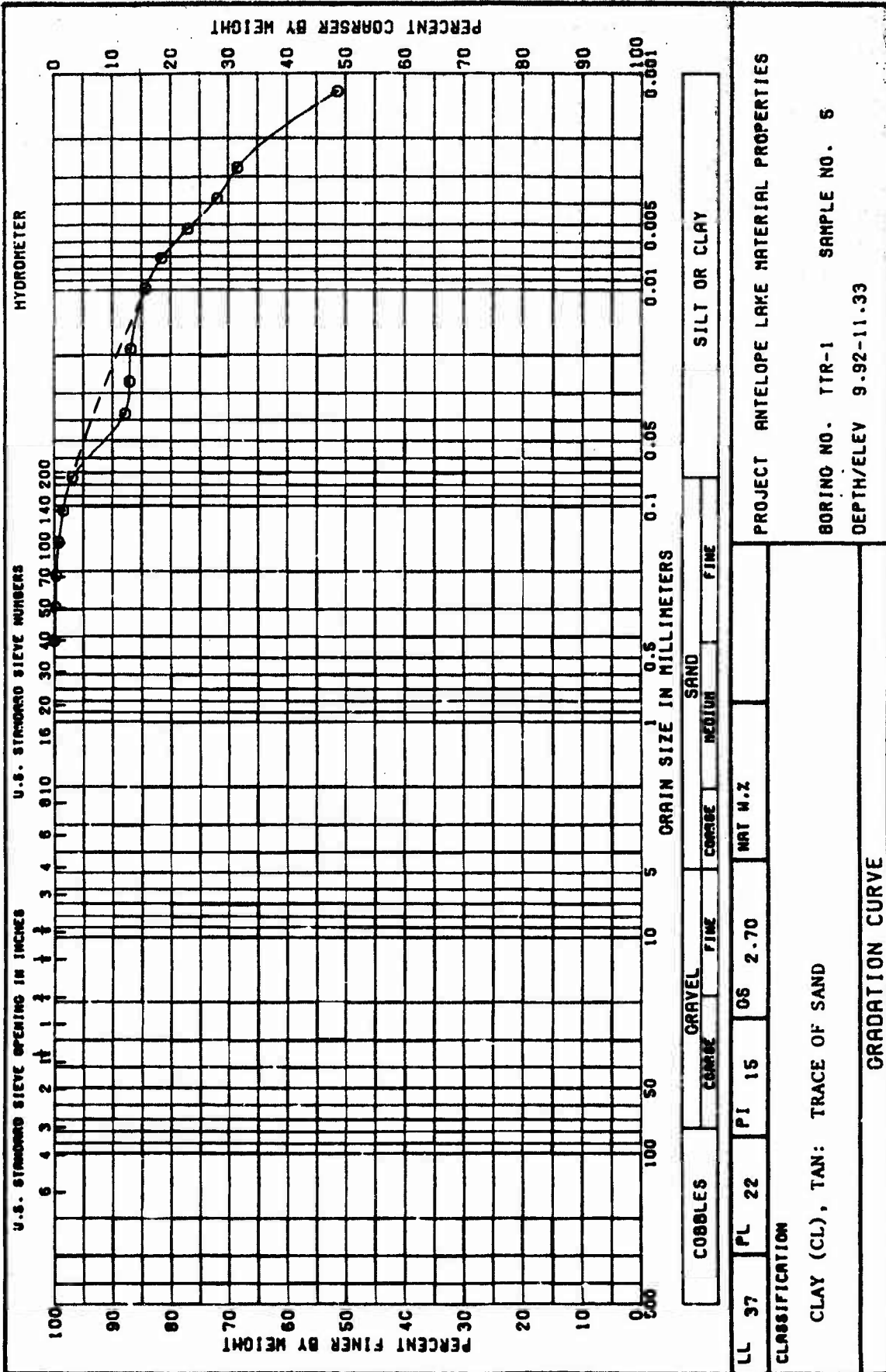
This report documents a mechanical property investigation conducted for SNLL on undisturbed samples of Antelope Lake soils (see Figure 3.1). The purposes of the investigation were to experimentally determine the mechanical responses of these soils and to provide representative material properties to SNLL. The completed laboratory test program obtained mechanical response data from 6 static unconfined compression tests and 12 static triaxial compression tests. Analyses of the test data indicated that the in situ material will become fully saturated at relatively low levels of mean normal stress, i.e., less than 14 MPa for materials from Layers 1 and 3 and less than 4 MPa for materials from Layer 2 (see Figure 3.6). Once the materials become fully saturated, no appreciable increase in strength will be developed as levels of mean normal stress increase, i.e., the materials will have reached their Mises limit (Figure 3.7).

Representative response curves for triaxial shear (Figures 3.13 and 3.14) and isotropic compression (Figure 3.6) were deduced from the test data for the three in situ layers. The mechanical responses of Layers 1 and 3 were the same; the materials in Layer 2 had lower strengths and softer isotropic compression responses prior to full saturation.

REFERENCES

1. Ehrgott, J. Q., and Sloan, R. C.. November 1971. "Development of a Dynamic High-Pressure Triaxial Test Device," Technical Report S-71-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
2. Ehrgott, J. Q. May 1971. "Calculation of Stress and Strain from Triaxial Test Data on Undrained Soil Specimens," Miscellaneous Paper S-71-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
3. Headquarters, Department of the Army, Office, Chief of Engineers. 30 November 1970 (Amended 1 May 1980). "Laboratory Soils Testing," EM-1110-2-1906, Washington, DC.
4. US Army Engineer Waterways Experiment Station. April 1960 (Reprinted May 1967). "The Unified Soil Classification System," Technical Memorandum No. 3-357, Vicksburg, MS.





