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1	REPORT	7/28/1966	FOUNDATION INVESTIGATION (SUBSURFACE SOIL BORINGS) FOR LOS ALAMOS MESON PHYSICS FACILITY	20	

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Albuquerque
TESTING LABORATORY
ALBUQUERQUE TESTING LABORATORY
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8888

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Lab No. 6209 Date July 28, 1966

Report to Giffels & Rossetti, Inc. Job 66-17 Rec'd 8/8/66

Submitted By Giffels & Rossetti, Inc. ~~Sampled~~ Drilled By Albuquerque Testing Laboratory

Project Foundation Investigation (Subsurface Soil Borings) for Los Alamos Meson Physics Facility, Los Alamos, New Mexico

Source of Material Twenty-five miscellaneous depth test borings drilled at designated locations at the project site in Los Alamos, New Mexico

TEST RESULTS

Introduction:

The test borings were made between June 2 and 30, 1966, using a Mobile B-61 "Pacemaker" Rotary Drill mounted on a 1965 International Loadstar 1700, 4x4 truck. The drill itself was powered by a Ford industrial engine. The test holes were drilled using the following equipment:

1. Five and one-half inch (5½") diameter, continuous flight, 5-foot sectional augers.
2. Ten-foot length, double tube, bottom discharge, 3 7/8 inch outside diameter core barrel equipped with tungsten carbide or diamond coring bits.

Standard penetration tests were made at noted vertical intervals in the test borings at the time of drilling. These tests were conducted to obtain an indication of the degree of fusion of the underlying volcanic tuff and to obtain tuff samples for visual inspection. Penetration tests were conducted in the auger drilled portions of all test borings and in core drilled portions where insufficient core was recovered.

Compressed air was utilized during all core drilling operations to remove cuttings and provide a bit cooling medium. Loss of air circulation occurred in several test holes and is noted on the appropriate boring log. Auger drilling was accomplished without fluid circulation.

Test Boring Locations:

The locations of test borings are given on the "Test Boring Layout", drawing No. LAM-A-CE-3X. Field location of test borings was furnished by personnel of the A.E.C. Irregular topographic features or the location of trees necessitated relocation of some borings. These relocations were minor with the exception of holes 6, 7 & 8. Test boring No. 6 was offset approximately 25 feet west of the designated location; boring No. 7 approximately 18 feet southwest; and boring No. 8 approximately 60 feet north.

Respectfully Submitted,
ALBUQUERQUE TESTNG LAB.
Original Signed By
John P. Boyd
Registered Professional Engineer

cc- C.S. Huff w/sepia of logs
B.D. Dirks w/print " "
J.V.J " " "
VFL " " "

Test Data & Results:

The "Boring Log Graphs of Test Holes", given on cross-section sheets 1 and 2, depict the subsurface soil and rock conditions encountered in the test borings and show:

1. The results and locations of the standard penetration tests.
2. The percent of core recovered from core drilled portions of test borings.
3. The unconfined compressive strength (p.s.i.) of typical recovered core sections.
4. The grain-size classification of typical penetration samples recovered below elevation 6970 in zones where cores were not obtainable.
5. The moisture content of typical recovered core sections or typical recovered penetration samples from zones where cores were not obtainable.
6. The dry densities (in lbs. per cu. ft.) of typical recovered core sections.

Test data and results of moisture-density tests, approximate elastic modulus determinations, and triaxial compression tests are appended to this report, rather than tabulated upon the "Boring Log Graphs". Discussions and recommendations precede these appended test results.

Best Available Copy

Subsurface Soil & Rock Conditions:

Irregular depths of silty to clayey sand surface soils were encountered in the majority of borings. This soil mantle is generally quite thin; however, considerable thicknesses of surface soils were noted at several boring locations.

The surface soils are in turn underlain by welded volcanic tuff bedrock. formations. These formations are apparently ash flows which have been consolidated and fused or welded to varying degrees, and are composed of mineral crystals (quartz and sanadine notably), pumice, latite and rhyolite fragments and other debris fused in a frothy matrix which is siliceous in composition. The volcanic tuff rock is porous, of low unit weight and is generally soft and friable in comparison with other rock formations. Recovered cores and visual inspection indicated that the volcanic tuff formation contains vertical, horizontal and diagonal seams or fractures. Within the zone of weathering these seams often appear to be open and filled with silty clays or calcite. At depth these seams appear to be tightly closed and the formations are consequently more competent. The tuff formations are composed of essentially cohesionless materials and pulverized portions of sound tuff are non-plastic. Tuff recovered from weathered zones exhibits low plasticity which probably results from chemical decomposition of minerals within the tuff formation and the presence of clays in opened seams. The tuff formations encountered often appear irregular without sharp contacts between flows of dissimilar character. Even within an apparently continuous flow horizontal and vertical variation is noted in composition, density and degree of fusion or strength.

Generalized descriptions of the character of the underlying volcanic tuff encountered in specific portions of the project site follow:

1. Area between Test Holes 1 and 4

Test borings in this region penetrated a welded volcanic tuff which is apparently well fused. Tuff encountered within this region is a light pinkish gray in color and generally exhibits high density and high, though not uniform, compressive strength. Joints are indicated within the recovered core sections but appear to be tightly closed, and the general formation appears competent and moderately sound. Weathering is not indicated to extensive depth. A less well fused tuff was encountered above footing level between approximate elevations 6989 and 6976 in Test Hole No. 4.

2. Area between Test Holes 4 and 16

Within this region a lightly welded, light gray, more pumiceous and very friable tuff overlies harder tuff comparable to that encountered in borings 1 thru 4. The contact between these apparently differing tuff flows is gradual rather than sharply defined

and slopes downward to the east. Friable tuff extends to approximate elevation 6975 in boring No. 5., approximate elevation 6965 in boring No. 8, and approximate elevation 6948 in boring No. 12. As in the region between borings 1 and 4, joints appear to be tightly closed indicating a generally competent formation. Partial or complete loss of air circulation was experienced in borings 12, 13 and 14 at approximate elevation 6946 or below. This circulation loss could indicate a less competent zone within the underlying tuff and may have been caused by an air permeable, cavitated or severely fractured area. Thin core sections which had parted on approximate horizontal planes were recovered from areas where air circulation loss was experienced. Some diagonal jointing was also observed in cores recovered from these zones.

3. Test Holes 19 and 20

Significant depths of clayey surface soils exist at these locations. Light gray, pumiceous and very friable tuff was encountered beneath these soils to approximate elevations 6947 with a harder more competent tuff formation below. An apparent weakened, fractured or cavitated zone exists between elevations 6936 and 6927. Within this region the drill string would often penetrate a short distance without appreciable resistance.

4. Test Hole No. 22

At this location a medium hard, moderately competent tuff was encountered. This tuff becomes friable and more pumiceous with increasing depth. Weathering is pronounced near the surface and calcite filled seams were noted to depths slightly below five feet.

5. Test Hole No. 21

At this location, hard, well fused, light pinkish gray volcanic tuff was found. Weathered seams were observed to a ten foot depth with a competent and sound tuff formation noted below.

6. Test Holes 24 thru 28

Hard, well fused volcanic tuff was predominant in this area below the zone of weathering with several intervals of lightly fused, friable tuff observed in several borings. These friable tuff zones were not continuous between adjacent borings and indicate possible discontinuities in this vicinity.

Discussion of Tests & Results

The penetration resistance values, "N" values, obtained from standard penetration tests conducted in volcanic tuffs do not appear to be directly indicative of the density of the tuff as they would be when conducted in

cohesionless soils. Rather, these "N" values appear to be more directly influenced by the degree of fusion of the volcanic tuff. Where low resistance values were encountered, core was not recoverable, and very friable tuff is indicated. More complete recovery of broken and undersize, moderately friable core was possible in zones where "N" values of approximately 50 were experienced. More complete recovery of nearly full size core was possible in zones where "N" values ranged between 100 and refusal, and compentent volcanic tuff is generally indicated in these areas.

Recovered cores usually parted on horizontal planes of weakness or seams into relatively thin sections during drilling, with the longest competent sections generally being about one foot in length. Exceptions were noted in test borings 3, 12 and 13 where several long competent core sections were obtained.

Unconfined compressive strengths were obtained for typical recovered tuff cores. Because short sections often were recovered, especially in areas where slightly friable tuff was encountered, some tests were conducted upon sections with ratios of length to diameter less than 2 to 1. Where longer core sections appeared to be representative of the tuff encountered in a core run these were used in compressive strength determinations. Considerable variation is apparent in the unconfined compressive strengths obtained and probably results from a lack of homogeneity within the tuff formation. Compressive failures were either diagonal or concoidal, but in many instances passed irregularly through large pumice inclusions. When such irregularities were observed in the failure surface, compressive strengths were lower than for seemingly similar tuff sections which had no large pumice inclusions. The higher strengths obtained would probably be less representative of the ultimate strength of a specific tuff interval than the average of numerous tests obtained at random throughout the interval. The majority of compressive strengths reported are representative of the underlying, harder and more competent tuff interval. A few, notably those obtained for cores recovered from borings 8, 9, 6 at elevation 6970 and 14 at elevation 6943, are representative of tuff in the transitional area where a gradual hardening occurs. Strengths reported for samples recovered from test pits located in the vicinity of Test Hole 15 pertain to the friable tuff interval which could not be successfully cored.

Stress strain curves were obtained for several tuff samples from the differing intervals. The elastic modulus values obtained from these plots were generally more uniform for samples of the harder, competent underlying tuff than were the compressive strengths; however, stress-strain relationships were established for relatively few samples. An elastic modulus of approximately 25,000 p.s.i. was obtained for the very friable tuff recovered from test pits while an approximate modulus of 200,000 p.s.i. is indicated for the underlying harder tuff. Intermediate values were obtained for tuff samples recovered from the transitional zone where gradual hardening is observed.

The grain-size distributions tabulated on the "Boring Log Graphs" are for tuff samples which have been pulverized during penetration testing.

Gravel-size particles are generally composed of uncrushed pieces of tuff; the coarse, medium, and fine sand size particles are usually individual mineral crystals; while the silt-size and some of the fine sand size particles are produced by pulverization of the matrix which fuses the tuff deposit into a low strength rock. These grain size distributions should prove indicative of the general particle size range of tuff rock which will be removed and crushed during excavation processes.

Moisture density relationships were obtained by A. S. T. M. test method D-1557 for pulverized tuff samples obtained from various borings. Maximum densities were nearly equal for pulverized samples of both hard and friable tuff. The addition of hard, unbroken tuff fragments reduced the maximum densities slightly, and produced a soil in which moisture content control is apparently not especially critical. More nearly complete pulverization of the volcanic tuff produces a more well-graded soil which can be placed at slightly higher density.

Strength characteristics of the pulverized tuff soils were investigated by several triaxial compression tests conducted upon recompacted tuff cuttings. Very high strength parameters were obtained for samples compacted to densities higher than obtainable by A. S. T. M. test method D-1557, but parameters comparable to those of a medium-dense, poorly graded, sub angular sand were observed for samples less compact. Even though a slight degree of cohesion was evidenced for both the very dense and less compact specimens, the pulverized tuff should be considered cohesionless and any apparent cohesion discounted.

Moisture contents of recovered cores and penetration samples from considerable depth were uniformly low. Higher moistures should be anticipated within the tuff formations nearer ground level where water from precipitation could be trapped and would slowly evaporate. All moisture contents were obtained by drying the recovered core section or penetration sample and the container in which the sample had been sealed to constant weight at 110$\pm$ 5°C.

Density values of typical recovered core sections were determined by displacement of paraffin coated, oven dried core sections. Occasional core samples with regular cross sections were carefully measured and their density values checked against computed densities to insure validity of procedure. Most recovered core pieces were slightly irregular in section; therefore, volumn computation was difficult and impractical in many instances. Density values generally exceeded 90 lbs. per cu. ft. for most tuff which could be successfully cored, but unit weights averaging approximately 80 lbs. per cu. ft. were obtained for tuff samples removed from test pits at approximate elevation 6970 in the vicinity of boring 15 and for tuff chunks broken from outcrops between borings 7 and 11 at elevations between 6980 and 6990.

Conclusions and Recommendations:

Based upon the subsurface conditions encountered in the twenty-five test borings drilled on the proposed site of the Los Alamos Meson Physics Facility and the properties of the underlying tuff formations indicated by the testing program conducted, we submit the following opinions and recommendations concerning foundation and embankment design for the contemplated structures:

1. Bearing capacity and foundation recommendations follow for typical sections given on sheet L-1, entitled "Typical Foundation Sections and Loads":

Section AA:

This section will be founded at an elevation (approximate elevation 6956) which is below the bottom of test borings drilled in the vicinity. Prior to construction the nature of the underlying tuff rock should be verified to a significant depth below foundation elevation. If tuff comparable to that encountered in borings No. 1 and 2 between elevations 6970 and 6960 underlies this section for a significant depth, we recommend a maximum bearing capacity of 20 kips per sq. ft. be utilized in founding static loadings. If vibratory, equipment loadings are contemplated we would recommend maximum bearing capacities be reduced to 10 kips per sq. ft.

Toe pressures under the interior portion of the retaining wall foundation provide limiting or maximum bearing pressures. For the section shown, these pressures will probably be less than the maximum static bearing value recommended if fully active lateral earth pressures are developed (an essentially hydrostatic lateral pressure distribution). This section must be well supported when adjacent backfill is compacted. Vibratory compactors in particular could damage the retaining wall if bracing were inadequate.

Computed elastic settlement (assuming a Modulus of Elasticity of 200,000 psi) is less than 0.2 inches for the section shown. Inelastic settlements are largely unpredictable and could be caused by compression of fractured or pulverized tuff beneath footings, movement of the underlying tuff along seams or joints, closing of opened seams or other unpredictable occurrence. If the tuff underlying the foundation is relatively competent, we would not anticipate major inelastic settlements.

Section BB:

The total loading on the beam channel will approach 5 kips per sq. ft. and will include the 2 kips per sq. ft. live load, the dead load of the structure and the weight of backfill. Net bearing values will be less, but where overburden pressures are released by excavation elastic

settlements should be computed using gross bearing capacities.

Bearing capacity is adequate between borings 1 and 7, and computed elastic settlement (assuming a Modulus of Elasticity of 200,000 psi) is negligible. Inelastic settlements of major magnitude are not expected for this portion of the beam channel. Between borings 7 and 12 the beam channel will be based upon a fairly soft, friable volcanic tuff which possesses low compressive strength. In the proximity of boring 12, computed elastic settlement (assuming a Modulus of Elasticity of 20,000 psi to elevation 6945) approaches 0.4 inches. Inelastic settlements could be appreciable and result in total settlements greater than the 1/2 inch considered allowable. Static bearing capacities between 4 and 6 kips per sq. ft. may be allowable for the friable tuff located between borings 7 and 12 at elevation 6970, but settlement characteristics of this tuff should be carefully evaluated by several large scale plate bearing tests. Loaded or contact areas in these tests should be as large as practicle.

A suggested alternate would be to base the beam channel upon belled piers between borings 7 and 12 with all piers carried into the gradually deepening, more competent underlying tuff encountered in test borings. Net bearing capacities of approximately 20 kips per sq. ft. would be allowable for these piers, and for the deeper piers increased bearing values would be warranted.

For the individual footing based at elevation 6998± we recommend a bearing capacity of 4 kips per sq. ft. for static loadings. These footings should be carried several feet into tuff, and as the ground surface is irregular in this locality, adjustments may be necessary in foundation depths. Foundation excavations should be carefully cleaned and inspected to insure that footings will be based on unbroken tuff. If these foundations are to be subjected to vibratory loadings piers carried into underlying, harder tuff would be preferred. Computed elastic settlement for a 4' x 4' foundation loaded to 60 kips (assuming a Modulus of Elasticity of 20,000 psi) would be negligible. Inelastic settlements would probably be of greater magnitude but should not exceed the maximum allowable settlement.

Section CC:

Toe pressures under the interior portion of the retaining wall foundation will probably exceed the allowable bearing capacity of the underlying friable tuff for the section as detailed. Elastic settlements could approach the maximum allowable and inelastic settlements could proove excessive. Vibrations transmitted through the retaining wall footing during compaction of backfill adjacent to the retaining wall could pulverize the underlying, friable tuff and produce additional localized, damaging settlements.

Utilization of belled piers based upon the more competent underlying tuff is recommended for this section. Lateral earth pressures could be reduced, in actuallity, by limiting the width of cut beyond the exterior

face of the retaining wall section and thereby reducing the quantity of backfill soil actually supported by the retaining structure. Conservative design procedure, however, will probably dictate that the wall be so proportioned to withstand fully active pressures, at least, to prevent damage from localized shifting or sliding of the adjacent tuff rock.

Section DD:

As in section AA, this foundation will be based at an elevation below the bottom of adjacent test borings. Again assuming that hard competent tuff underlies this footing to significant depths, maximum bearing values suggested for section AA are recommended. The use of 20 kips per sq. ft. would produce the smallest section that we deem practical for foundations with little confining surcharge. Very small, heavily loaded sections could cause localized slippage or failure along joints or seams existing within the tuff rock. Computed elastic settlement (assuming a Modulus of Elasticity of 200,000 psi) would be negligible for a 4' x 4' foundation loaded to 300 kips.

Section EE:

We recommend that this section be founded on belled piers carried to the more competent tuff at approximate elevation 6945. We recommend that a maximum gross bearing capacity of 30 kips per sq. ft. be used for static loadings if any severely fractured zones existing for a short distance beneath the pier are pressure grouted. If dynamic or vibratory loadings are contemplated a reduction to at most 20 kips per sq. ft. is recommended. Computed elastic settlements (assuming a Modulus of Elasticity of 200,000 psi) would be negligible and probably less than the elastic compression of a two foot diameter pier 25 feet long loaded with 550 kips. These recommendations are for footings widely spaced where interaction of pressure bulbs will not occur.

10 Kip per sq. ft. Slab, 50' x 50':

As for section EE we recommend this section be founded on belled piers carried to approximate elevation 6945±. Severely fractured zones within the underlying tuff should be pressure grouted. Air circulation was lost during coring operations at this elevation in nearby test borings. Since core recovery was high and circulation was eventually restored, cavitation if present is probably not excessive. More likely the circulation loss occurred in a severely fractured area. Because piers will be closely spaced and their pressure bulbs interact, bearing capacities recommended for section EE should be reduced when designing foundations for this large, heavily loaded section. Maximum bearing capacities between 20 and 25 kips per sq. ft. are recommended in the design of a pier foundation as described above. Computed elastic settlement for a 50' x 50' area, founded at elevation 6945 and loaded to a net intensity of 10 kips per sq. ft. would be approximately 0.25 inches if a Modulus of Elasticity of 150,000 psi were assumed to elevation 6845. This large

loaded area will be susceptible to inelastic settlements, and loading release or alteration would cause elastic rebound.

Test Borings 19 and 20

Light structural loadings are anticipated within this area. We recommend building foundations be carried at least several feet into underlying tuff and recommend the following presumptive bearing values for statically loaded footings:

Footing Type	Elevation	Max. Recommended Presumptive Bearing Cap.
Continuous foundation with a minimum width of 18"	Between 6960 & 6947	4 kips/sq.ft.
Spot footings or piers with a min. dimension of approximately 5'	Between 6960 & 6947	4 kips/sq.ft.
Piers with a diameter of approximately 4'	Between 6947 & 6945	10 kips/sq. ft.

The weakened zone encountered at elevation 6937 and below dictates a considerable bearing capacity reduction for piers or footings placed upon the harder tuff encountered at elevation 6947. If vibratory loadings or heavy structural loadings are contemplated, we recommend a foundation elevation of 6947 feet.

Test Boring 22:

Light structures without basement are anticipated at this location. We recommend an approximate foundation elevation of 7021 and a maximum presumptive bearing capacity of 6 kips per sq. ft. for continuous footings with a minimum width of 18 inches or a individual footing with a minimum dimension of four feet.

Test Boring 21:

Light structures without basement are again anticipated. We recommend bearing values outlined for boring 22 be used at a foundation elevation of 6995. Hard competent tuff is available at greater depths.

Test Boring 24 thru 28:

Light structures without basement are again anticipated. We recommend footings be carried several feet into volcanic tuff rock and at least four feet below ground level. Minimum footing sections described for boring 22 are again recommended. Maximum presumptive bearing capacities of 4 kips per sq. ft. are indicated where penetration values, "N" values, of less than 30 were obtained; and 6 kips per sq. ft. is recom-

mended where "N" values exceeded 30 consistently. If very heavy loadings or vibratory loadings are contemplated, footings should be based in areas where "N" values exceed 50.

General Observations, All Sections:

The volcanic tuff should not be considered as a uniform, cohesive soil with allowable bearing capacities equalling or often exceeding the unconfined compressive strength. Joints or seams were observed or are indicated in all tuff formations either drilled or visually inspected. These joints or seams would provide potentially weakened zones within the formation and thus produce a formation without homogeneous strength characteristics. Considering this, it is our opinion that a safety factor of at least 5 and possibly as high as 10 should be used in determining an allowable bearing capacity for the volcanic tuff formation when the unconfined compressive strength of this formation is known. For static loadings only, a factor of 5 would in our opinion proove adequate, but for vibratory loadings a factor as high as 10 may be indicated.

As unconfined compressive strength tests were determined for specimens at their low, natural moisture contents, these bearing capacities pertain to relatively dry tuff formations. Care should be exercised during construction to prevent intrusion of water into foundation excavations during construction. Backfills against retaining walls should be sloped slightly to afford surface drainage away from these walls to prevent saturation of these backfills and underlying tuff.

Particular care should be taken to insure that overcuts are not made during foundation excavation. We recommend that no backfill be permitted beneath foundations, and that excavations be carefully cleared of all loose soil and debris before concrete placement to insure a good contact between foundations and sound, underlying tuff.

Settlement predictions for the various foundation sections were made on the basis of elastic deflections within the loaded tuff formation, and thus differ from methods traditionally utilized for settlement prediction in soils. Other settlements which are non-elastic in nature and which are largely unpredictable in magnitude may occur when the tuff formation is stressed. It is our opinion these non-elastic settlements will be of minor consequence in the harder, more competent tuffs which exhibit "N" values between 100 and refusal. In the more friable tuffs, especially those with very low "N" values, these settlements could be of major consequence.

2. It is our opinion that the tuff excavated from on site will provide an excellent material for embankment fill and fill behind retaining structures. To provide suitable fills we would recommend that no unbroken tuff particles exceeding three inches in dimension be allowed in fills and that the tuff be pulverized until a minimum of 50 percent will pass

a No. 4 mesh sieve. The pulverized tuff will be an essentially cohesionless soil and compaction methods suitable for sands should prove appropriate. Small steel wheeled vibratory rollers would probably compact this material most efficiently - perhaps to densities in excess of those obtained by A. S. T. M. test method D-1557-64T. Shrinkages will result when the volcanic tuff is pulverized and recompacted with a probable shrinkage range between 10 and 30 percent.

3. We believe that excavated volcanic tuff can be adequately pulverized without the use of on-site crushing or screening equipment. Heavy dozer drawn rippers may be required during excavation, especially between borings 1 and 5. The softer more friable tuffs may be readily removed by bottom discharge carry-alls without previous ripping. Much pulverization will be accomplished during excavation. Any remaining crushing can probably be accomplished by crawler tractors pulling sheepsfoot rollers when excavated materials are stockpiled.

4. For fill slopes we would consider a slope ratio of 2:1 (2 horizontal to 1 vertical) as optimum. Since these fill materials are cohesionless erosion protection or slope maintenance will be necessary. Nearly vertical cut slopes have proven satisfactory in the tuff formations for highway cuts around Los Alamos.

Respectfully Submitted,

ALBUQUERQUE TESTING LABORATORY

By John P. Boyd

John P. Boyd, Materials Engineer

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ALBUQUERQUE, NEW MEXICO

Lab No. 6209 Date July 13, 1966

Engineer or Architect Giffels & Rossetti

Contractor

Sample Identification Composite cuttings from Test Holes 1 & 4 to Elev. 6970

Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Method of Compaction A.S.T.M. D 1557 Method "B"

Date Received June 3, 1966 Date Tested June 6, 1966

LABORATORY DETERMINATION OF OPTIMUM MOISTURE AND MAXIMUM DENSITY

Test Results

Trial No.	1	2	3	4			
Water added (cc)	517	603	690	776			
Weight of Cylinder + Wet Soil (lbs)	23.20	23.62	23.68	23.58			
Weight of Cylinder (lbs)	----------	---------- 14.60	----------	----------			
Weight of Wet Soil (lbs)	8.60	9.02	9.08	8.98			
Weight Density (lbs/cu ft)	114.6	120.2	121.0	119.7			

Volume of mold used in compaction test 0.075 cu. ft.

Weight Wet Soil ~~(grams)~~ (lbs)	8.61	9.00	9.07	8.96			
Weight Dry Soil ~~(grams)~~ (lbs)	7.68	7.91	7.83	7.61			
% Moisture in terms of dry soil weight	12.11	13.78	15.84	17.74			
Dry Density (lbs/cu ft)	102.2	105.6	104.4	101.6			

Respectfully Submitted,
ALBUQUERQUE TESTING LAB.
Original Signed By
David T. Lloyd
Registered Professional Engineer

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Laboratory Reference No. 6209 Date July 14, 1966

MODIFIED
PROCTOR COMPACTION TEST

Reported To: Giffels & Rossetti

Architect and/or Engineer " "

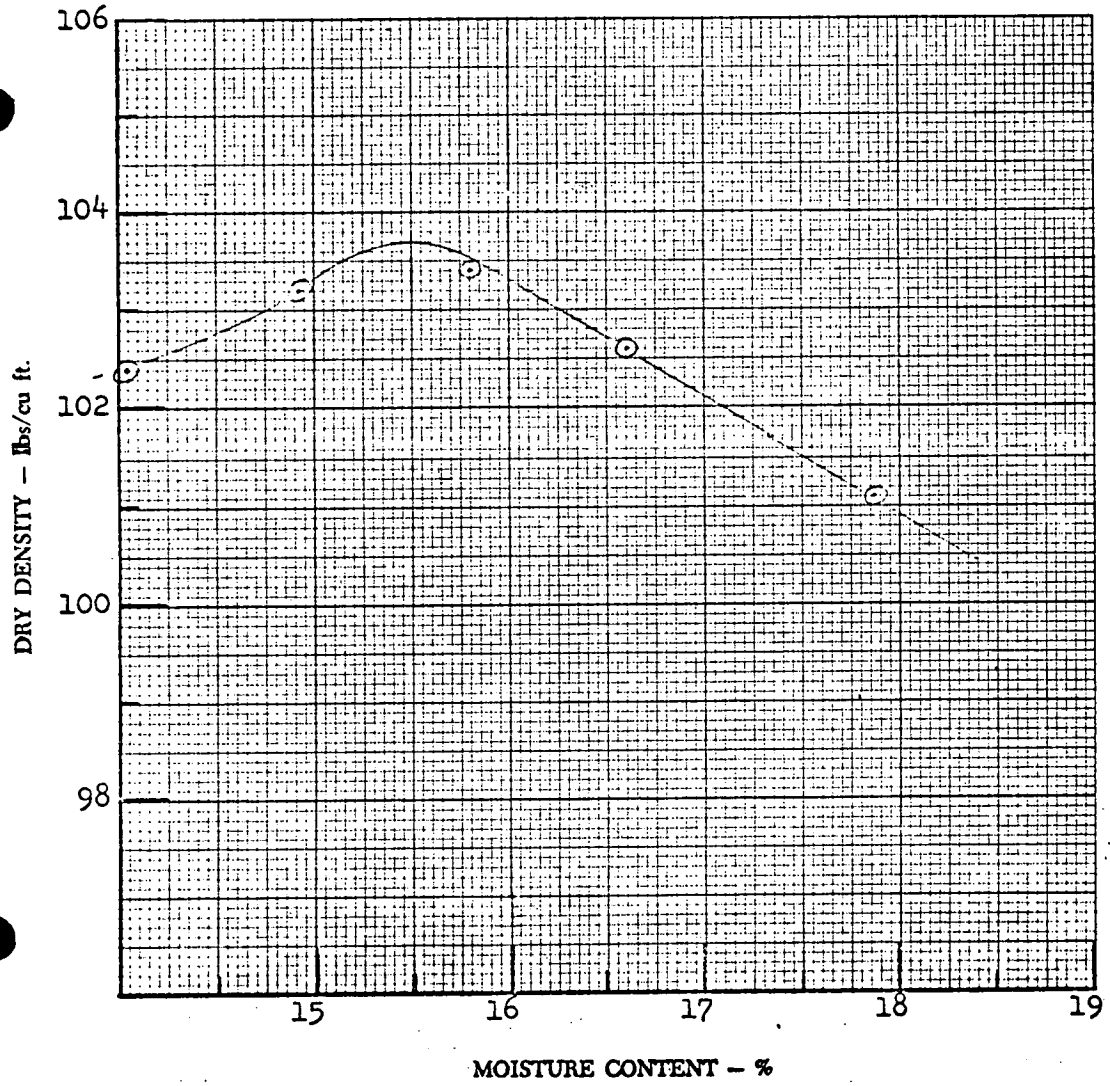
Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Sample Identification 50% Composite volcanic tuff cuttings from Test Holes 1 & 4 to Elevation 6970; 50% Minus 3/4" to Plus No. 4 mesh volcanic tuff fragments obtained

TEST RESULTS

Maximum Dry Density — 103.7 lbs/cu. ft.