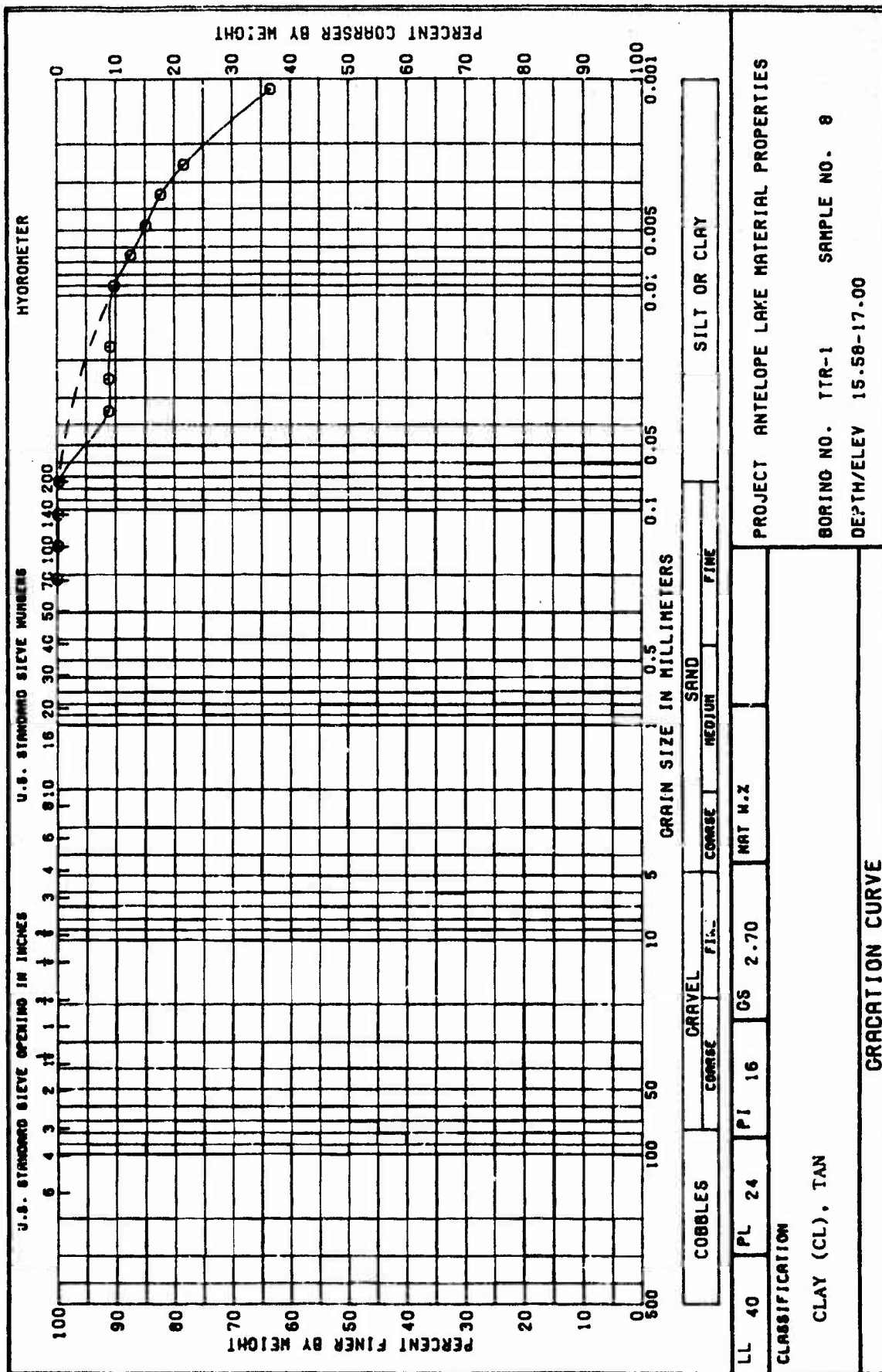


PLATE 4

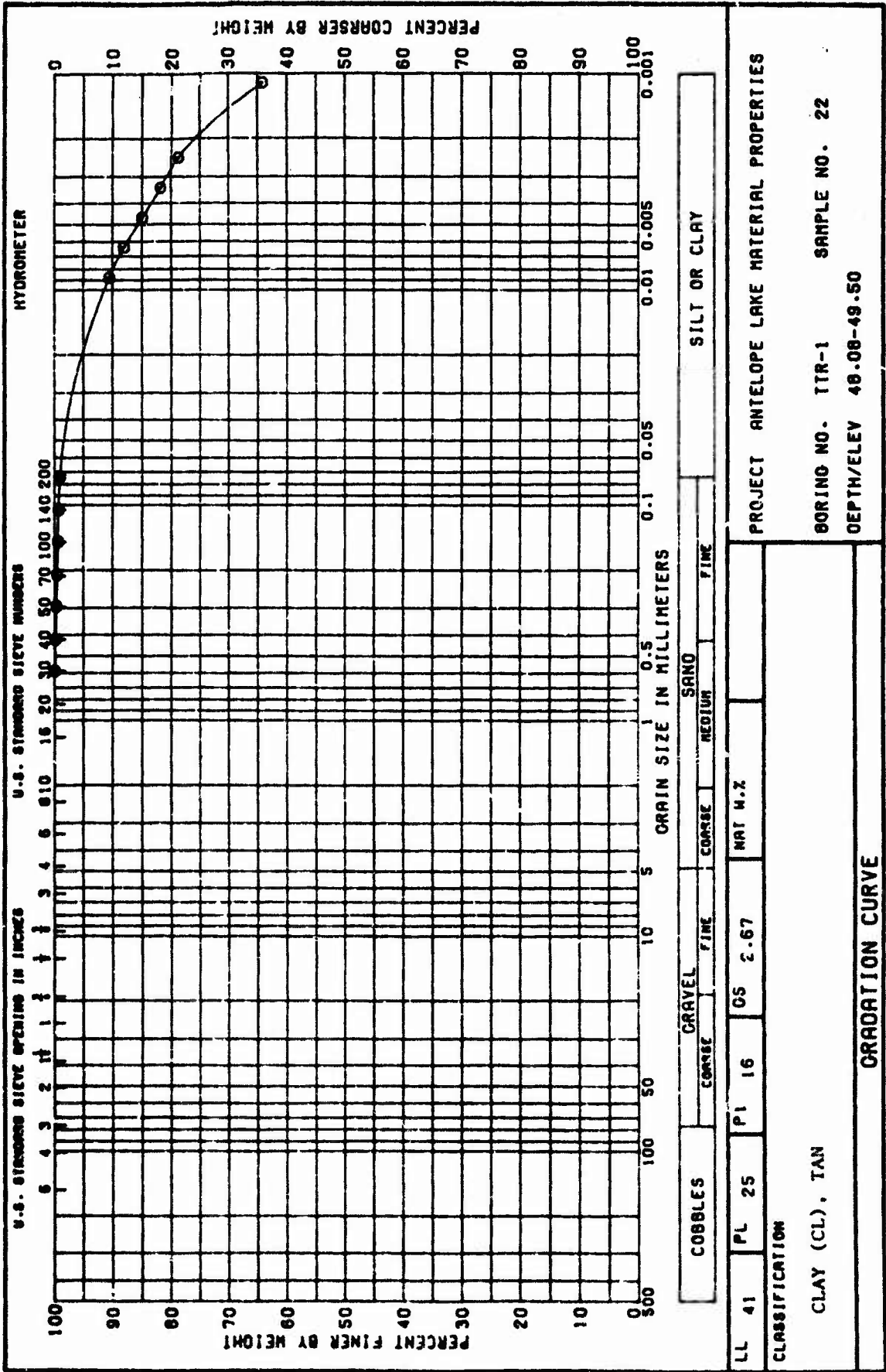
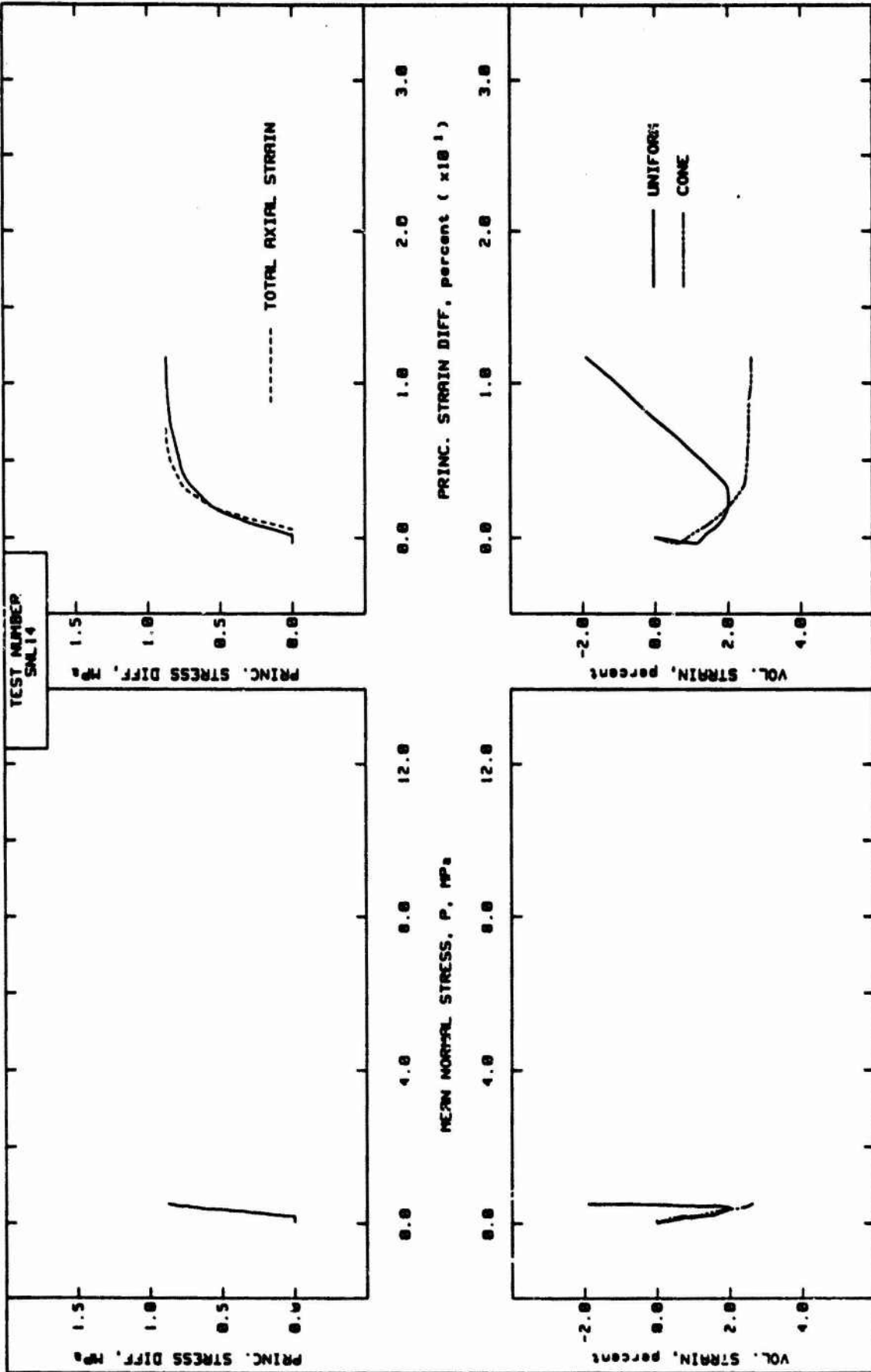