Optimum Moisture — 15.5 %



Gradation of Aggregate or Soil Used in Compaction Test

Screen Size	Cumulative % Passing
3/4"	100.0
1/2"	65.4
3/8"	57.2
No. 4	50.0
No. 10	47.7
No. 30	32.8
No. 60	26.2
No. 100	23.2
No. 200	19.3
No. 270	17.6
Wash Test	16.1

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ALBUQUERQUE, NEW MEXICO

Lab No. 6209 Date July 14, 1966

Engineer or Architect Giffels & Rossetti

Contractor

Sample Identification 50% Composite volcanic tuff cuttings from Test Holes 1 & 4 to elevation 6970; 50% Minus 3/4" to Plus No. 4 mesh volcanic tuff fragments obtained from sound recovered core sections.

Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Method of Compaction A.S.T.M. D-1557 Method "D"

Date Received June 3, 1966 Date Tested July 12, 1966

LABORATORY DETERMINATION OF OPTIMUM MOISTURE AND MAXIMUM DENSITY

Test Results

Trial No.	1	2	3	4	5		
Water added (cc)	603	646	690	733	776		
Weight of Cylinder + Wet Soil (lbs)	23.36	23.50	23.59	23.57	23.54		
Weight of Cylinder (lbs)	----------	----------	14.60	----------	----------		
Weight of Wet Soil (lbs)	8.76	8.90	8.99	8.97	8.94		
Weight Density (lbs/cu ft)	116.8	118.6	119.8	119.6	119.2		

Volume of mold used in compaction test 0.075 cu. ft.

Weight Wet Soil (~~grams~~) (lbs)	8.77	8.93	9.01	8.98	8.97		
Weight Dry Soil (~~grams~~) (lbs)	7.69	7.77	7.78	7.70	7.61		
% Moisture in terms of dry soil weight	14.04	14.93	15.81	16.62	17.87		
Dry Density (lbs/cu ft)	102.4	103.2	103.4	102.6	101.1		

Respectfully Submitted,
ALBUQUERQUE TESTING LAB.
Original Signed By
David T. Lloyd
Registered Professional Engineer

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ALBUQUERQUE, NEW MEXICO

Laboratory Reference No. 6209 Date July 14, 1966

MODIFIED
PROCTOR COMPACTION TEST

Reported To: Giffels & Rossetti

Architect and/or Engineer " "

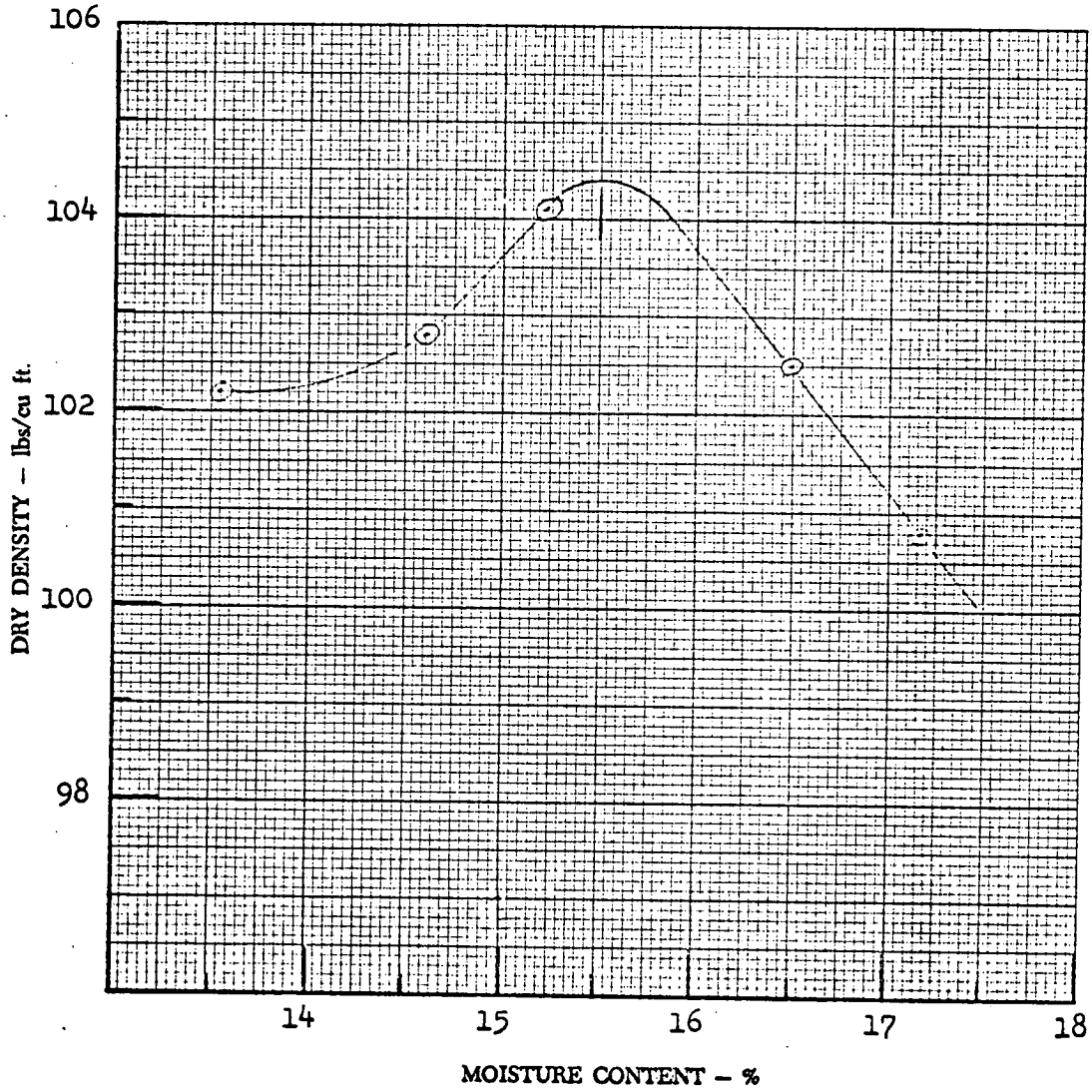
Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Sample Identification Composite volcanic tuff cuttings from Test Hole 7 & 11 to Elevation 6970

TEST RESULTS

Maximum Dry Density – 104.4 lbs/cu. ft.

Optimum Moisture – 15.5 %



Gradation of Aggregate or Soil Used in Compaction Test

Screen Size	Cumulative % Passing
No. 4	100.0
No. 10	96.2
No. 30	62.9
No. 60	50.0
No. 100	44.0
No. 200	35.2
No. 270	30.9
Wash Test	26.8

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ALBUQUERQUE, NEW MEXICO

Lab No. 6209 Date July 14, 1966

Engineer or Architect Giffels & Rossetti

Contractor

Sample Identification Composite volcanic tuff cuttings from Test Hole 7 & 11 to Elev. 6970

Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Method of Compaction A.S.T.M. D-1557 Method "B"

Date Received July 1, 1966 Date Tested July 8, 1966

LABORATORY DETERMINATION OF OPTIMUM MOISTURE AND MAXIMUM DENSITY

Test Results

Trial No.	1	2	3	4	5		
Water added (cc)	603	646	689	733	776		
Weight of Cylinder + Wet Soil (lbs)	23.30	23.44	23.60	23.56	23.46		
Weight of Cylinder (lbs)	-------	-------	14.60	-------	-------		
Weight of Wet Soil (lbs)	8.70	8.84	9.00	8.96	8.86		
Weight Density (lbs/cu ft)	116.0	117.8	120.0	119.4	118.1		

Volume of mold used in compaction test 0.075 cu. ft.

Weight Wet Soil ~~(grams)~~ (lbs)	8.72	8.87	9.01	8.97	8.87		
Weight Dry Soil ~~(grams)~~ (lbs)	7.68	7.74	7.82	7.70	7.57		
% Moisture in terms of dry soil weight	13.54	14.60	15.22	16.49	17.17		
Dry Density (lbs/cu ft)	102.2	102.8	104.1	102.5	100.8		

Respectfully Submitted,
ALBUQUERQUE TESTING LAB.
Original Signed By
David T. Lloyd
Registered Professional Engineer

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ALBUQUERQUE TESTING LABORATORY

Laboratory Reference No. 6902 Date July 13, 1966

MODIFIED
PROCTOR COMPACTION TEST

Reported To: Giffels & Rosetti

Architect and/or Engineer " "

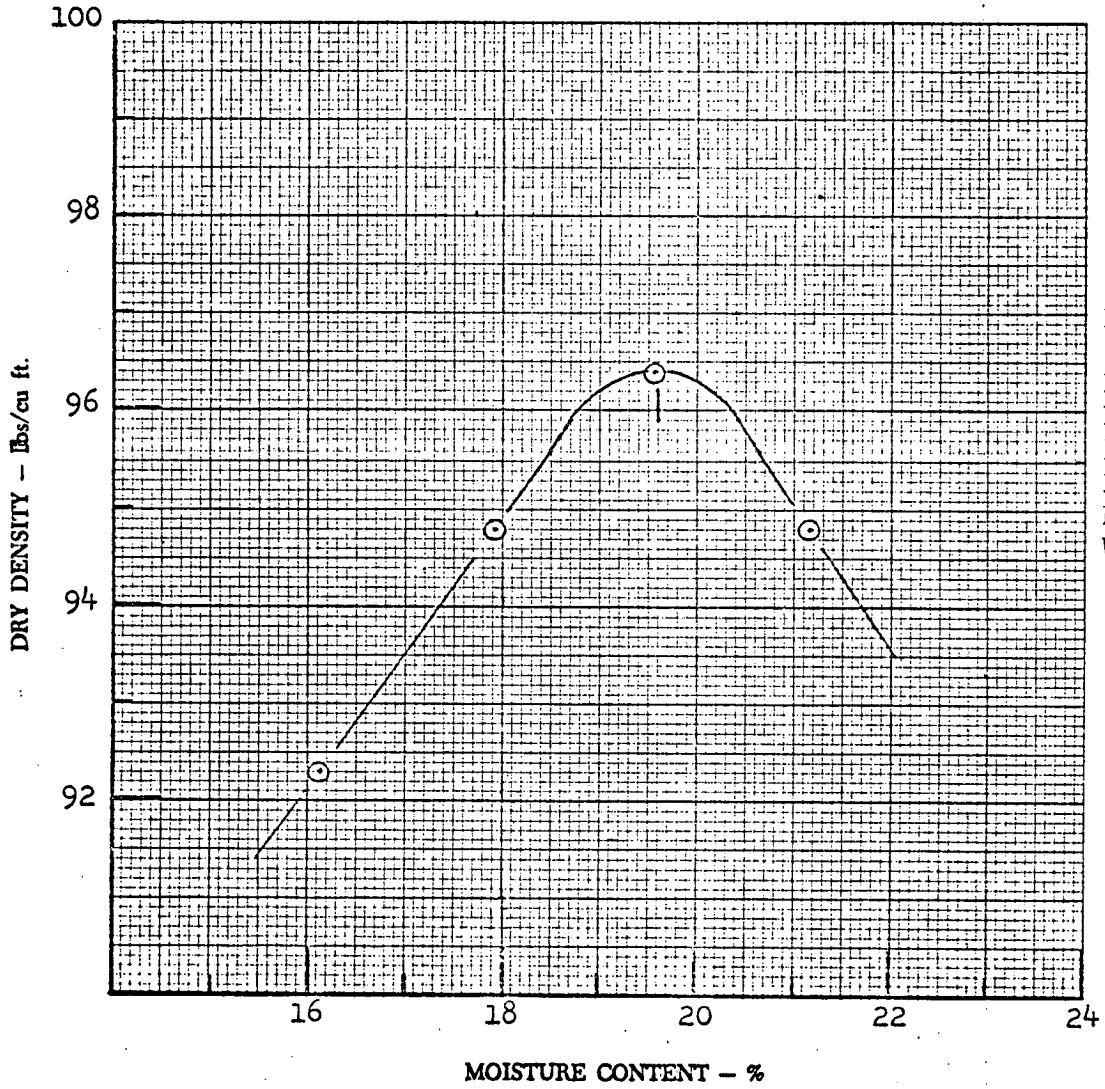
Project Los Alamos Meson Physics Facility- Los Alamos, New Mexico

Sample Identification Friable volcanic tuff removed from outcrops between Test Hole 7 & 11 and crushed to minus No. 4 mesh size.

TEST RESULTS

Maximum Dry Density – 96.4 lbs/cu. ft.

Optimum Moisture – 19.6 %



Gradation of Aggregate or Soil Used in Compaction Test

Screen Size	Cumulative % Passing
No. 4	100.0
No. 10	89.2
No. 30	46.7
No. 60	34.0
No. 100	28.5
No. 200	22.4
No. 270	20.0
Wash Test	17.0

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ALBUQUERQUE, NEW MEXICO

Lab No. 6902 Date July 13, 1966

Engineer or Architect Giffels & Rossetti

Contractor

Sample Identification Friable volcanic tuff removed from outcrops between Test Hole 7 & 11 and crushed to minus No. 4 mesh size

Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Method of Compaction A.S.T.M. D 1557 Method "B"

Date Received June 24, 1966 Date Tested June 29, 1966

LABORATORY DETERMINATION OF OPTIMUM MOISTURE AND MAXIMUM DENSITY

Test Results

Trial No.	1	2	3	4			
Water added (cc)	689	776	862	948			
Weight of Cylinder + Wet Soil (lbs)	22.64	22.99	23.25	23.22			
Weight of Cylinder (lbs)	-------	-------	14.60	-------			
Weight of Wet Soil (lbs)	8.04	8.39	8.65	8.62			
Weight Density (lbs/cu ft)	107.2	111.8	115.3	114.9			

Volume of mold used in compaction test 0.075 cu. ft.

Weight Wet Soil (~~grams~~) (lbs)	8.07	8.42	8.68	8.65			
Weight Dry Soil (~~grams~~) (lbs)	6.95	7.14	7.26	7.14			
% Moisture in terms of dry soil weight	16.12	17.93	19.56	21.15			
Dry Density (lbs/cu ft)	92.3	94.8	96.4	94.8			

Respectfully Submitted,
ALBUQUERQUE TESTING LAB.
Original Signed By
David T. Lloyd
Registered Professional Engineer

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Laboratory Reference No. 6209 Date July 13, 1966

MODIFIED
PROCTOR COMPACTION TEST

Reported To: Giffels & Rossetti

Architect and/or Engineer " "

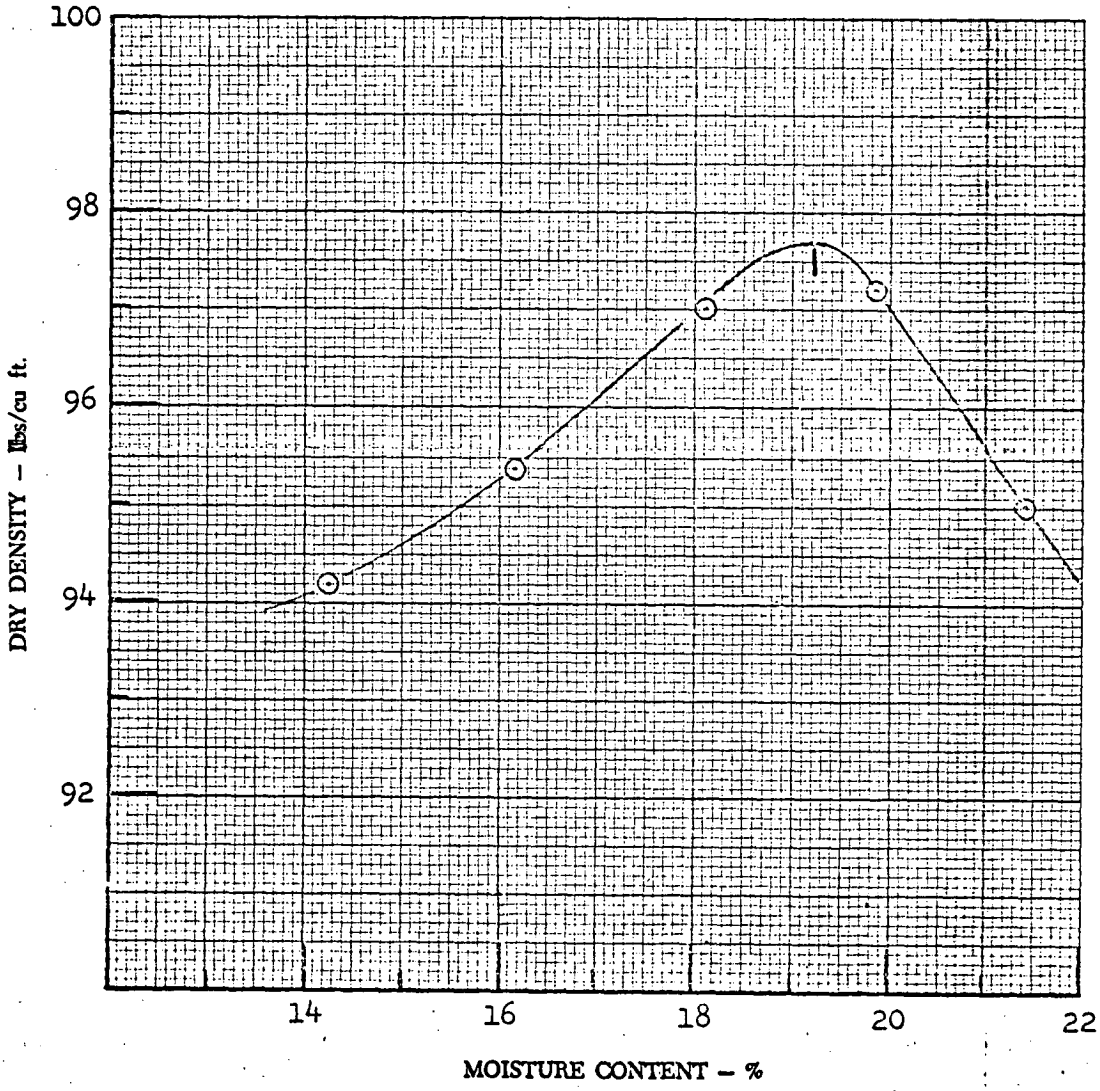
Project Los Alamos Meson Physics Facility - Los Alamos, New Mexico

Sample Identification Friable volcanic tuff removed from outcrops between Test Hole 7 & 11 and crushed to minus 3/4" size

TEST RESULTS

Maximum Dry Density — 97.7 lbs/cu. ft.

Optimum Moisture — 19.2 %



Gradation of Aggregate or Soil Used in Compaction Test

Screen Size	Cumulative % Passing
3/4"	100.0
1/2"	89.5
3/8"	73.7
No. 4	59.0
No. 10	52.6
No. 30	27.6
No. 60	20.1
No. 100	16.8
No. 200	13.2
No. 270	11.8
Wash Test	10.0

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ALBUQUERQUE, NEW MEXICO

Lab No. 6209 Date July 13, 1966

Engineer or Architect Giffels & Rossetti

Contractor

Sample Identification Friable volcanic tuff removed from outcrops between Test Hole 7 & 11 and crushed to Minus 3/4" size

Project Los Alamos Meson Physics Facility- Los Alamos, New Mexico

Method of Compaction A.S.T.M. D 1557 Method "D"

Date Received June 24, 1966 Date Tested June 29, 1966

LABORATORY DETERMINATION OF OPTIMUM MOISTURE AND MAXIMUM DENSITY

Test Results

Trial No.	1	2	3	4	5		
Water added (cc)	603	689	776	862	948		
Weight of Cylinder + Wet Soil (lbs)	22.67	22.91	23.19	23.34	23.25		
Weight of Cylinder (lbs)	-------	--------	14.60	-------	-------		
Weight of Wet Soil (lbs)	8.07	8.31	8.59	8.74	8.65		
Weight Density (lbs/cu ft)	107.6	110.8	114.5	116.5	115.3		

Volume of mold used in compaction test 0.075 cu. ft.

Weight Wet Soil (~~grams~~) (lbs)	8.10	8.33	8.63	8.76	8.67		
Weight Dry Soil (~~grams~~) (lbs)	7.09	7.17	7.29	7.31	7.14		
% Moisture in terms of dry soil weight	14.24	16.18	18.10	19.84	21.43		
Dry Density (lbs/cu ft)	94.2	95.4	97.0	97.2	95.0		

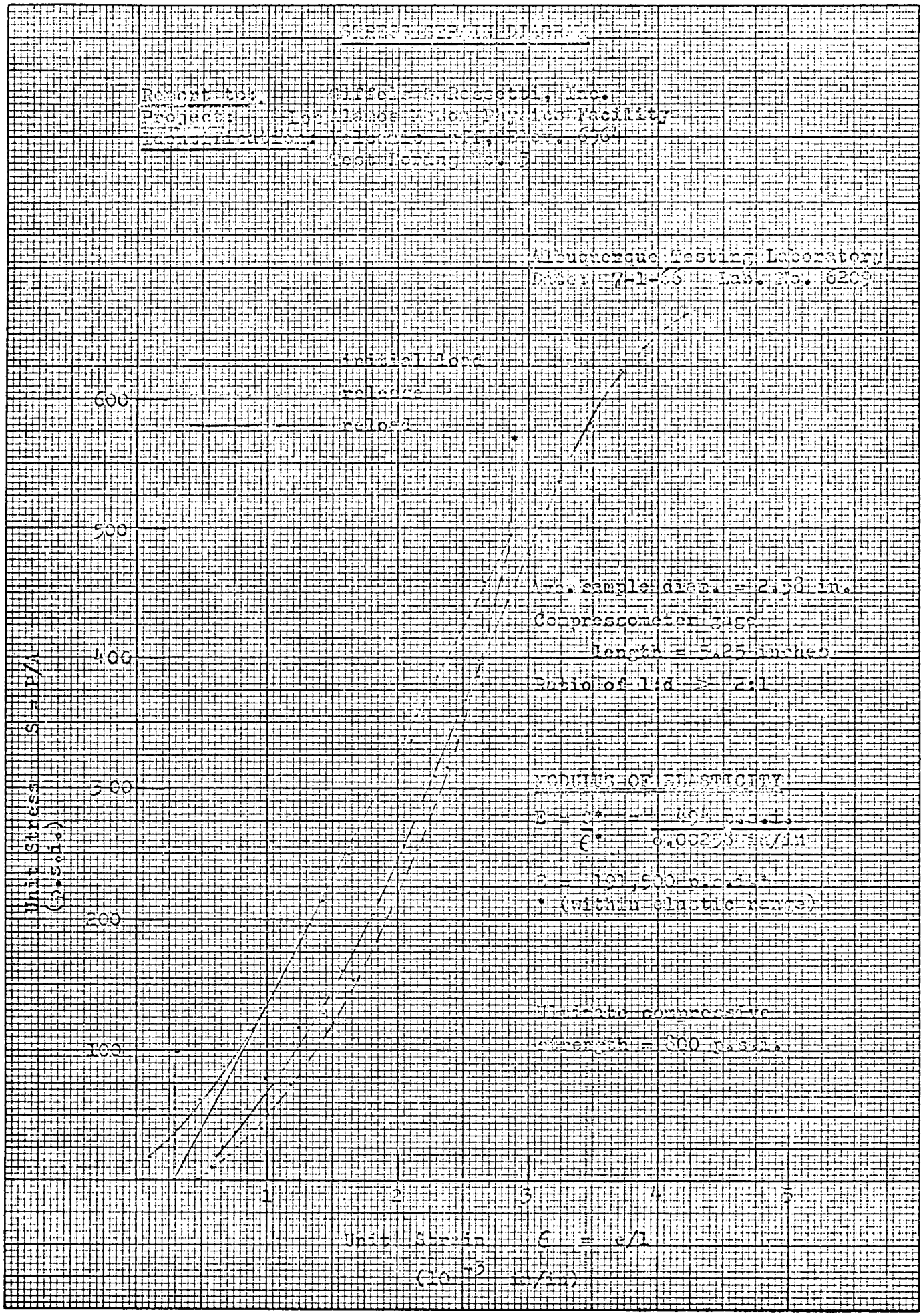
Respectfully Submitted,
ALBUQUERQUE TESTING LAB.
Original Signed By
David T. Lloyd
Registered Professional Engineer

Lab. No. 6209
Giffels & Rossetti

ALBUQUERQUE TESTING LABORATORY

TEST DATA
Unconfined Compressive Strength

Test Hole & Elevation	Ave. Diameter (in.)	X-Section Area (sq. in.)	Height (in.)	Compressive Load (lbs)	Compressive Strength (p.s.i.)	Ratio ℓ:d
1- 6968	2.55	5.11	3.8	6250	1225	1.5
1- 6960	2.48+	4.85	5.2	3300	680	2+
2-6968	2.51	4.95	4.1	5100	1030	1.6
3- 6966	2.55	5.11	4.2	5700	1115	1.65
3- 6964	2.58	5.23	7+	4200	805	2+
4- 6965	2.55	5.11	7+	5000	980	2+
4- 6964	2.60	5.31	4.0	4550	855	1.55
5- 6961	2.55	5.11	3.5	6750	1320	1.4
6- 6970	2.52	5.00	4.6	2800	560	1.8
6- 6962	2.48+	4.85	3.3	6250	1290	1.3
7- 6962	2.51	4.95	4.7	4450	900	1.9
8- 6965	2.52	5.00	4.3	1200	240	1.7
9- 6962	2.52	5.00	4.2	1350	270	1.7
9- 6961	2.55	5.11	4.0	1375	270	1.6
10	No core recovered					
11- 6953	2.52-	4.97	4.0	3850	775	1.6
12- 6944	2.44+	4.70	4.8	4850	1030	2.0
12- 6934	2.53	5.03	4.4	5300	1055	1.75
12- 6932	2.59	5.27	6+	3300	625	2+
13- 6946	2.60	5.31	5.2	4950	930	2.0
13- 6938	2.54	5.07	4.4	4100	810	1.75
13- 6930	2.59-	5.25	5.3	3200	610	2+
14- 6943	2.52-	4.27	5.2	2050	410	2+
14- 6940	2.60	5.31	4.6	3650	685	1.75
14- 6932	2.56	5.15	5.1	5150	1000	2.0
15- 6937	2.59-	5.25	4.6	5800	1105	1.8
15- 6925	2.52	4.97	3.8	2000	400	1.5
16- 6945	2.55	5.11	5.3	5150	1010	2+



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20 X 20 PER INCH

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L[illegible] No. 6209
Giffels & Rossetti

TEST DATA

Stress Strain Determinations

Core Sample, T.H. No. 3, Elev. 6964

Initial Loading		Release		Reloading	
Compressometer Dial Reading (10^{-4} in.)	Axial Load (lbs)	Compressometer Dial Reading (10^{-4} inches)	Axial Load (lbs)	Compressometer Dial Reading (10^{-4} in.)	Axial Load (lbs)
5	50	300	2590	60	60
10	90	275	2020	70	140
15	120	250	1660	80	200
20	145	225	1325	90	280
25	170	200	1055	105	410
30	195	175	805	130	615
35	225	150	675	165	850
40	255	125	390	190	1075
45	290	100	210	215	1345
50	325	75	100	240	1620
60	400	50	0+	265	1930
70	460	40	0	290	2240
80	530			315	2510
90	605			340	2810
100	695			365	3050
110	760			390	3260
120	850			440*	3480
130	940				
140	1030				
150	1125				
160	-				
170	1310				
180	-				
190	1500				
200	1600				
220	1770				
240	1990				
260	2200				
280	2400				
300	2590				

Ave. sample diameter = 2.58 inches
Compressometer gage length = 5.25 inches

Total deformation = $\frac{\text{Dial reading}}{2.0}$

* - Compressometer removed

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Requested by: [illegible]

Prepared: [illegible]

Identification: [illegible] 6965

[illegible] No. 4

[illegible] Laboratory

Date: 7-1-66 Lab. No. 6209

Ave. sample diam. = 2.55 in.

Compressometer gage length = 5.25 inches

Ratio of L : d = 2 : 1

Modulus of Elasticity

$E = \frac{\sigma}{\epsilon} = \frac{[illegible]}{0.00097}$

E = 200,700 p.s.i.*

* (within elastic range)

Ultimate Compressive strength = 980 p.s.i.