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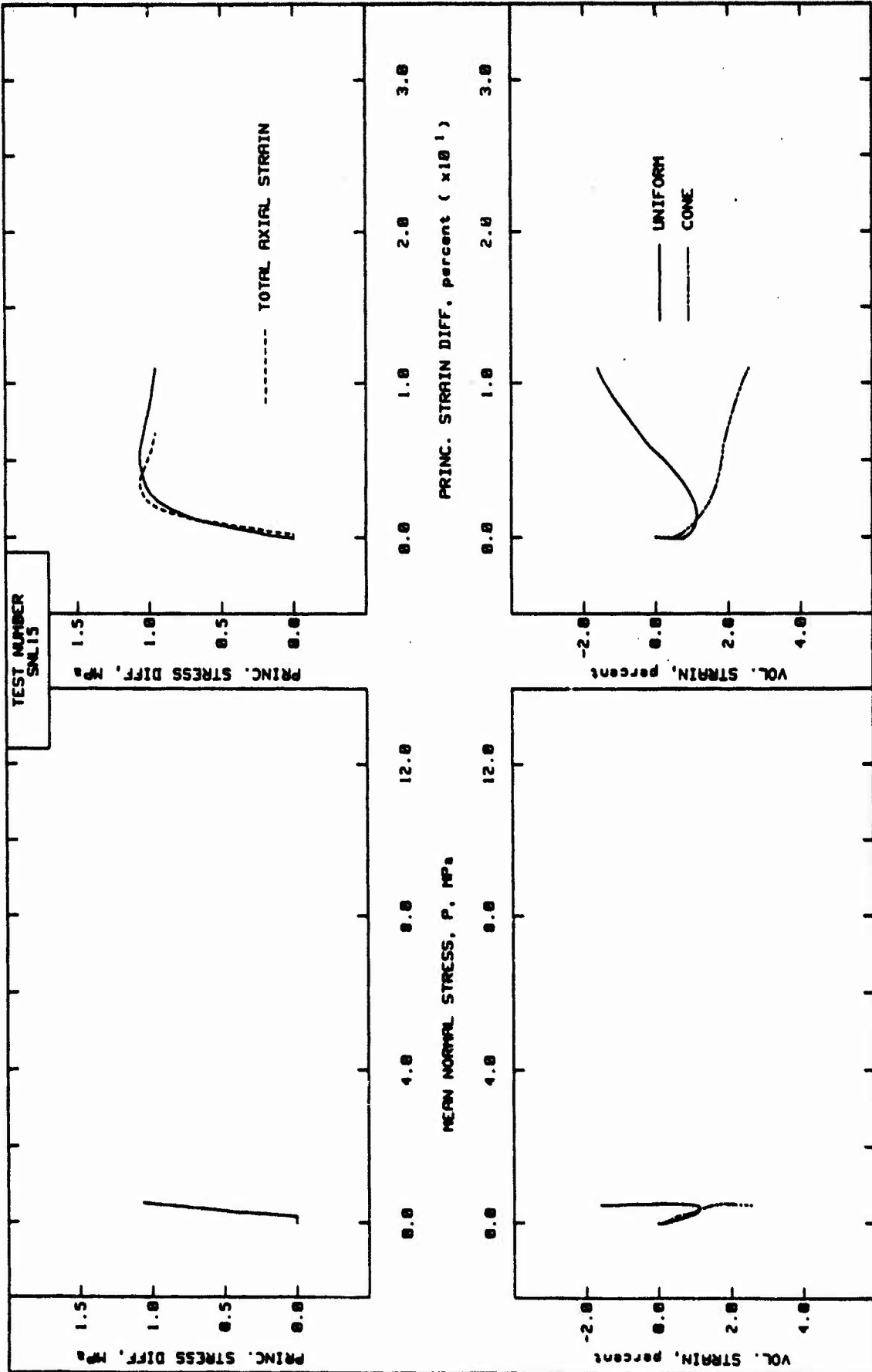
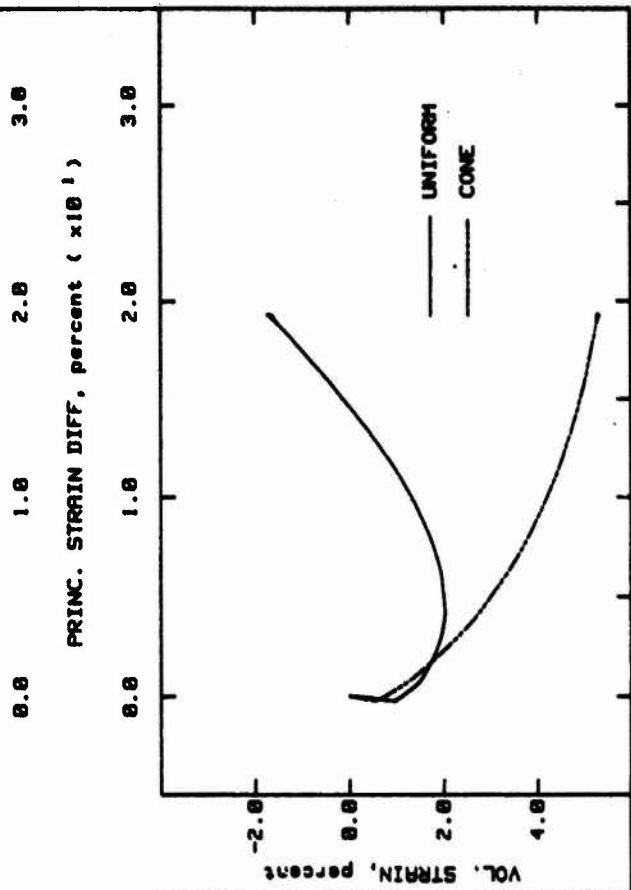
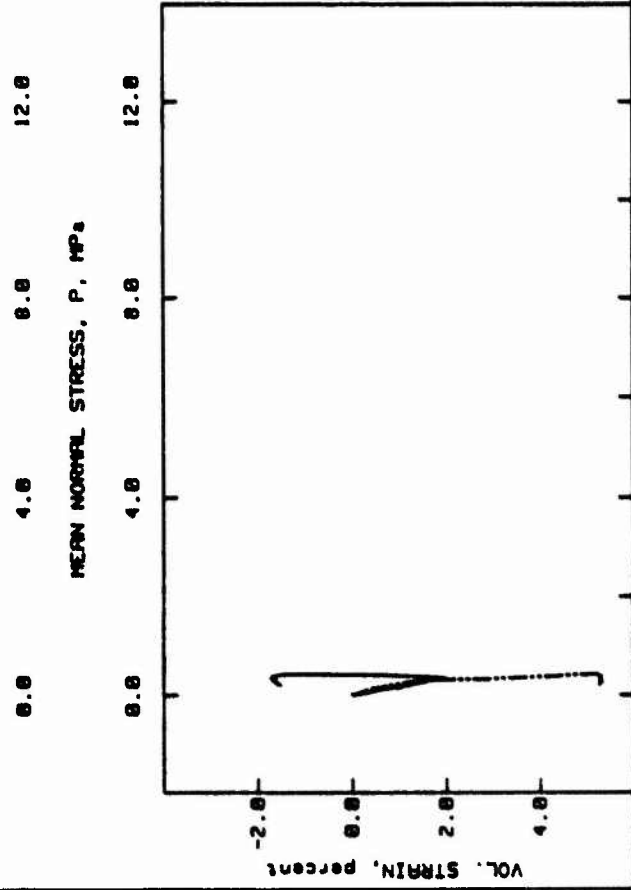
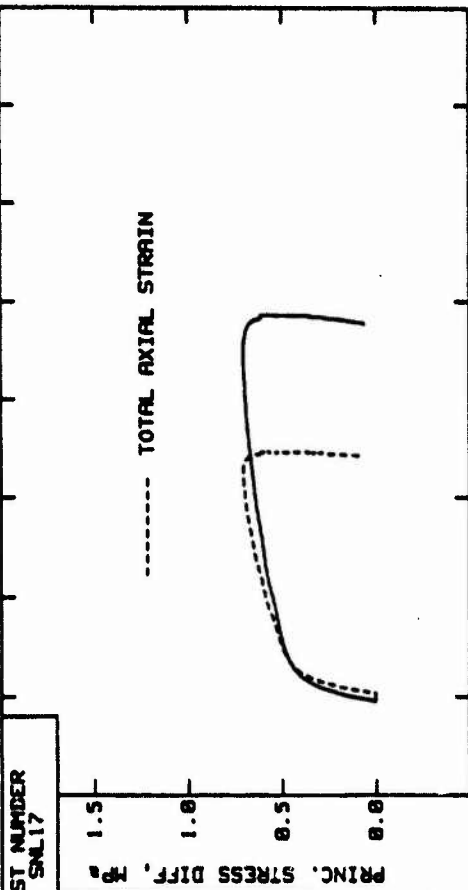
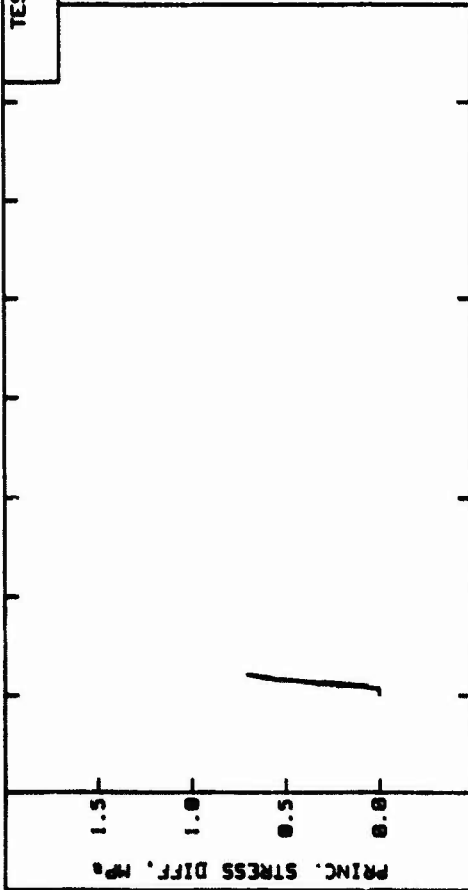


PLATE 10

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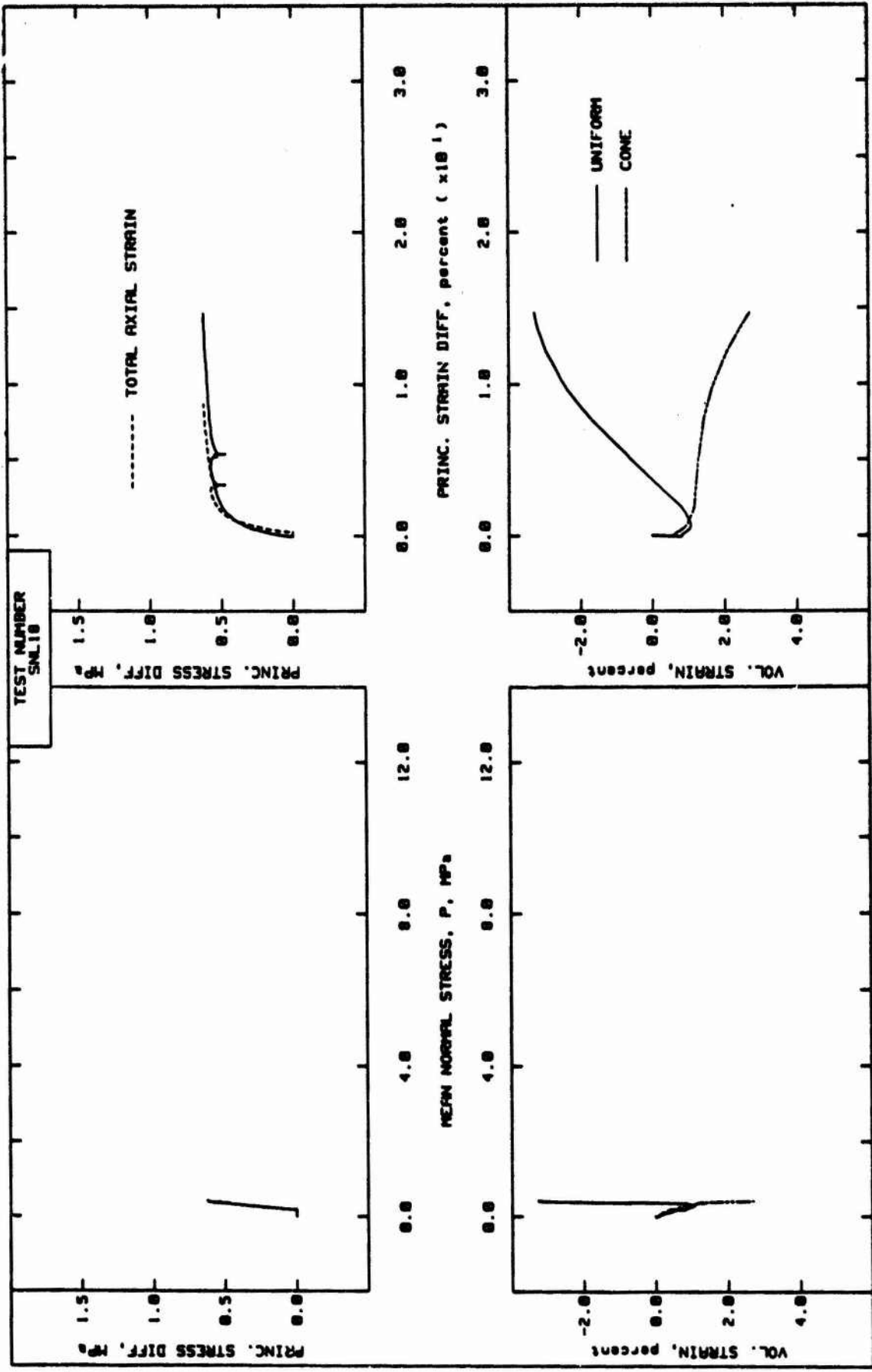