ALBUQUERQUE TESTING LABORATORY

Lab. No. 6209
Giffels & Rossetti

TEST DATA

Stress Strain Determinations

Core Sample, T.H. No. 4, Elev. 6965

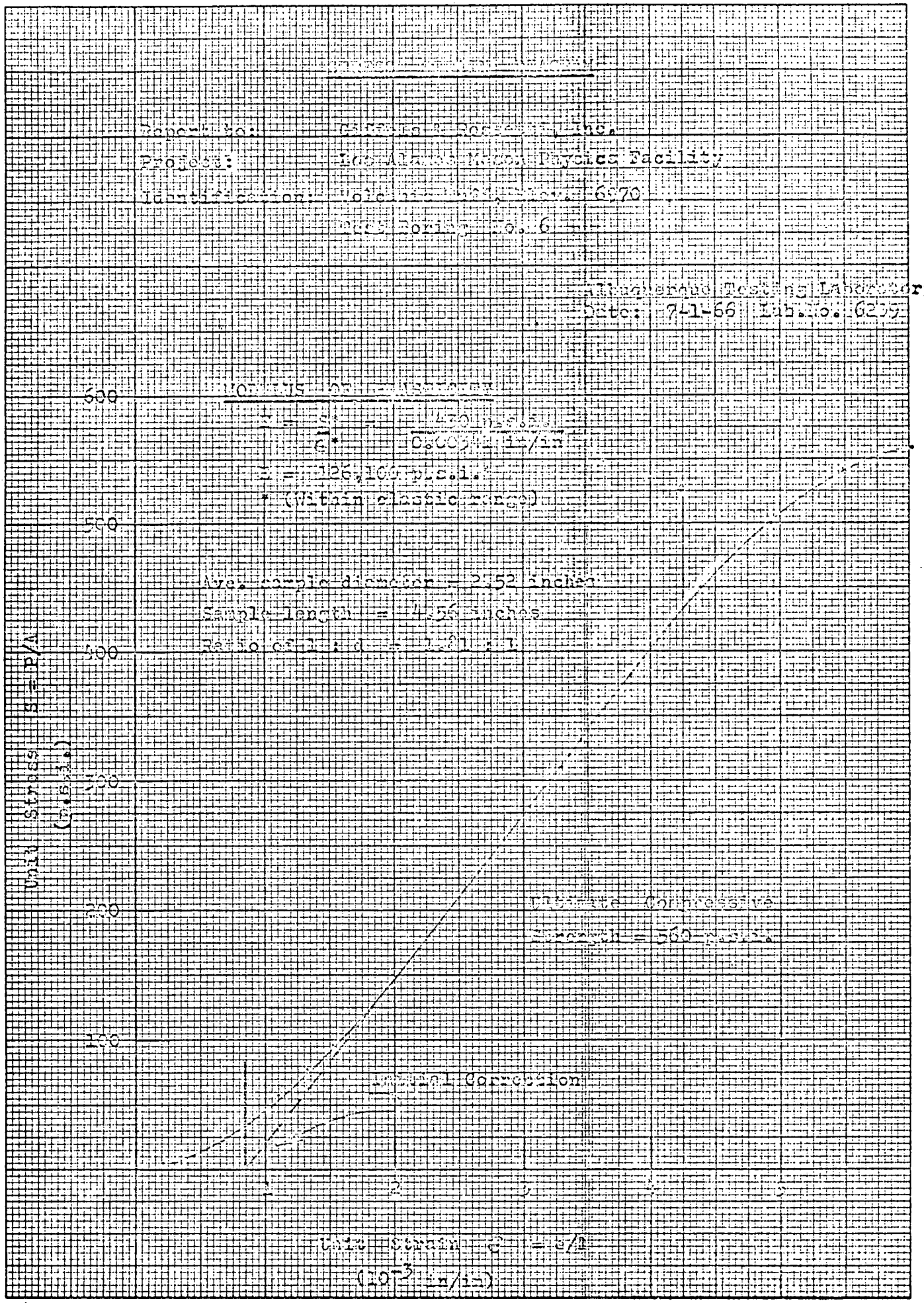
Initial Loading

Compressometer Dial Reading (10^{-4} inches)	Axial Load (lbs)
10	90
20	160
30	220
40	285
50	345
60	410
70	480
80	540
90	620
100	690
125	890
150	1100
175	1325
200	1560
225	1800
250	2030
275	2300
300	2530
325	2800
350 *	3040

*Compressometer removed

Ave. sample diameter = 2.55 inches
Compressometer gage length = 5.25 inches

Total deformation = $\frac{\text{dial reading}}{2.0}$



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TEST DATA

Stress Strain Determinations

Core Sample, T.H. No. 6, Elev. 6970

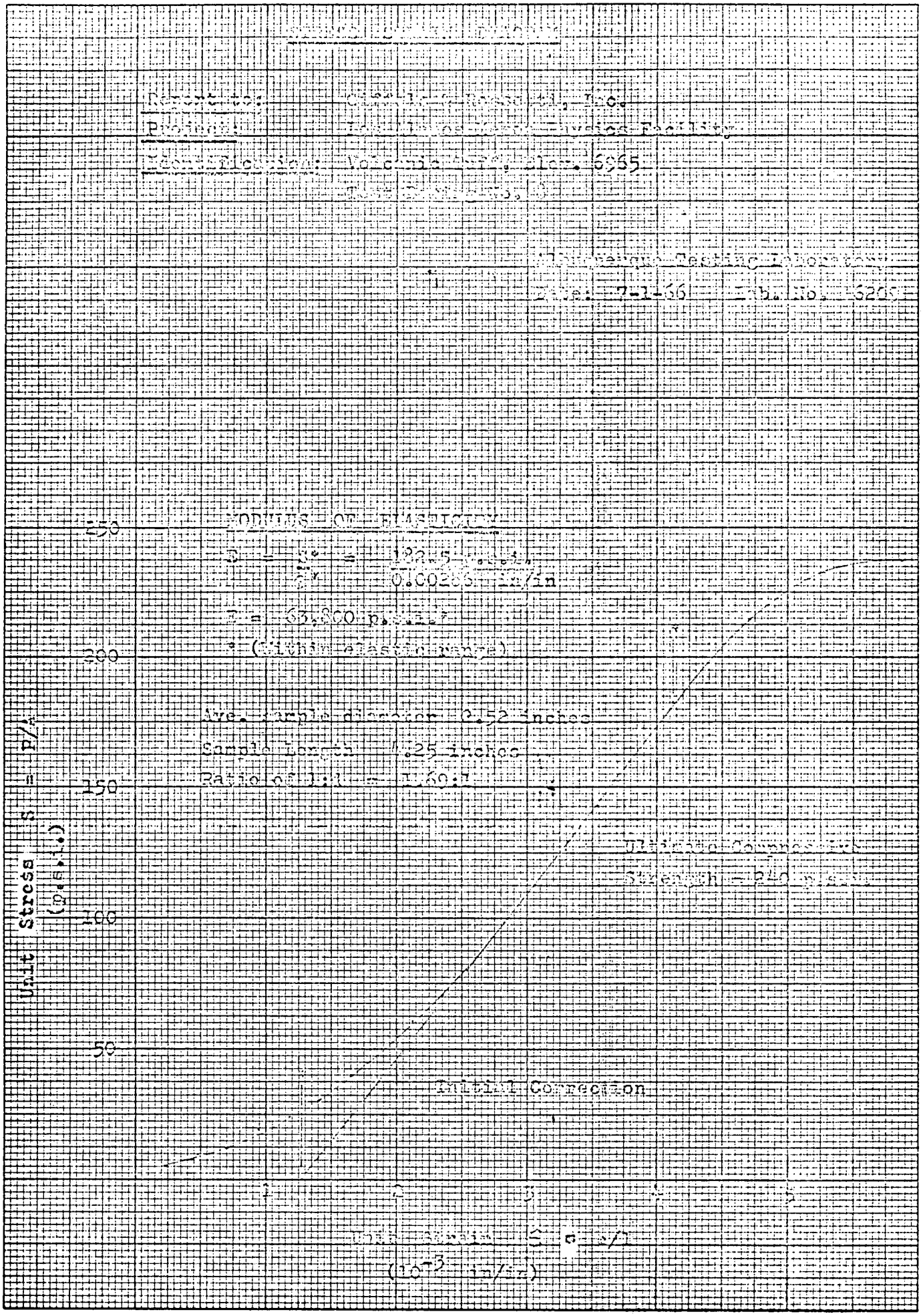
Initial Loading

Axial Compression Dial Reading * (10^{-4} inches)	Axial Load (lbs)
10	25
20	60
30	110
40	190
50	290
60	385
70	480
80	600
90	720
100	850
125	1200
150	1550
175	1910
200	2250
225	2500
250	2710
275	2790
Ultimate	2800

* Core section of insufficient length to affix compressometer. Axial movement of testing machine platen measured by two Ames dial indicators.

Ave. sample diameter = 2.52 inches
Sample length = 4.56 inches

Total deformation = dial reading



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TEST DATA

Stress Strain Determinations

Core Sample, T.H. No. 8, Elev. 6965

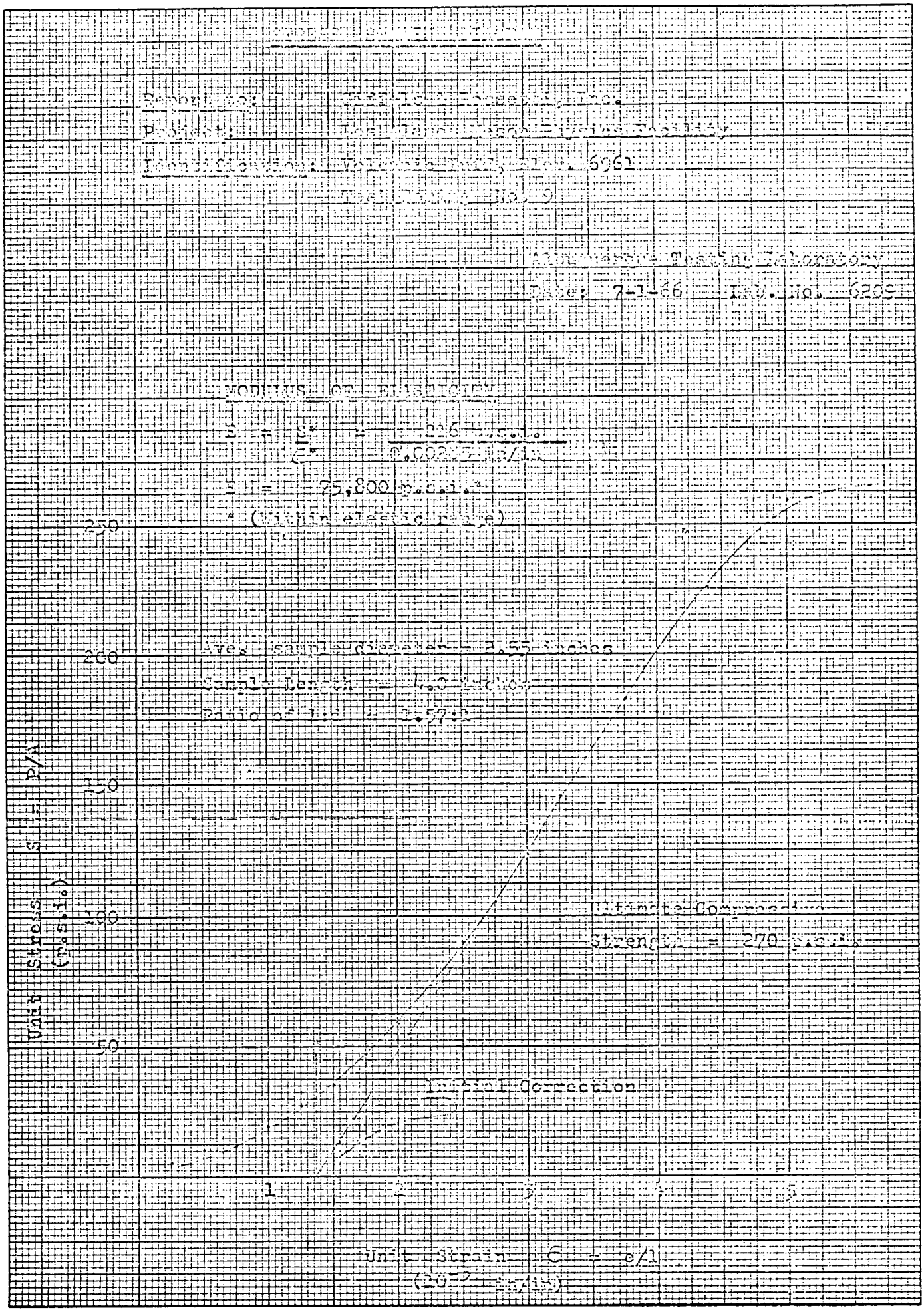
Initial Loading

Axial Compression Dial Reading * (10⁻⁴ inches)	Axial Load (lbs)
10	25
20	45
30	60
40	95
50	120
60	155
70	200
80	250
90	305
100	355
110	415
120	490
130	560
140	630
150	710
175	910
200	1070
225	1160
250	1180
Ultimate	1200

*Axial compression measured by Ames dial indicators

Average sample diameter = 2.52 inches
Sample length = 4.25 inches

Total deformation = dial reading



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TEST DATA

Stress Strain Determination

Core Sample, T.H. No. 9, Elev. 6961

Initial Loading

Axial Compression* Dial Reading (10 inches)	Axial Load (lbs)
10	30
20	55
30	60
40	100
50	140
60	180
70	240
80	300
90	375
100	460
110	540
120	630
130	740
140	840
150	930
175	1150
200	1325
225	1350
Ultimate	1375

*Axial compression measured by Ames dial indicators

Average sample diameter = 2.55 inches
Sample length = 4.00 inches

Total deformation = dial reading

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TEST DATA

Stress Strain Determinations

Core Sample, T.H. No. 12, Elev. 6932

Initial Loading

Compressometer Dial Reading (10^{-4} inches)	Axial Load (lbs)
10	100
20	190
30	260
40	340
50	410
60	490
70	560
80	650
90	725
100	810
125	1020
150	1230
175	1430
200	1630
225	1830
250	2025
275	2230
300	2430
325	2630
350	2810
375	2980
400 *	3130

* Compressometer removed

Ave. sample diameter = 2.59 inches
Compressometer gage length = 5.25 inches

Total deformation = $\frac{\text{dial reading}}{2.0}$

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TEST DATA

Stress Strain Determinations

Volcanic tuff removed from Test Pit No. 1, 60' North of T.H. No. 15, Elev. 6970±

Initial Loading

Axial compression* Dial Reading (10 inches	Axial Load (lbs)	
10	40	
20	60	
30	90	
40	120	
50	140	
60	160	
70	175	
80	200	
90	240	
100	265	
110	325	
120	390	
130	450	
140	525	
160	690	
180	860	
200	1050	
225	1300	
250	1550	
275	1775	
300	1965	
325	2060	
350	2115	
375	2125	Ultimate
400	2110	

Ave. X-section dimensions = 4.02 x 4.03 inches

Sample length = 4.30 inches

Total deformation = dial reading

*Axial compression measured by Ames dial indicators

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TEST DATA

Stress Strain Determinations

Volcanic tuff removed from Test Pit No. 2,

90' Northwest of T.H. No. 15, Elev. 6970±

Initial Loading

Axial compression Dial Reading* (10 inches)		Axial Load (lbs)
10		40
20		60
30		100
40		130
50		140
60		150
70		170
80		205
90		240
100		290
110		360
120		450
130		550
140		655
160		875
180		1100
200		1310
225		1540
250		1760
275		1960
300		2080
325		2150
350		2175
375	Ultimate	2200

Ave. X-section dimensions = 4.06 x 4.10 inches

Sample length = 4.75 inches

Total deformation = dial reading

*Axial compression measured by Ames dial indicators

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ALBUQUERQUE TESTING LABORATORY

Lab. No. 6209

Giffels & Rossetti

TEST DATA

Stress Strain Determination

Volcanic tuff removed from Test Pit No. 3,

90' West of T. H. No. 15, Elev. 6970±

Initial Loading		Release		Reloading	
Axial Compr* Dial reading (10⁻⁴ inches)	Axial Load (lbs)	Axial compr. Dial Reading (10⁻⁴ inches)	Axial Load (lbs)	Axial Compr. Dial Reading (10⁻⁴ inches)	Axial Load (lbs)
10	20	225	650	125	100
20	50	200	410	150	210
30	60	175	230	175	360
40	90	150	95	200	560
50	100	125	30	225	810
60	125	100	15	250	1040
70	140			275	1250
80	160			300	1420
90	210			325	1560
100	240			350	1670
110	275			375	1750
120	325			400	1810
130	375			425	1840
140	430			Ultimate	1870
160	540				
180	660				
200	795				
225	940				
250	1110				