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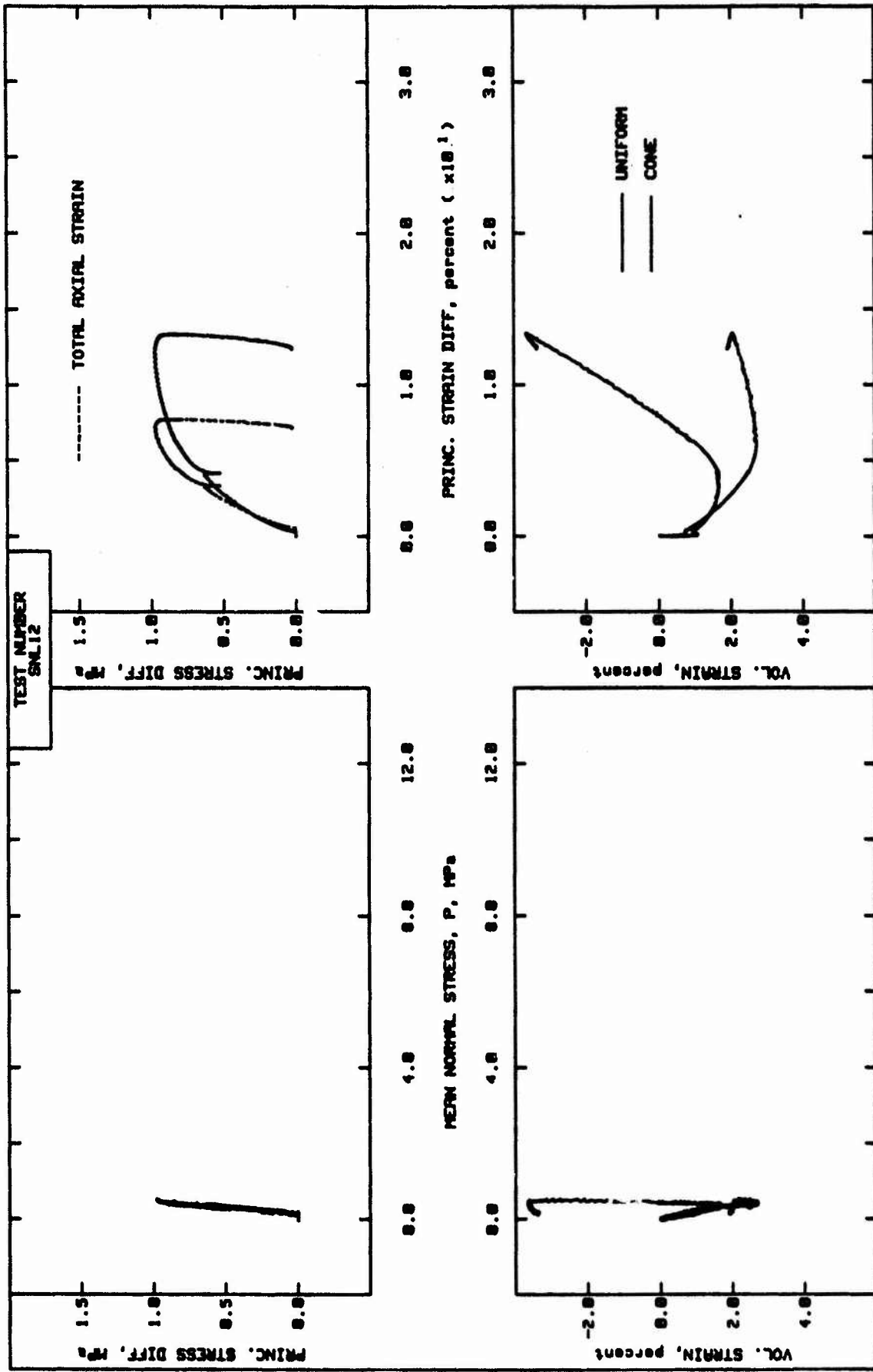
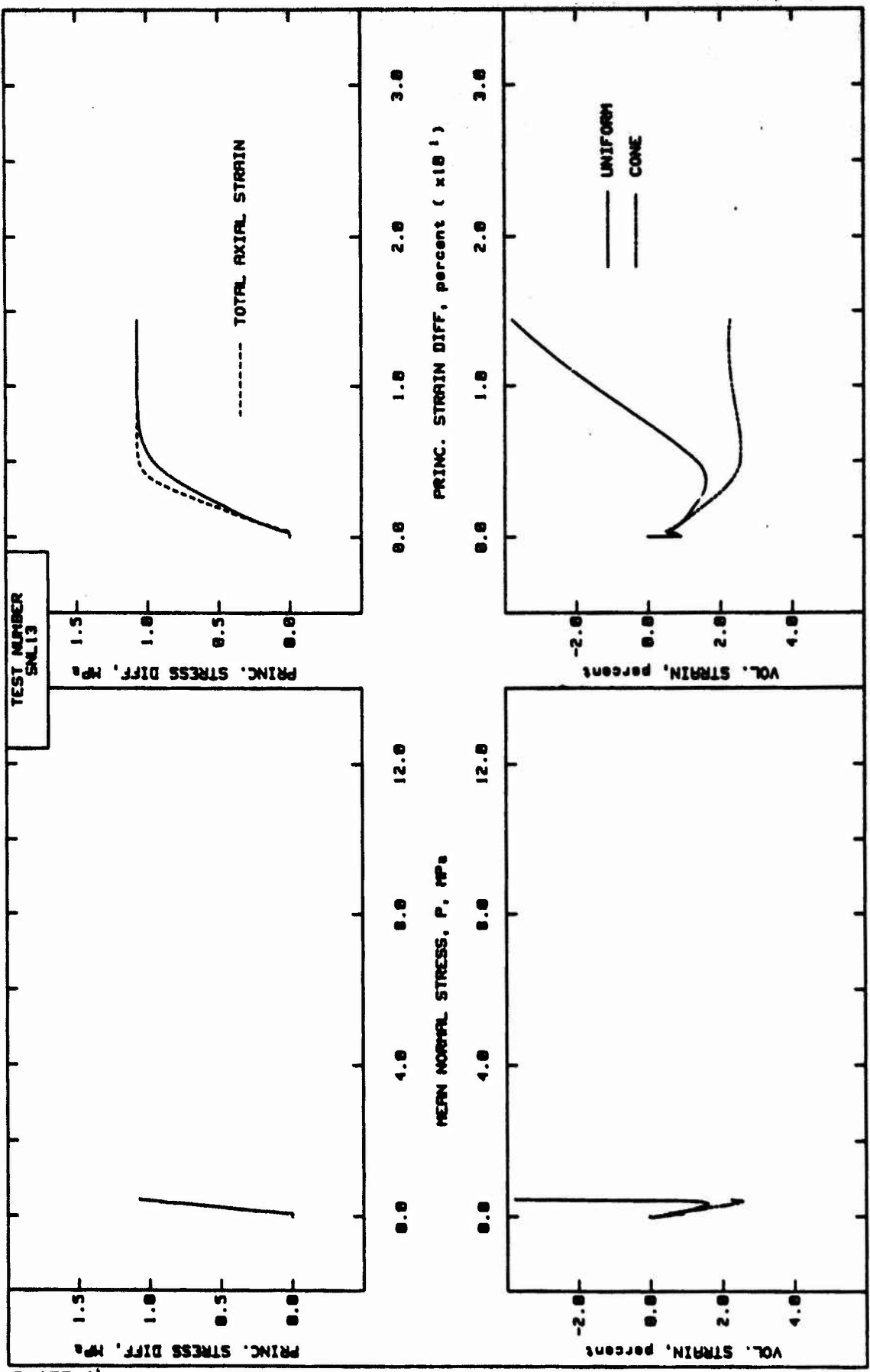
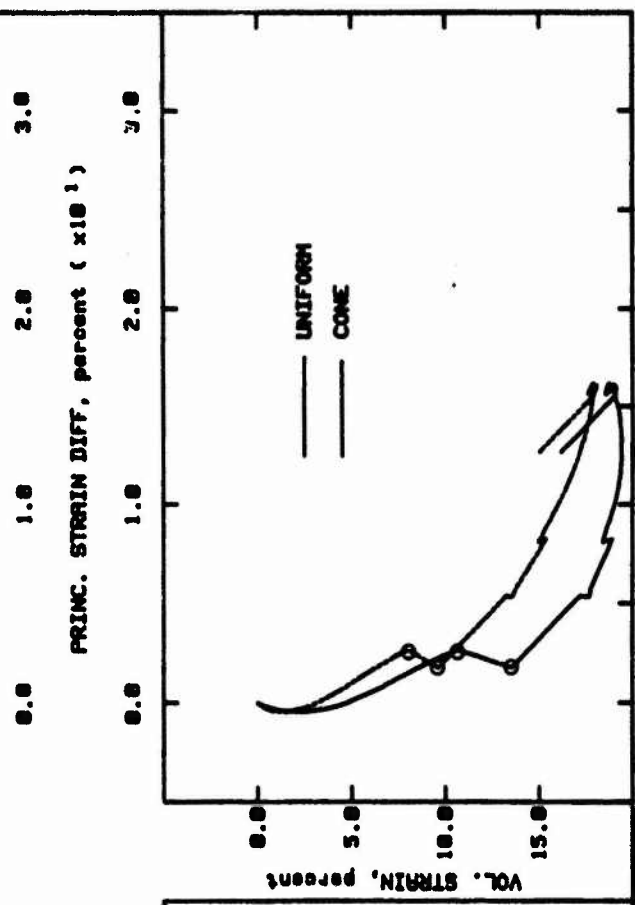
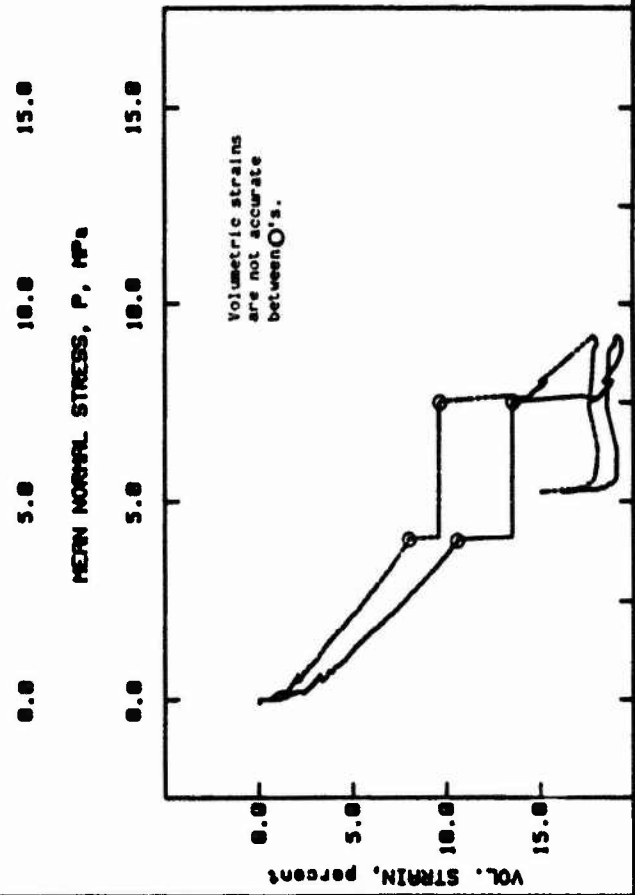
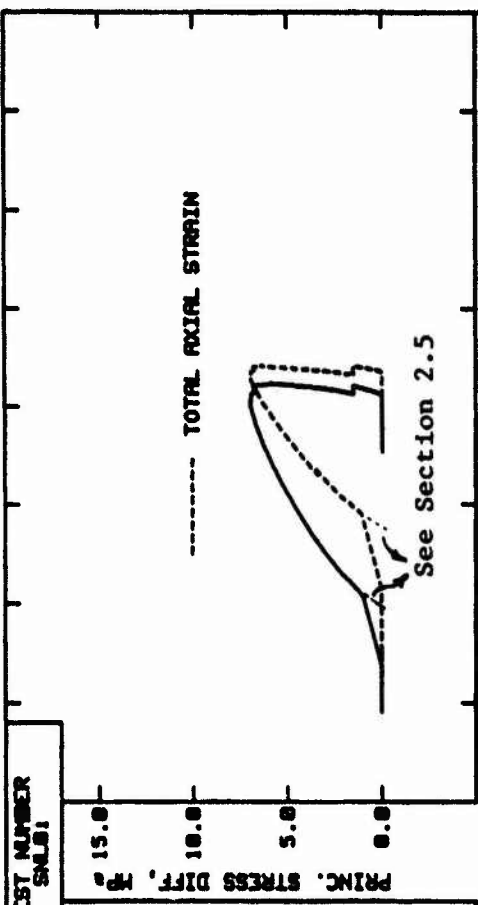
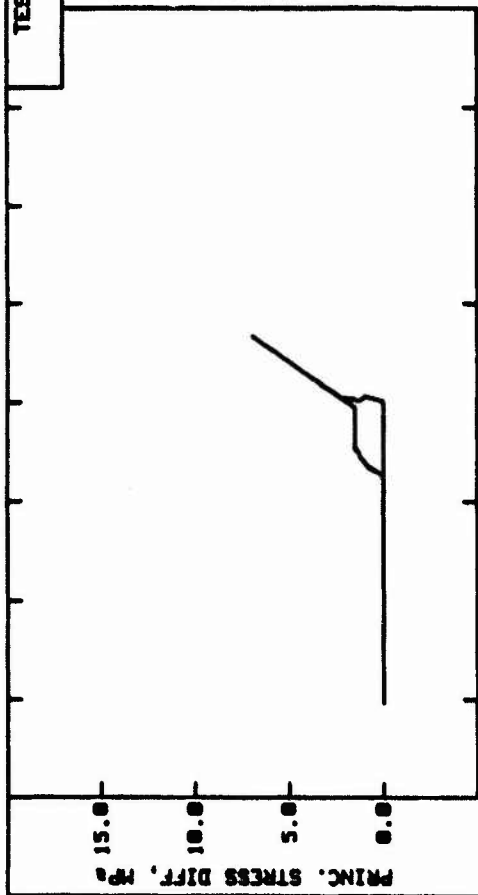


PLATE 13



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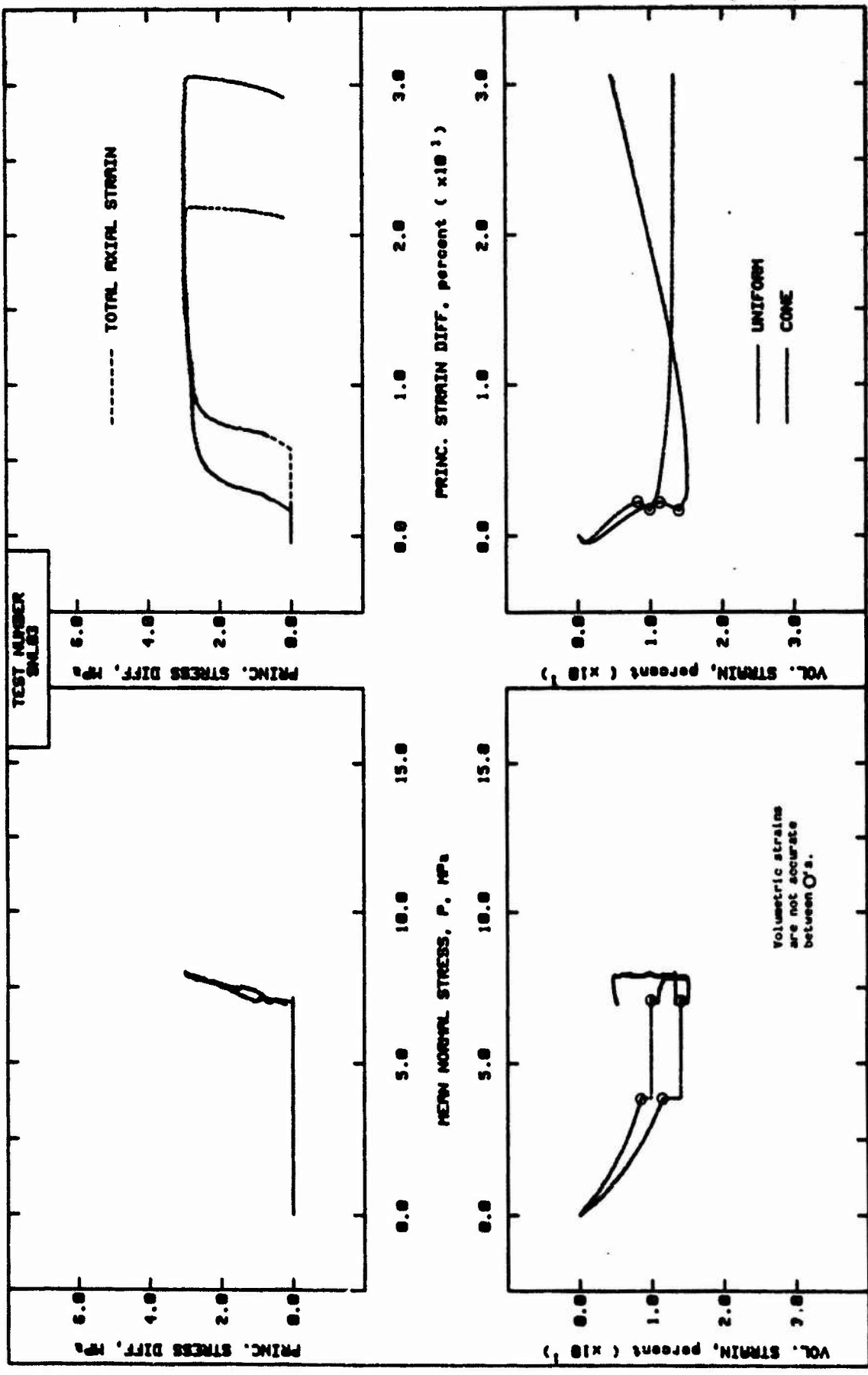
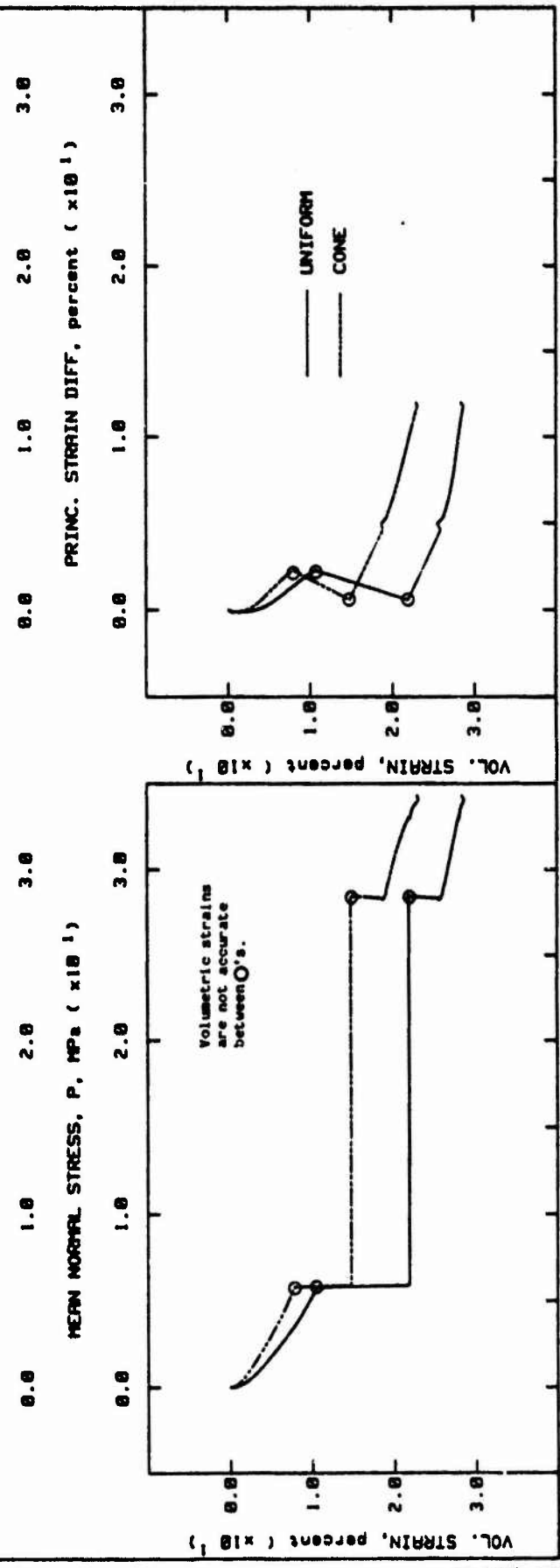