*Axial compression measured by Ames dial indicators

Ave. X-section dimensions = 3.95 x 3.98 inches

Sample length = 5.80 inches

Total deformation = dial reading

Lab. No. 6209 July 19, 1966

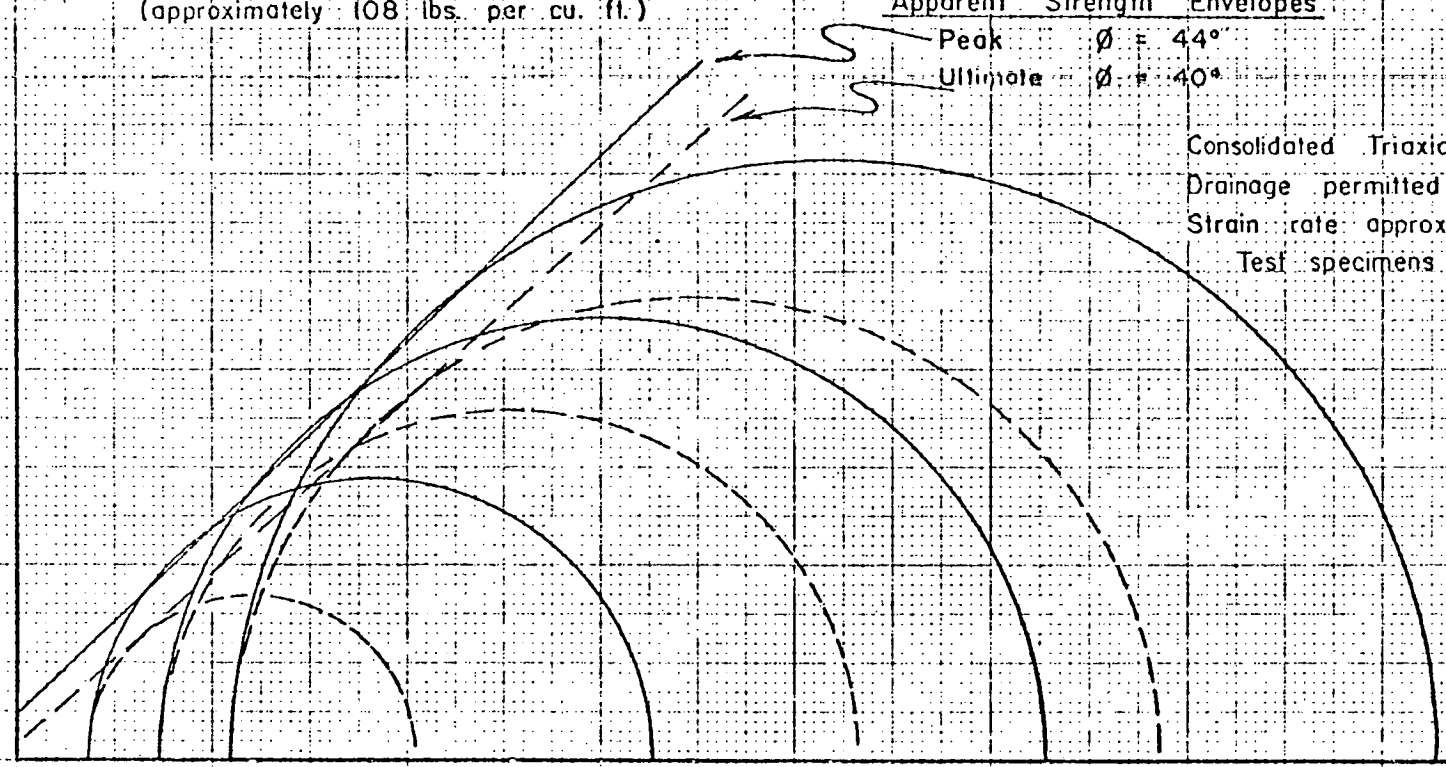
MOHR DIAGRAM

Reported to: Giffels & Rossetti, inc.

Project: Los Alamos Meson Physics Facility

Sample Identification: Volcanic tuff cuttings from T. H. 7 & 11 to elevation 6970

Tuff cuttings compacted to a very dense state.
(approximately 108 lbs. per cu. ft.)



Scale: 1" = 4 tons per sq. ft.

Albuquerque Testing Laboratory

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XXXXXXXXXXXXXXXXXXXXXXXXX

Volcanic Tuff Cuttings - T.H. 7 & 11
Elevation 6970

1 July 14, 1966

1.313 in 2.816 in 1.354 sq. in.

262.0 gm
138.5 gm
123.5 gm 108.0 gm
14.35 108.0
103.4
20 28.7 cc

27.3 Δ 1.4

2 0.937 lbs per division

0.000 .007

ft 0.0092 2.811 in

Dial Reading (in)	Vertical Strain (ε)	Δ	Δ/L	Corr. Area (ft²)		xxxxxxx (ft²)		
0	0			0.0092			27.3	0.0
24	0.010	0.0076	0.27	0.0092	22.49	2440	"	"
58	0.020	0.0142	0.50	0.0092	54.35	5910	"	"
92	0.030	0.0208	0.74	0.0093	86.20	9270	27.2	-0.1
123	0.040	0.0277	0.98	0.0093	115.2	12390	"	"
153	0.050	0.0347	1.23	0.0093	143.4	15420	"	"
180	0.060	0.0420	1.49	0.0093	168.7	18140	"	"
204	0.070	0.0496	1.76	0.0094	191.2	20340	27.3	0.0
222	0.080	0.578	2.05	0.0094	208.0	22130	27.5	+0.2
235	0.090	0.0665	2.36	0.0095	220.2	23180	27.8	+0.5
239.5	0.100	0.0760	2.70	0.0096	224.4	23380	28.1	+0.8
239.0	0.110	0.0861	3.06	0.0097	223.9	23090	28.4	+1.1
226.0	0.120	0.0974	3.46	0.0098	211.8	21610	28.7	+1.4
185.0	0.140	0.1215	4.32	0.0099	173.3	17510	29.0	+1.7
153.0	0.160	0.1447	5.15	0.0100	143.4	14340	29.1	+1.8
144.5	0.180	0.1656	5.89	0.0101	135.4	13410	29.3	+2.0
143.5	0.200	0.1856	6.60	0.0102	134.5	13180	29.4	+2.1
145.0	0.225	0.2105	7.49	0.0103	135.9	13190	"	"
148.0	0.250	0.2352	8.37	0.0104	138.7	13340	"	"
151.5	0.275	0.2598	9.24	0.0105	142.0	13520	29.5	+2.2
152.5	0.300	0.2848	10.13	0.0106	142.9	13480	"	"

Lab. No. 6209
Giffels & Rossetti

XXXXXXXXXXXXXXXXXXXXXXXXX

2 Volcanic Tuff Cuttings - T.H. 7 & 11 July 15, 1966
Elevation 6970

1.313 in 2.816 in 1.354 sq. in.

262.0 gm -
138.5 gm -
123.5 gm 107.0 gm
15.42 107.0 gm
102.5
40 28.4 cc
27.0 1.4
2 0.937 lbs per division
0.000 .006
c ft 0.0092 2.810 in

				ft			xxxxxxx ft	
0	0			0.0092			27.0	0.0
37	0.010	0.0063	0.22	0.0092	34.67	3770	26.9	-0.1
81	0.020	0.0119	0.42	0.0092	75.90	8250	"	"
124	0.030	0.0176	0.63	0.0092	116.2	12630	26.8	-0.2
165	0.040	0.0235	0.84	0.0092	154.6	16800	"	"
209	0.050	0.0291	1.04	0.0093	195.8	21060	"	"
252	0.060	0.0348	1.24	0.0093	236.1	25390	"	"
289	0.070	0.0411	1.46	0.0093	270.8	29120	"	"
318	0.080	0.0482	1.72	0.0093	298.0	32040	26.9	-0.1
343	0.090	0.0557	1.98	0.0094	321.4	34190	27.0	0.0
361	0.100	0.0639	2.27	0.0094	338.3	35980	27.2	+0.2
371	0.110	0.0729	2.59	0.0095	347.6	36590	27.3	+0.3
374	0.120	0.0826	2.94	0.0095	350.4	36890	27.4	+0.4
369	0.130	0.0931	3.31	0.0096	345.8	36020	27.6	+0.6
351	0.140	0.1049	3.73	0.0097	328.9	33910	27.8	+0.8
337	0.160	0.1263	4.49	0.0098	315.8	32220	28.1	+1.1
313.5	0.180	0.1486	5.29	0.0099	293.8	29670	28.2	+1.2
303.5	0.200	0.1696	6.04	0.0100	284.4	28440	"	"
308	0.225	0.1942	6.91	0.0101	288.6	28570	"	"
317	0.250	0.2183	7.77	0.0102	297.0	29120	"	"
320	0.275	0.2430	8.65	0.0103	299.8	29110	"	"
323	0.300	0.2677	9.53	0.0104	302.6	29100	"	"
324.5	0.325	0.2926	10.41	0.0105	304.1	28960	"	"
327	0.350	0.3173	11.29	0.0106	306.4	28910	"	"
329.5	0.375	0.3420	12.17	0.0107	308.7	28850	"	"
327	0.400	0.3673	13.07	0.0108	306.4	28370	"	"

Lab. No. 6209
Giffels & Rossetti

XXXXXXXXXXXXXXXXXXXXXXXXX

Volcanic Tuff Cuttings - T.H. 7 & 11
Elevation 6970

July 15, 1966

3

1.313 in 2.816 in 1.354 sq. in.

262.5 gm -
138.5 gm -
124.0 gm 107.6 gm
15.24 107.6
103.1 -
60 28.5 cc

26.1 2.4

2 0.937 lbs per division to 400 lbs.

0.000 .015

c ft 0.0091 2.801 in

						xxxxxxxx ft		
				ft				
0	0			0.0091	0		26.1	0.0
46	0.010	0.0054	0.19	0.0091	43.10	4740	26.0	-0.1
79	0.020	0.0121	0.43	0.0091	74.02	8130	"	"
119	0.030	0.0181	0.65	0.0081	111.5	12250	25.9	-0.2
162	0.040	0.0238	0.85	0.0091	151.8	16680	25.8	-0.3
210	0.050	0.0290	1.04	0.0091	196.8	21630	"	"
249	0.060	0.0351	1.25	0.0092	233.3	25360	"	"
294	0.070	0.0406	1.45	0.0092	275.5	29950	25.7	-0.4
335	0.080	0.0465	1.66	0.0092	313.9	34120	"	"
367	0.090	0.0533	1.90	0.0092	343.9	37380	"	"
399	0.100	0.0601	2.14	0.0092	373.9	40640	"	"
431	0.110	0.0669	2.39	0.0092	403.0	43800	"	"
460	0.120	0.0740	2.64	0.0093	425.0	45700	"	"
484	0.130	0.0816	2.91	0.0093	445.0	47850	"	"
504	0.140	0.0896	3.20	0.0093	454.0	48820	25.8	-0.3
517	0.150	0.0983	3.51	0.0094	463.0	49260	25.9	-0.2
522	0.160	0.1078	3.85	0.0094	466.0	49570	"	"
521	0.170	0.1179	4.21	0.0095	465.0	48950	26.0	-0.1
509	0.180	0.1291	4.61	0.0095	457.0	48100	26.1	0.0
488	0.200	0.1512	5.40	0.0096	444.0	46250	26.3	+0.2
440	0.220	0.1760	6.28	0.0097	409.0	42160	26.5	+0.4
429	0.240	0.1971	7.04	0.0098	401.5	40970	"	"
423	0.260	0.2177	7.77	0.0099	396.4	40040	"	"
417	0.280	0.2383	8.51	0.0100	390.7	39070	26.4	+0.3
412.5	0.300	0.2588	9.24	0.0101	386.5	38270	"	"
418	0.325	0.2832	10.11	0.0102	391.7	38400	"	"
426	0.350	0.3074	10.97	0.0102	399.2	39140	26.3	+0.2
424	0.375	0.3326	11.87	0.0103	397.3	38570	"	"
427	0.400	0.3573	12.76	0.0104	400.0	38460	"	"

Lab. No.: 6209

July 19, 1965

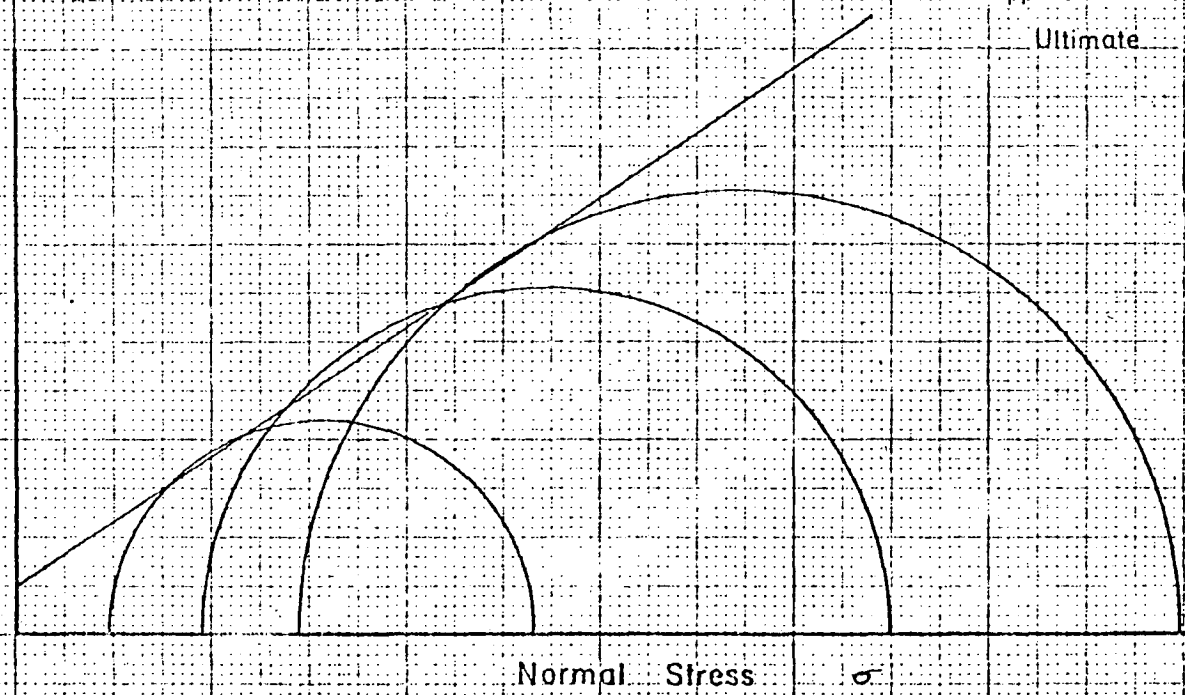
MOHR DIAGRAM

Reported to: Giffels & Rossetti, Inc.