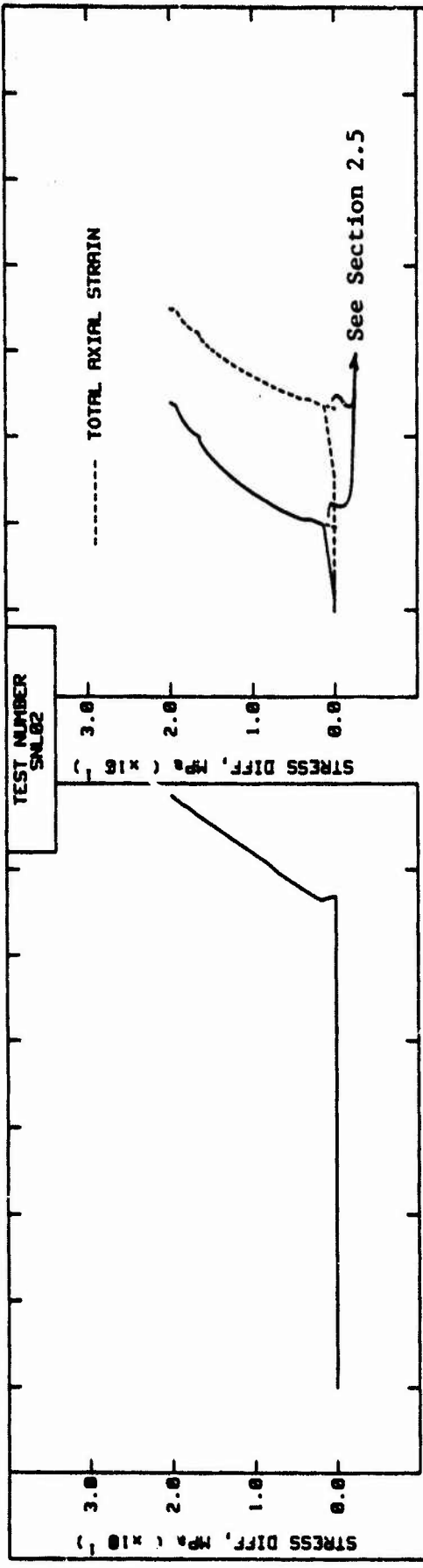
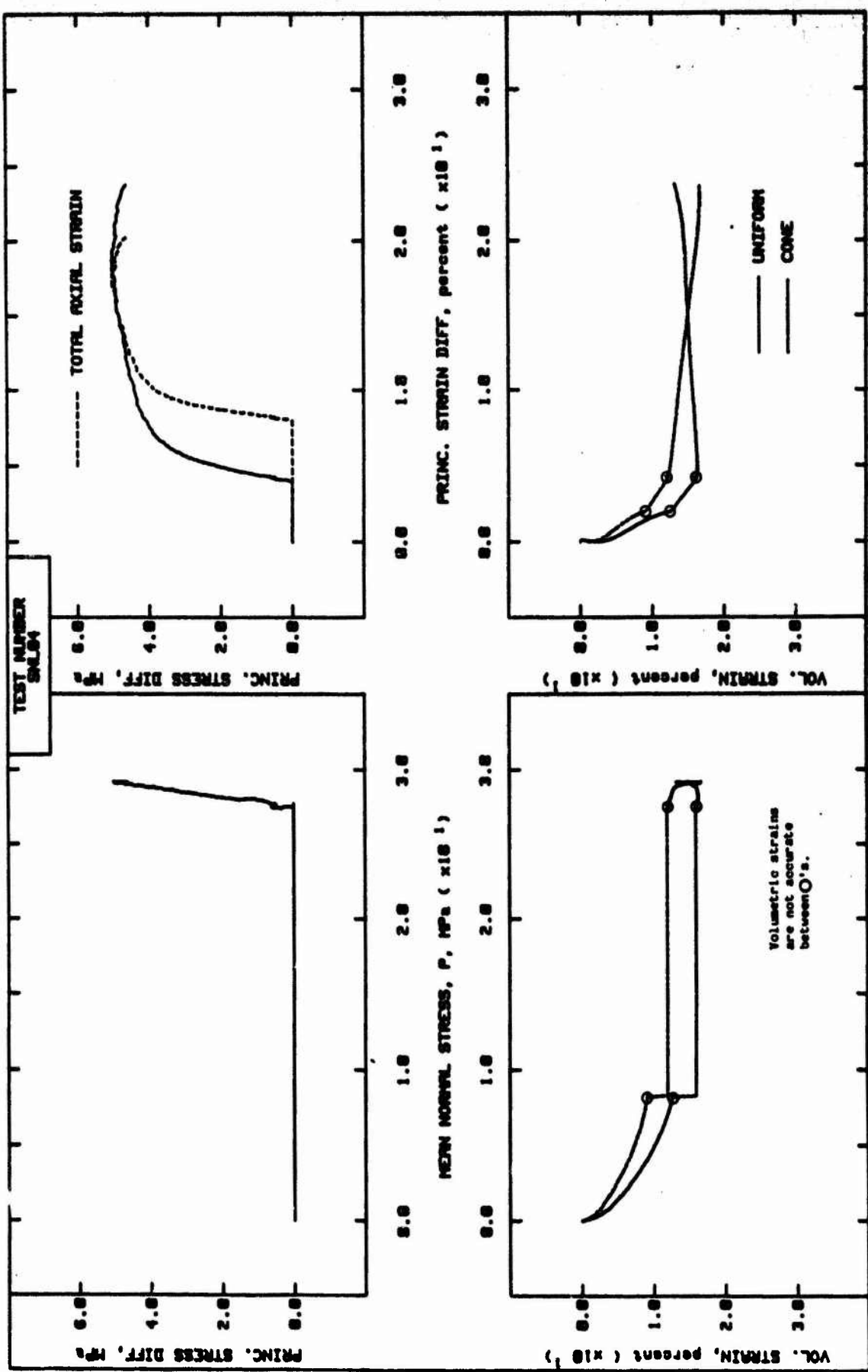
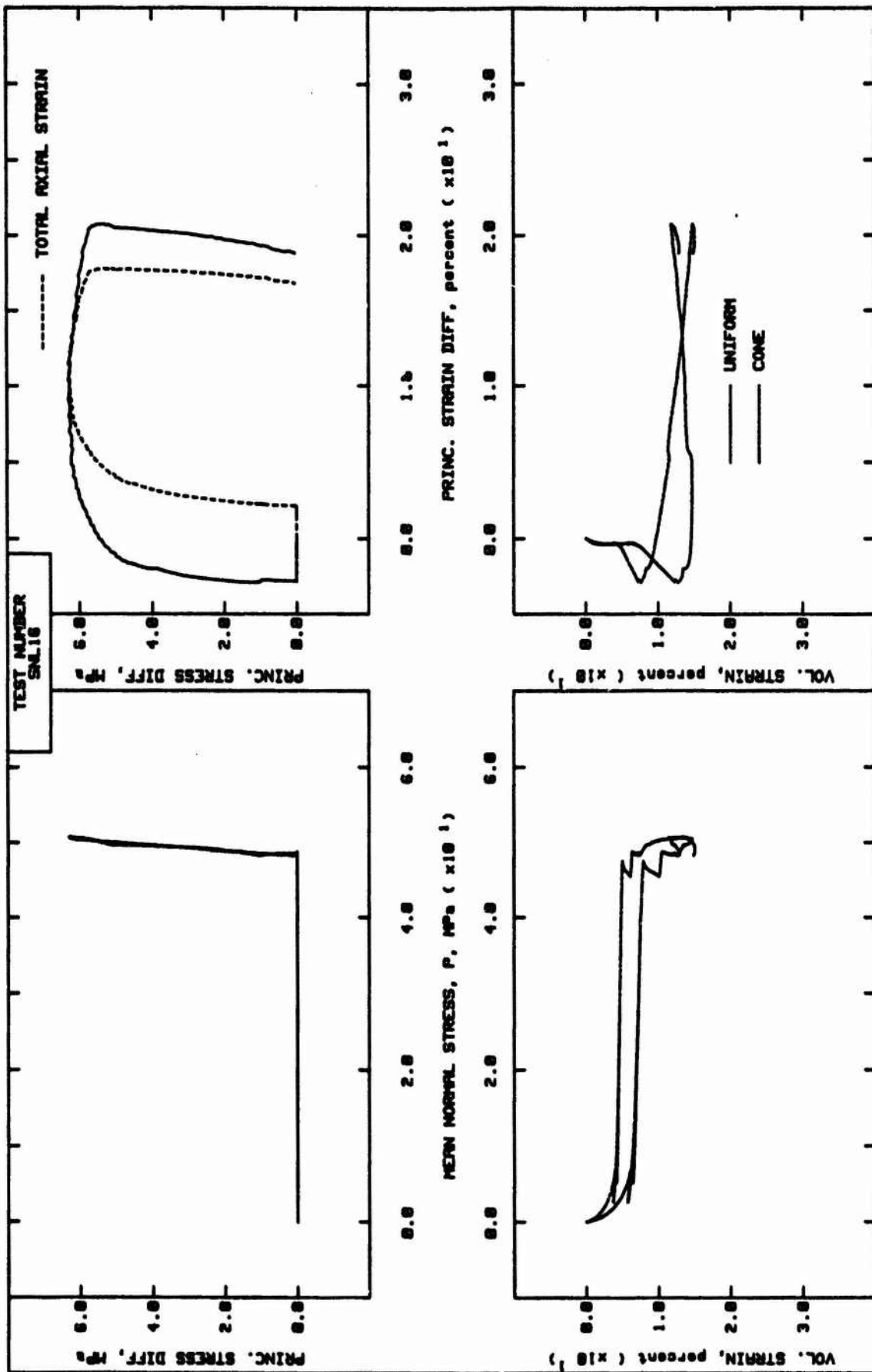