Project: Los Alamos Meson Physics Facility

Sample Identification: Volcanic tuff cuttings from T. H. 7 & 11 to elevation 6970

Tuff cuttings compacted to a medium dense state.
(approximately 98 lbs. per cu. ft.)



Apparent Strength Envelope
Ultimate Ø = 33°

Unconsolidated Triaxial Shear Tests
No drainage during test.
Strain rate approximately 1% per min.
Test specimens not saturated.

Scale: 1" = 3 tons per sq. ft.

Albuquerque Testing Laboratory

Lab. No. 6209
Giffels & Rossetti

xxxxxxxxxxxxxxxxxxxxxxxxx

Volcanic Tuff Cuttings - T.H. 7 & 11
Elevation 6970

4 July 15, 1966

1.313 in 2.816 in 1.354 sq. in.

252.3 gm -
138.5 gm -
113.8 gm 98.0 gm
16.12 98.0
93.9 -
20 -

2 0.937 lb per division
0.000 .005
ft. 0.0094 2.811 in.

xxxxxxx

				ft		ft.
0	0			0.0094	0	
21	0.010	0.0079	0.28	0.0094	19.68	2090
41	0.020	0.0159	0.56	0.0094	38.42	4090
64	0.030	0.0236	0.84	0.0095	59.97	6310
85	0.040	0.0315	1.12	0.0095	79.64	8380
101	0.050	0.0399	1.42	0.0095	94.64	9960
113	0.060	0.0487	1.73	0.0096	105.9	11030
121	0.070	0.0579	2.06	0.0096	113.4	11810
127	0.080	0.0673	2.39	0.0096	119.0	12400
131	0.090	0.0769	2.73	0.0097	122.8	12660
134	0.100	0.0866	3.08	0.0097	125.6	12940
136	0.120	0.1064	3.78	0.0098	127.4	13000
136.5	0.140	0.1264	4.49	0.0098	127.9	13050
136	0.160	0.1464	5.20	0.0099	127.4	12870
135	0.180	0.1665	5.91	0.0100	126.5	12650
135	0.200	0.1865	6.62	0.0101	126.5	12520
135	0.225	0.2115	7.51	0.0102	126.5	12400
135	0.250	0.2365	8.40	0.0103	126.5	12280

Lab. No. 6209
Giffels & Rossetti

XXXXXXXXXXXXXXXXXXXXXXXXXX

Volcanic Tuff Cuttings - T.H. 7 & 11
Elevation 6970

5 July 15, 1966

1.313 in 2.816 in 1.354 sq. in.

253.0 gm -
138.5 gm -
114.5 gm 98.4 gm
16.36 98.4
94.2 -
40

-

2 0.937 lb. per division
0.000 .010
ft 0.0094 2.806 in.

				ft		xxxxxxx ft
0	0			0.0094	0	
14	0.010	0.0086	0.31	0.0094	13.13	1400
41	0.020	0.0159	0.57	0.0094	38.42	4090
74	0.030	0.0226	0.80	0.0095	69.34	7300
100	0.040	0.0300	1.07	0.0095	93.70	9860
123	0.050	0.0377	1.34	0.0095	115.2	12130
141	0.060	0.0459	1.64	0.0096	132.1	13760
158	0.070	0.0542	1.93	0.0096	148.1	15420
172	0.080	0.0628	2.24	0.0096	161.2	16790
184	0.090	0.0716	2.55	0.0096	172.4	17960
194	0.100	0.0806	2.87	0.0097	181.8	18740
201	0.110	0.0899	3.20	0.0097	188.3	19420
208	0.120	0.0992	3.54	0.0097	194.9	20090
218	0.140	0.1182	4.21	0.0098	204.3	20840
223	0.160	0.1377	4.91	0.0099	209.0	21110
226	0.180	0.1574	5.61	0.0100	211.8	21180
228	0.200	0.1772	6.32	0.0100	213.6	21360
229	0.225	0.2021	7.20	0.0101	214.6	21240
229.5	0.250	0.2270	8.09	0.0102	215.0	21080
229.5	0.275	0.2520	8.98	0.0103	215.0	20880
229.5	0.300	0.2770	9.87	0.0104	215.0	20680
229.5	0.325	0.3020	10.76	0.0105	215.0	20480

Lab. No. 6209
Giffels & Rossitti

XXXXXXXXXXXXXXXXXXXXXXXX

Volcanic Tuff Cuttings - T.H. 7 & 11
Elevation 6970

6 July 16, 1966

1.313 in 2.816 in 1.354 sq. in.

252.2 gm -
138.5 gm -
113.7 gm 97.8 gm
16.26 97.8
93.7 -
60 -

- △ -

2 0.937 lb. per division

0.000 0.011
ft. 0.0094 2.805 in

		△	≤	ft.		xxxxxxx ft
0	0			0.0094	0	
28	0.010	0.0072	0.26	0.0094	26.24	2790
62	0.020	0.0138	0.49	0.0094	58.09	6180
90	0.030	0.0210	0.75	0.0095	84.33	8880
120	0.040	0.0280	1.00	0.0095	112.4	11840
144	0.050	0.0356	1.27	0.0095	134.9	14200
168	0.060	0.0432	1.54	0.0095	157.4	16570
190	0.070	0.0510	1.82	0.0096	178.0	18540
202	0.080	0.0598	2.13	0.0096	189.3	19720
221	0.090	0.0679	2.42	0.0096	207.1	21570
234	0.100	0.0766	2.73	0.0097	219.3	22600
242	0.110	0.0858	3.06	0.0097	226.8	23380
254	0.120	0.0946	3.37	0.0097	238.0	24540
270	0.140	0.1130	4.03	0.0098	253.0	25820
280	0.160	0.1320	4.70	0.0099	262.4	26500
286	0.180	0.1514	5.40	0.0099	268.0	27070
290	0.200	0.1710	6.10	0.0100	271.7	27170
293	0.225	0.1957	6.98	0.0101	274.5	27180
296	0.250	0.2204	7.86	0.0102	277.3	27190
298	0.275	0.2452	8.74	0.0103	279.2	27110
299	0.300	0.2701	9.63	0.0104	280.2	26940
299	0.325	0.2951	10.52	0.0105	280.2	26690
300	0.350	0.3200	11.41	0.0106	281.1	26520

RECEIVED 9-8-70
DISTRIBUTED 9-9-70

#430 Foundations

GIFFELS & ROSSETTI, INC. ARCHITECTS • ENGINEERS • PLANNERS
MARQUETTE BUILDING / DETROIT, MICHIGAN 48226 • CABLE GIFFROSS • 313 / 961 2084

September 2, 1970

Mr. Charles S. Huff, Chief
Engineering, Construction &
Maintenance Branch
U. S. Atomic Energy Commission
Los Alamos, New Mexico 87544

Re: Los Alamos Meson Physics Facility
Los Alamos, New Mexico
G & R Project 66017

Subject: Experimental Area - Phase II and Phase III
Test Borings Report

Dear Mr. Huff:

Enclosed is a copy of Albuquerque Testing Laboratory's supplemental report on test borings in Beam Area "C" and the area east of Beam Area "A", as shown on drawing LAM-E-CE-6X, Revision #1.

Very truly yours,

GIFFELS & ROSSETTI, Inc.

T. Maeda

T. Maeda
Assistant Project Director

TM:aae

cc: P. D. Edwards w/copy
L. R. Springsteen

Encl.

Albuquerque
TESTING LABORATORY
SUB SOIL INVESTIGATION — PHYSICAL TESTING — INSPECTION — RESEARCH
532 JEFFERSON ST., N. E. P. O. BOX 4101 PHONE 255-8916 255-1322
ALBUQUERQUE, NEW MEXICO 87106

Lab No. 7830 - SUPPLEMENTAL Date AUGUST 20, 1970

Report to GIFFELS & ROSSETTI, INC.

Submitted By SAME ~~XXXXX~~ DRILLED By ALBUQUERQUE TESTING LABORATORY, INC.

Project LOS ALAMOS MESON PHYSICS FACILITY - GIFFELS & ROSSETTI PROJECT No. 66017

Source of Material SEVEN (7) MISCELLANEOUS DEPTH AUGER & DIAMOND CORE DRILLED TEST BORINGS MADE AT THE REQUESTED LOCATIONS ON THE SITE DURING THE WEEKS OF JULY 27, AUGUST 3 AND AUGUST 10, 1970.

TEST RESULTS

GENTLEMEN:

ENCLOSED, PLEASE FIND THE BORING LOG GRAPHS FOR TEST HOLES 47 THROUGH 53, EAST OF BERM AREA A, ALONG WITH THE RESULTS OF REQUESTED LABORATORY TESTS FOR THE ABOVE REFERENCED PROJECT.

YOU WILL NOTE THAT FOR BOTH AREA "C" AND THE AREA EAST OF BERM AREA A, BOTH UNCONFINED COMPRESSIVE STRENGTH TESTS AND MODULUS OF ELASTICITY TESTS WERE RUN ON RECOVERED CORE SAMPLES AT VARIOUS AND RANDOM CORE DEPTHS. ALTHOUGH RECOVERED CORE SECTIONS VISUALLY APPEARED TO BE TYPICAL AND REPRESENTATIVE FOR A PARTICULAR CORE RUN, CONSIDERABLE VARIATIONS IN BOTH UNCONFINED COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY VALUES WERE OBTAINED.

CC: MR. LARRY SPRINGSTEEN
LOS ALAMOS FIELD OFFICE

Respectfully Submitted,
ALBUQUERQUE TESTING LAB.
Original Signed By
Robert K. Lloyd
Registered Professional Engineer

LAB NO. 7830-
SUPPLEMENTAL

BORING LOG GRAPH - EAST OF BERM AREA A

VERTICAL SCALE: 1" = 5'

TEST HOLE NO. 47
ELEV. = 6966 ±

Elev.	Depth	Description	N	S	Moisture Content "M" - %	"AIR-DRY" Density Lbs. per Cu. Ft.	Ultimate Unconfined Compressive Strength (P.S.I.)	Modulus of Elasticity (P.S.I.)		
6965	0'	LIGHT GRAY, POROUS, SOFT TO MEDIUM SOFT VOLCANIC TUFF. (MOIST TO DAMP - SATURATED AT 10' DEPTH) POSSIBLE MAN-MADE FILL TO APPROX. 13' TO 15' DEPTH.								
6960			29	15 14	15.20					
6955			34	15 19	SATURATED					
6950	13'	WEATHERED TUFF AND BROWN SANDY SILT AND SILTY SAND. MEDIUM DENSE.	50+	50-5"	8.05					
6945			23	11 12	7.17					
6940	22'	LIGHT GRAY, POROUS, MEDIUM SOFT TO MEDIUM HARD, FRIABLE, VOLCANIC TUFF. TRACES OF BROWN SILT INTRUSIONS.	28	14 14	1.34					
6935			45	22 23	1.25					
				50+						
6930	35'	LIGHT GRAY & PINK, POROUS, WELDED VOLCANIC TUFF ROCK, MEDIUM	RECOVERY = 80%	50-1"	0.64	94.5	813	119,000	A	35' TO 45'
						98.8	826	----	B	
						97.1	645	91,000	C	
						92.1	520	----	D	
						96.4	541	122,000	E	
	45'	HARD TO HARD BUT RECOVERED CORES FRACTURED & BROKEN, WITH HORIZONTAL & DIAGONAL SEAMS.	REC = 55%	DIAMOND CORE	DRILLED	87.3	355	----	A	45' TO 55'
6911	55'									

BORING LOG GRAPH - EAST OF BERM AREA A

VERTICAL SCALE: 1" = 5'

TEST HOLE NO. 48

ELEV. 6966 ±

Elev.	Depth	Description	N	C	Moisture Content "M" - %	Dry Density "D" - Lbs per cu.ft.
6965	0'	LIGHT GRAY TO PINK, POROUS, SOFT TO MEDIUM SOFT VOLCANIC TUFF. (MOIST TO DAMP.) POSSIBLE MAN-MADE FILL TO APPROX. 14' TO 16'. SOME BROWN SILT NOTED W/RECOVERED SAMPLES.		14	13.16	85.5
			28	14	13.45	81.1
6960				22	12.84	90.4
				13	15.69	86.0
			27	14	16.35	85.9
6955				19	17.30	90.7
	14'	BROWN, SANDY, CLAYEY SILT & SILTY FINE SAND (DAMP TO WET.) PIECES OF WEATHERED TUFF. LOOSE TO MEDIUM DENSE.		9	21.35	89.2
			19	10	22.40	86.2
6950				13	24.77	91.0
				6	20.10	97.3
			12	6	18.63	102.1
6945				11	23.06	93.9
				10	11.17	84.3
	25½'	LIGHT GRAY WEATHERED TUFF, SOFT TO MEDIUM SOFT. SOME BROWN SILT INTRUSIONS.	22	12	8.56	79.5
6940				18	8.29	82.5
				28	4.68	84.4
			57	29	4.05	83.5
6935	31'	LIGHT GRAY, POROUS, WELDED VOLCANIC TUFF ROCK. (HARD) RECOVERED CORES CONTAIN HORIZONTAL & DIAGONAL FRACTURES W/SOFT CELULAR PORTIONS		50	2.89	75.8
6930						
6925	41½'					

RECOVERY = 64%

DIAMOND CORE DRILLED

ATTERBERG LIMIT TESTS:

LL	PL	PI	
28.5	20.8	7.7	(TUBE 1)

Air-Dry Density Lbs. per cu.ft.	Ultimate Unconfined Compressive Strength (p.s.i.)	Modulus of Elasticity (p.s.i.)	
93.5	550	118,000	A
98.7	807	116,000	B
99.6	890	154,000	C

31½' TO 41½'

EUGENE DIETZGEN CO. MADE IN U.S.A.