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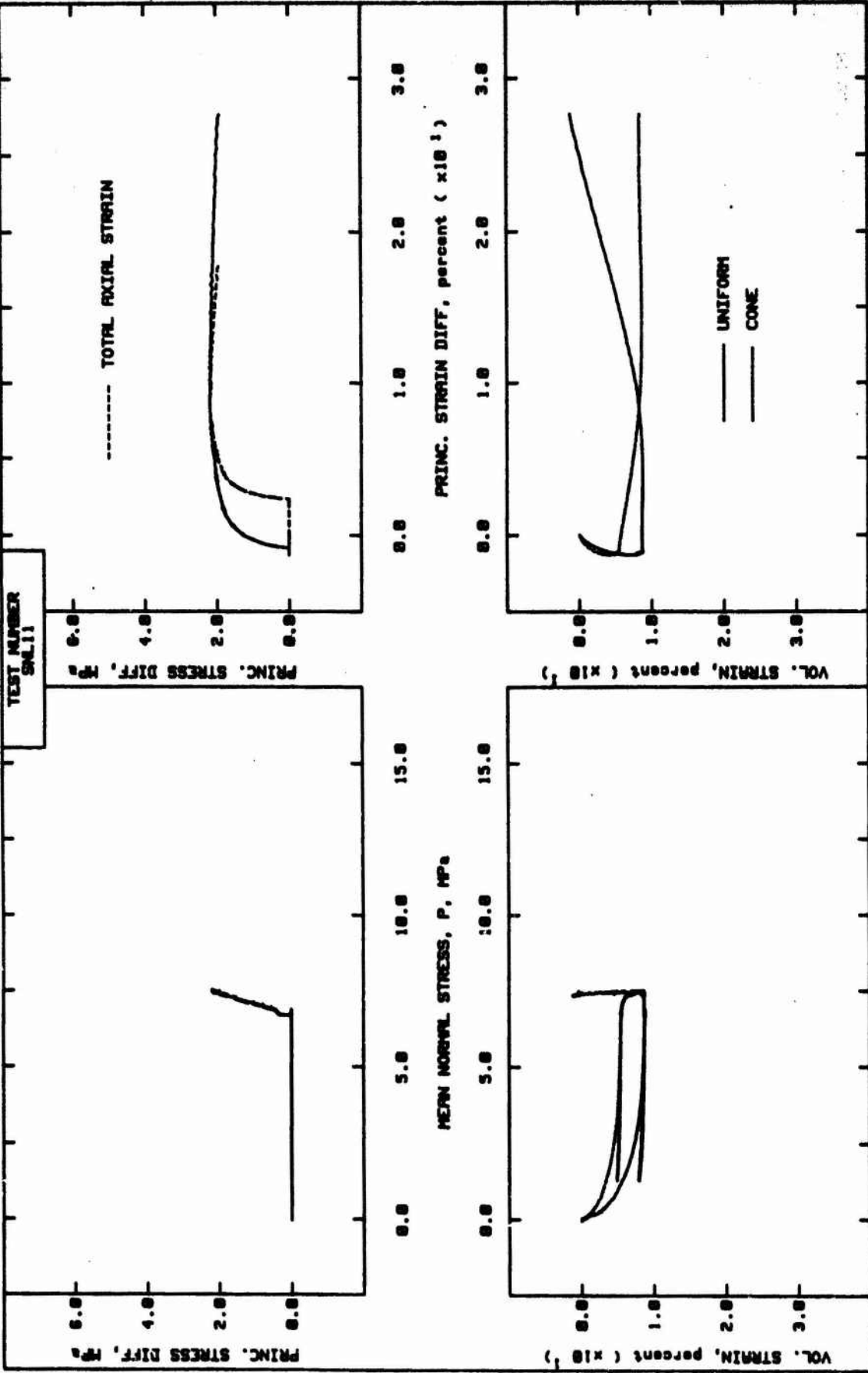


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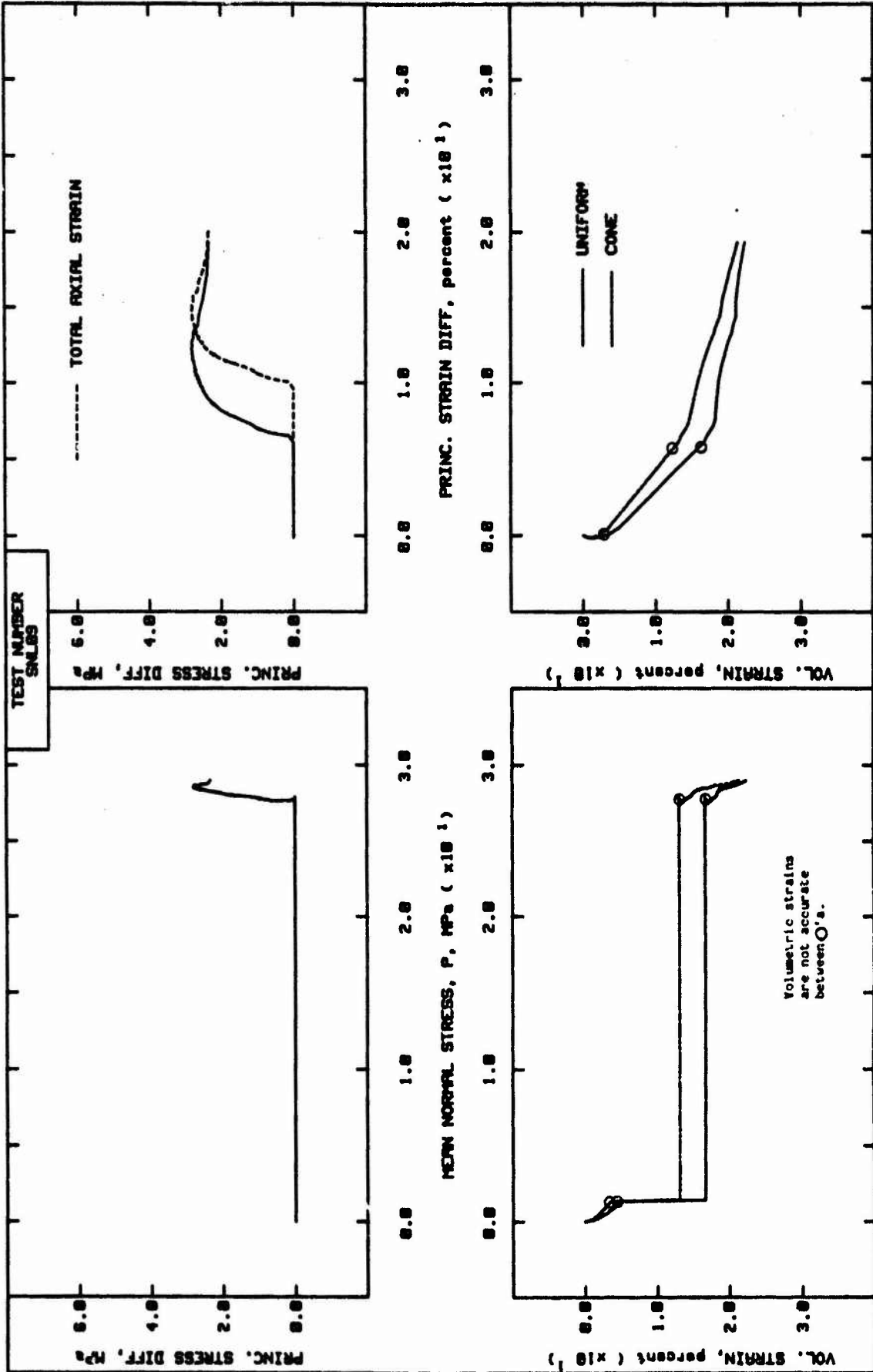


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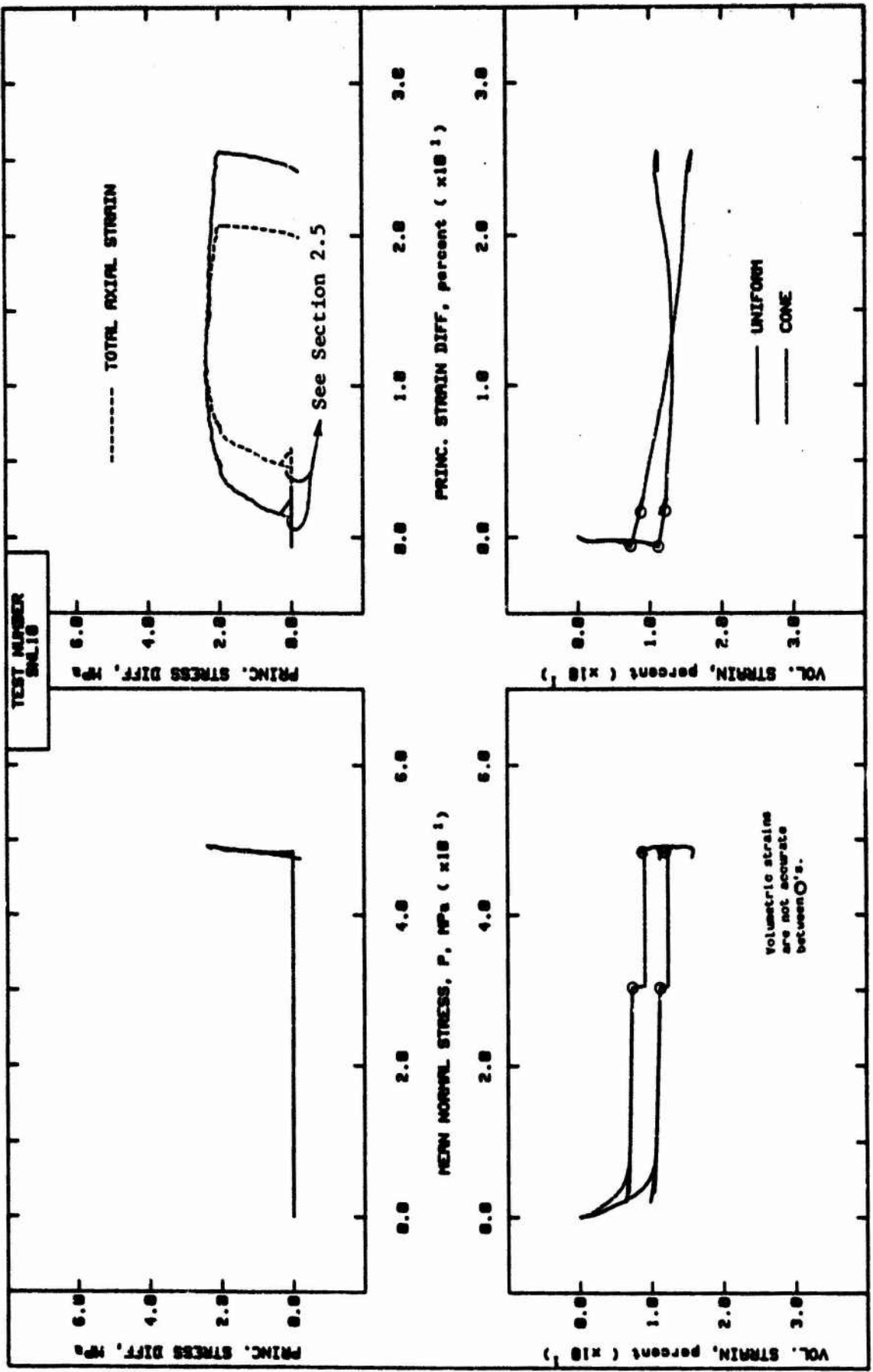
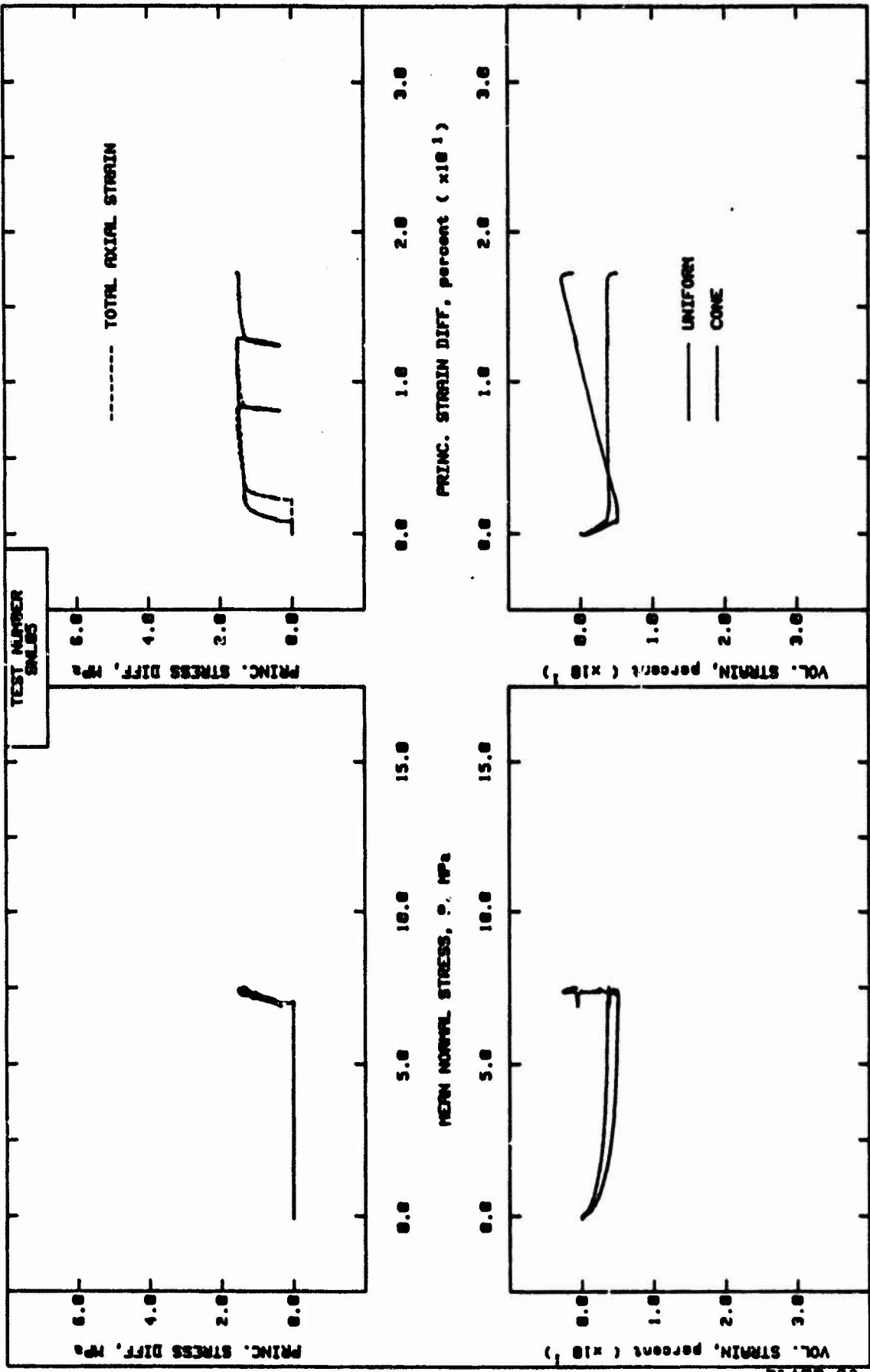
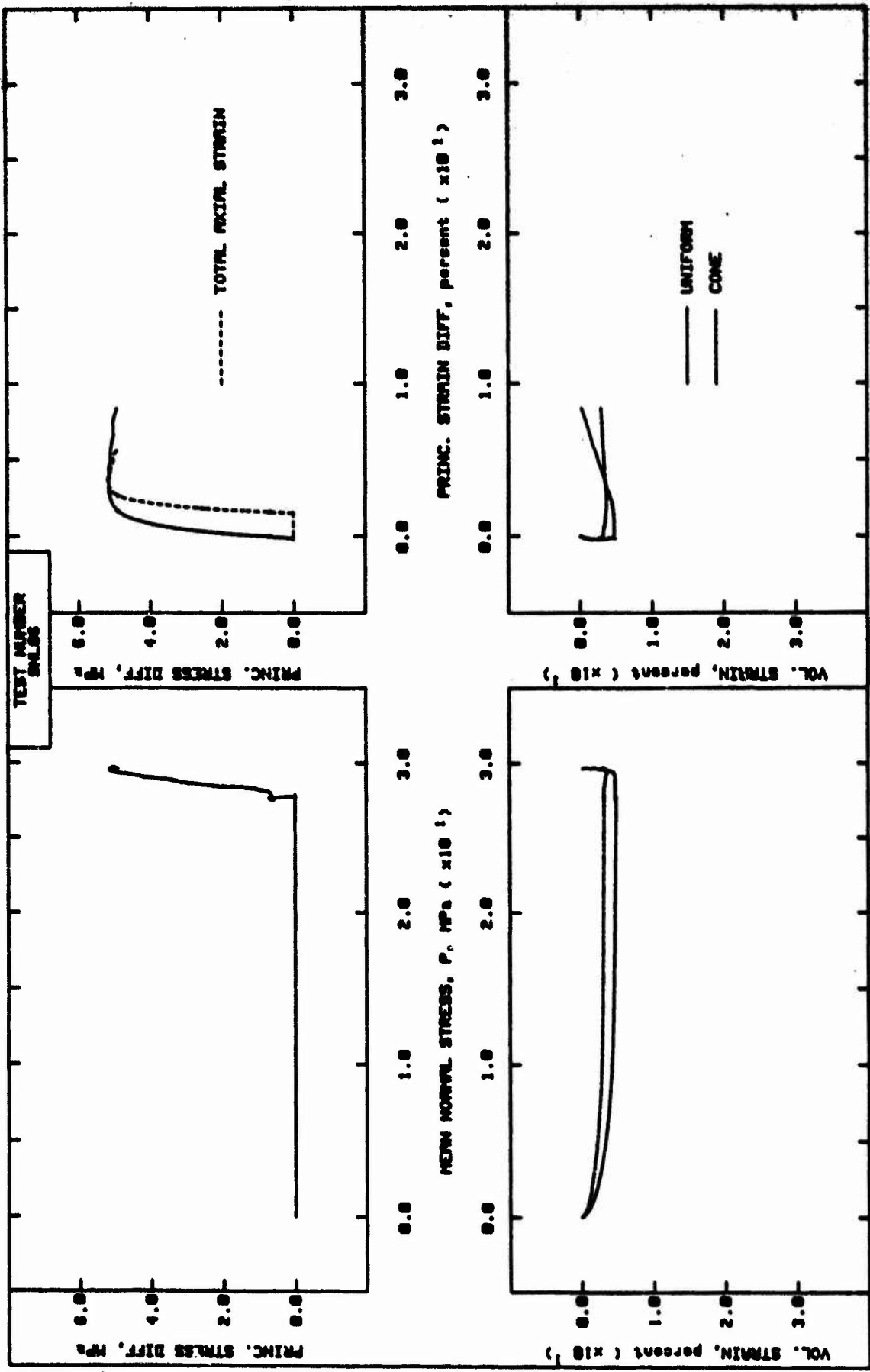


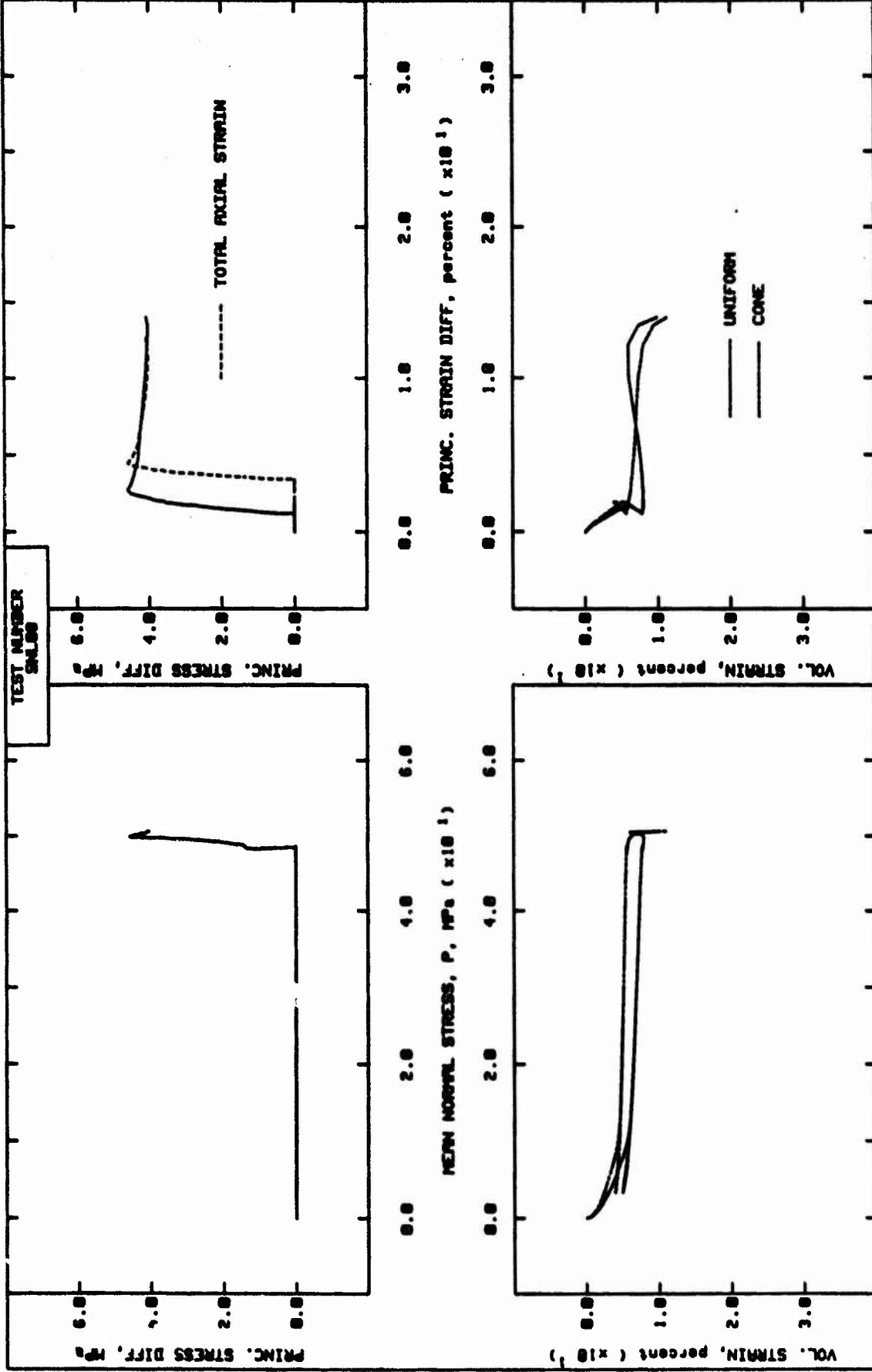
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