NO. 340P-20 DIETZGEN GRAPH PAPER 20 X 20 PER INCH

BORING LOG GRAPH - EAST OF BERM AREA A

VERTICAL SCALE: 1" = 5'

TEST HOLE NO. 49

ELEV. = 6966 ±

Elev.	Depth	Description	N	C	Moisture Content "M" - %	Dry Density "D" - Lbs. per cu.ft.
6965	0'	LIGHT GRAY, POROUS, SOFT TO MEDIUM SOFT VOLCANIC TUFF. (MOIST TO DAMP & WET) A LITTLE BROWN SILT NOTED.		14	11.62	87.0
			28	14	11.06	84.6
5960				20	11.28	86.8
				13	15.52	86.8
		POSSIBLE MAN-MADE FILL TO APPROX. 19' TO 20'.	27	14	13.67	93.0
6955				20	15.07	89.9
				13	20.11	89.9
			27	14	22.00	87.1
6950				22	24.18	88.2
	20'	BROWN, SANDY, CLAYEY SILT AND SILTY SAND. (DAMP TO WET) WITH PIECES OF GRAY, WEATHERED TUFF-GRADING TO GRAY WEATHERED TUFF W/SILT INTRUSIONS.		6	28.56	70.3
			16	10	50.90	80.9
5945				40	18.86	103.3
				8	15.56	100.8
			19	11	15.93	106.5
6940				20	13.10	117.3
	30'	1 TO 2 FT. OF LIGHT GRAY, WEATHERED, TUFF, FOLLOWED BY LIGHT GRAY POROUS, WELDED VOLCANIC TUFF ROCK, MED. HARD TO HARD. NUMEROUS HORIZONTAL & DIAGONAL FRACTURES.	50+	50-6"	6.16	---
6935					3.96	---
6930	40'					
		SOFT, CELLULAR PORTIONS PREDOMINATE FROM 30' TO 40' ±				

LOOSE TO MED. DENSE

RECOVERY = 80%

DIAMOND CORE DRILLED

EC. = 80%

"AIR-DRY" DENSITY LBS. PER CU.FT.	ULTIMATE UNCONFINED COMPRESSIVE STRENGTH (P.S.I.)	MODULUS OF ELASTICITY (P.S.I.)		
92.7	346	63,000	A*	AT 30' TO 40'
87.5	274	60,000	B	
92.8	526	88,000	C	
98.1	674	83,000	A	AT 40' TO 50'
90.7	443	68,000	B	

*WEATHERED

BORING LOG GRAPH - EAST OF BERM AREA A

VERTICAL SCALE: 1" = 5'

TEST HOLE NO. 50

ELEV. = 6966 ±

Elev.	Depth	Description	N	C	Moisture Content "M" - %	Dry Density "D" - Lbs. per cu. ft.
6965	0'	LIGHT GRAY, POROUS, SOFT TO MEDIUM SOFT VOLCANIC TUFF.		11	10.53	85.1
			24	13	10.17	81.9
6960				24	9.20	100.3
		SOME BROWN SILT AND/OR SILTY SAND INTRUSIONS NOTED.		11	12.66	84.7
			24	13	13.42	87.8
6955				23	15.33	87.1
		POSSIBLE MAN-MADE FILL TO APPROX. 20 TO 21 FT.		16	17.30	86.2
			32	16	18.19	90.3
6950		SAMPLES DAMP TO WET AT 15 TO 21½ FT.		20	19.43	90.0
				13	25.14	92.1
			24	11	28.54	87.2
6945	21'			9	29.04	86.1
		BROWN, SANDY, CLAYEY SILT AND/OR SILTY SAND W/PIECES OF GRAY WEATHERED TUFF (DAMP TO WET)		13	16.46	98.4
			31	18	15.59	105.2
6940	27'			31	13.81	113.4
		LIGHT GRAY, WEATHERED POROUS, VOLCANIC TUFF - MEDIUM HARD.		18	0.96	86.1
			43	25	2.33	86.7
6935	31'			50	3.78	93.1
		LIGHT GRAY, POROUS, WELDED VOLCANIC TUFF ROCK, MED. SOFT TO MED. HARD. * SAMPLES SOMEWHAT FRIABLE W/SOFT CELLULAR PORTIONS AND WITH CONSIDERABLE HORIZONTAL & VERTICAL FRACTURES.				
6930	35'					
6925	40'					

MEDIUM DENSE

REC. = 60%

DIAMOND CORE DRILLED

"AIR-DRY" DENSITY LBS. PER CU. FT.	ULTIMATE UNCONFINED COMPRESSIVE STRENGTH (P.S.I.)	
84.4	200	A
81.5	177	B

35' TO 40'

* 31' TO 40' - NO RECOVERY. CORE BARREL WEDGED IN HOLE - 2 HOURS TIME REQUIRED TO FREE.

EUGENE DIETZGEN CO. MADE IN U.S.A.

BORING LOG GRAPH - EAST OF BERM AREA A

Vertical Scale: 1" = 5'

Test Hole No. 51

Elev. = 6966 ±

Elev.	Depth	Description	N	C	Moisture Content "M" - %	Dry Density "D" - Lbs. per cu.ft.
6965	0'	Light gray, soft to medium soft volcanic tuff with some light brown silt. Possible man-made fill to approx. 19' to 20' depth.		11	10.76	81.5
6960			20	9	11.24	83.3
				18	10.81	85.7
				13	12.02	90.5
6955			30	17	12.39	88.4
				22	18.94	83.2
				17	16.41	87.3
6950			30	13	15.51	86.4
				22	15.77	87.4
	20'	Light gray, soft to med. soft, weathered along with loose to med. dense brown sandy clayey silt w/a little clay content. (Damp to wet.) Some root structure noted.		8	23.75	86.3
6945			19	11	18.13	90.9
				15	24.41	86.3
				9	25.02	93.4
6940			20	11	18.46	105.7
				23	21.37	100.2
	30'	Light gray medium hard, porous, volcanic tuff rock with some silt intrusions.		19	13.34	88.6
6935			39	20	11.20	86.8
				43	11.36	90.3
				39	7.30	76.7
6930	36'	Light gray porous, welded volcanic tuff rock. Rec'd cores contain horizontal & diagonal fractures, w/ soft cellular portions, predominant from 36' to 45'.	89+	50-5"	7.11	----
					7.91	----
6911	55'					

Med. hard to hard

36' to 45' Rec. = 44%

45' to 55' Rec. = 92%

Diamond Core Drilled

Atterberg Limit Tests:

LL	PL	PI	
28.2	17.5	10.7	(Tube 1)

"Air-Dry" Density Lbs. per cu.ft.	Ultimate Unconfined Compressive Strength (p.s.i.)	Modulus of Elasticity (p.s.i.)	
102.9	923	----	A 36' to 40'
94.4	593	77,000	B
101.0	822	138,000	A @ 45-47'
96.7	598	107,000	A @ 47-55'

BORING LOG GRAPH - EAST OF BERM AREA A

VERTICAL SCALE: 1" = 5'

TEST HOLE No. 52

ELEV. = 6966 ±

Elev.	Depth	Description	N	S	Moisture Content "M" - %
6965	0'	LIGHT GRAY W/SOME PINK, POROUS, SOFT TO MEDIUM SOFT VOLCANIC TUFF. (MOIST TO DAMP--WET AT 15'.) POSSIBLE MAN-MADE FILL TO APPROX. 17' TO 18'.	27	14, 13	13.09
6960			22	11, 11	15.54
6955			23	12, 11	27.57
6950	18'	BROWN SANDY SILT AND/OR SILTY FINE SAND. PIECES OF WEATHERED TUFF. (VERY LOOSE TO LOOSE)	5	3, 2	14.40
6945	23'	LIGHT GRAY, POROUS, MED. SOFT, FRIABLE VOLCANIC TUFF.	25	12, 13	8.68
6940	28'	LIGHT GRAY, POROUS, MEDIUM HARD TO HARD, WELDED, VOLCANIC TUFF ROCK. RECOVERED CORE SECTIONS BROKEN & WITH BOTH HORIZONTAL & DIAGONAL FRACTURES.	44	22, 22	0.80
6935			50+	50-2½"	1.44
6930					
6925					
6920	45'				

RECOVERY = 95 TO 98%

DIAMOND CORE DRILLED 35'

"AIR-DRY" DENSITY LBS. PER CU.FT.	ULTIMATE UNCONFINED COMPRESSIVE STRENGTH (P.S.I.)	MODULUS OF ELASTICITY (P.S.I.)		
98.2	866	123,000	A	35' TO 37'
100.2	1018	----	B	
99.0	932	158,000	A	37' TO 45'
97.8	871	----	B	
101.4	664	115,000	C	
99.4	765	----	D	
95.6	603	128,000	E	
96.5	837	----	F	
94.3	661	117,000	G	
92.4	626	----	H	
94.1	507	122,000	I	

BORING LOG GRAPH - EAST OF BERM AREA A

VERTICAL SCALE: 1" = 5'

*TEST HOLE NO. 53

ELEV. = 6966 ±

Elev.	Depth	Description	N	C	Moisture Content "M" - %	Dry Density "D" - Lbs. per cu. ft.
6965	0'	LIGHT GRAY, WITH SOME LIGHT PINK, POROUS, SOFT TO MEDIUM SOFT VOLCANIC TUFF.		11	12.67	85.6
6960			23	12	13.27	89.3
				16	13.63	87.9
		POSSIBLE MAN-MADE FILL TO APPROX. 17' TO 18'.		14	15.87	87.7
6955			28	14	17.70	87.8
				22	15.30	93.7
		A LITTLE BROWN SILT IN SAMPLES. (DAMP TO WET)		11	21.15	93.7
6950			25	14	23.75	86.4
				21	17.34	101.7
	18'	BROWN SANDY SILT AND VERY SILTY FINE SAND. (DAMP TO WET)		4	21.30	94.0
6945			12	8	21.17	98.5
				22	20.41	104.1
		LOOSE TO MEDIUM DENSE.		5	22.66	97.4
6940			13	9	21.09	96.0
				12	18.45	108.9
	27'	LT. GRAY, POROUS VOLCANIC TUFF. MEDIUM SOFT 27-28' BECOMING MED HARD @ 28-30'.		27	9.05	85.5
6935			55	28	8.81	81.7
		MED. SOFT TO MED. HARD LT. GRAY POROUS, MODERATELY FUSED VOLCANIC TUFF ROCK. REC'D CORES MOIST TO DAMP, FRIABLE, & W/ HORIZONTAL & DIAGONAL FRACTURES. SOME SOFT PORTIONS SLAKE READILY IN WATER.		50-5"	8.42	89.1
6930	**					
6925						

RECOVERY = 75%

DIAMOND CORE DRILLED

"AIR-DRY" DENSITY LBS. PER CU. FT.	ULTIMATE UNCONFINED COMPRESSIVE STRENGTH (P.S.I.)	MODULUS OF ELASTICITY (P.S.I.)	
82.6	207	---	A
90.1	345	---	B — 30'
94.9	626	93,000	C — TO
101.6	548	---	D — 40'
102.6	705	97,000	E

*LOCATED 8' NORTH OF PLAN LOCATION TO CLEAR STEEL ON SITE.

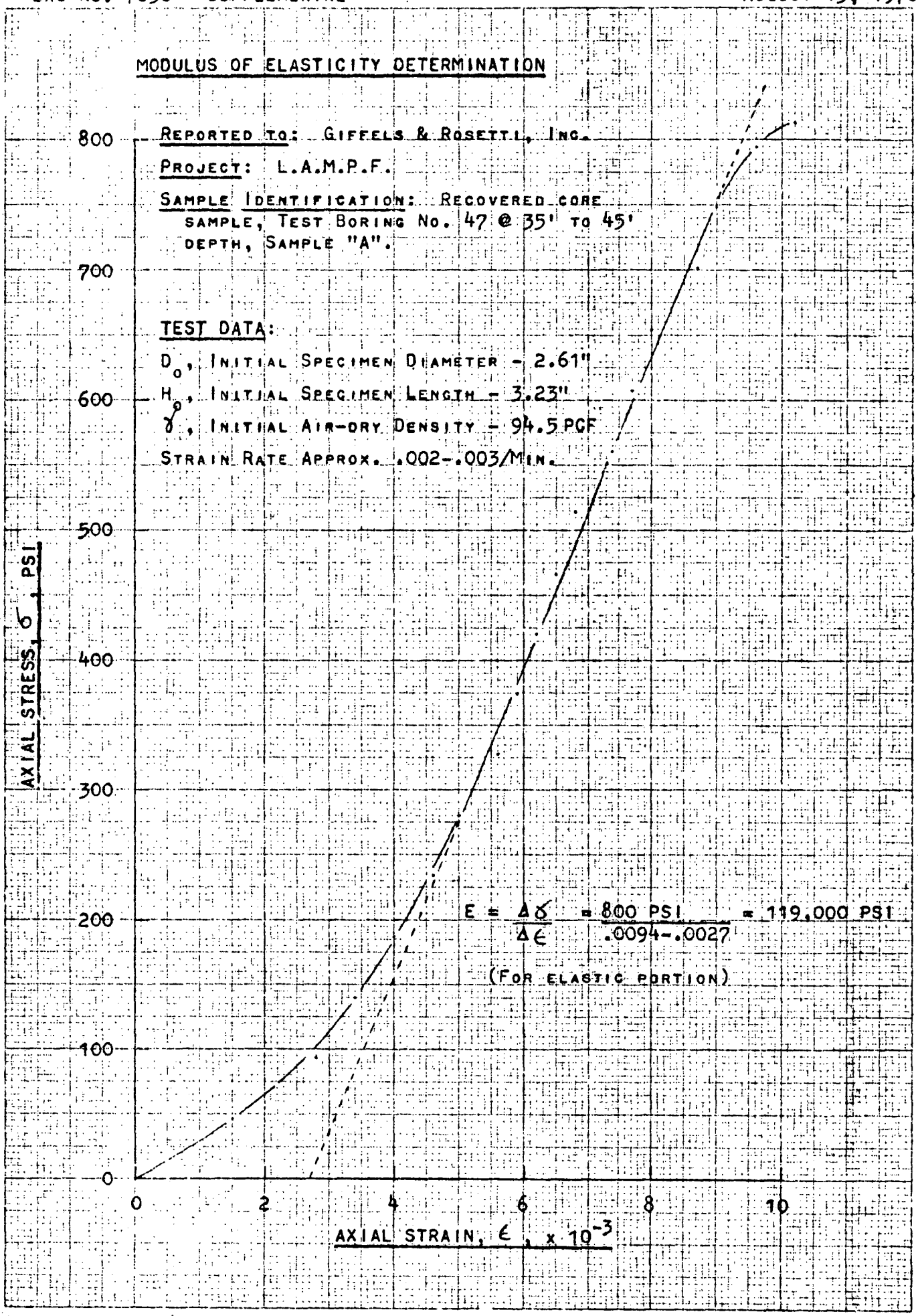
**CORE BARREL WEDGED IN HOLE FOR 1½ HOURS.

ALBUQUERQUE TESTING LABORATORY

GRAIN SIZE ANALYSES

TEST HOLE NUMBER	DEPTH (FT)	% GRAVEL	% COARSE SAND	% MEDIUM SAND	% FINE SAND	% TOTAL SAND	% SILT & CLAY
47	5'	1	5	36	17	58	41
	10'	1	5	35	13	53	46
	15'	0	2	23	8	33	67
	20'	0	1	19	11	31	69
	25'	0	4	38	20	62	38
	30'	0	5	38	17	60	40
	35'	0	5	36	18	59	41
48	20'	0	1	9	11	21	79
49	5'	25	7	31	13	51	24
	10'	4	3	36	19	58	38
	15'	11	10	34	15	59	30
	20'	1	3	20	19	42	57
	25'	0	2	18	11	31	69
	30'	1	11	34	34	79	20
51	5'	1	7	41	20	68	31
	10'	4	4	39	17	60	36
	15'	0	2	43	15	60	40
	20'	0	4	40	20	64	36
	25'	3	5	4	7	16	81
	30'	2	8	40	24	72	26
	35'	0	5	49	20	74	26
53	25'	0	1	12	8	21	79

MODULUS OF ELASTICITY DETERMINATION

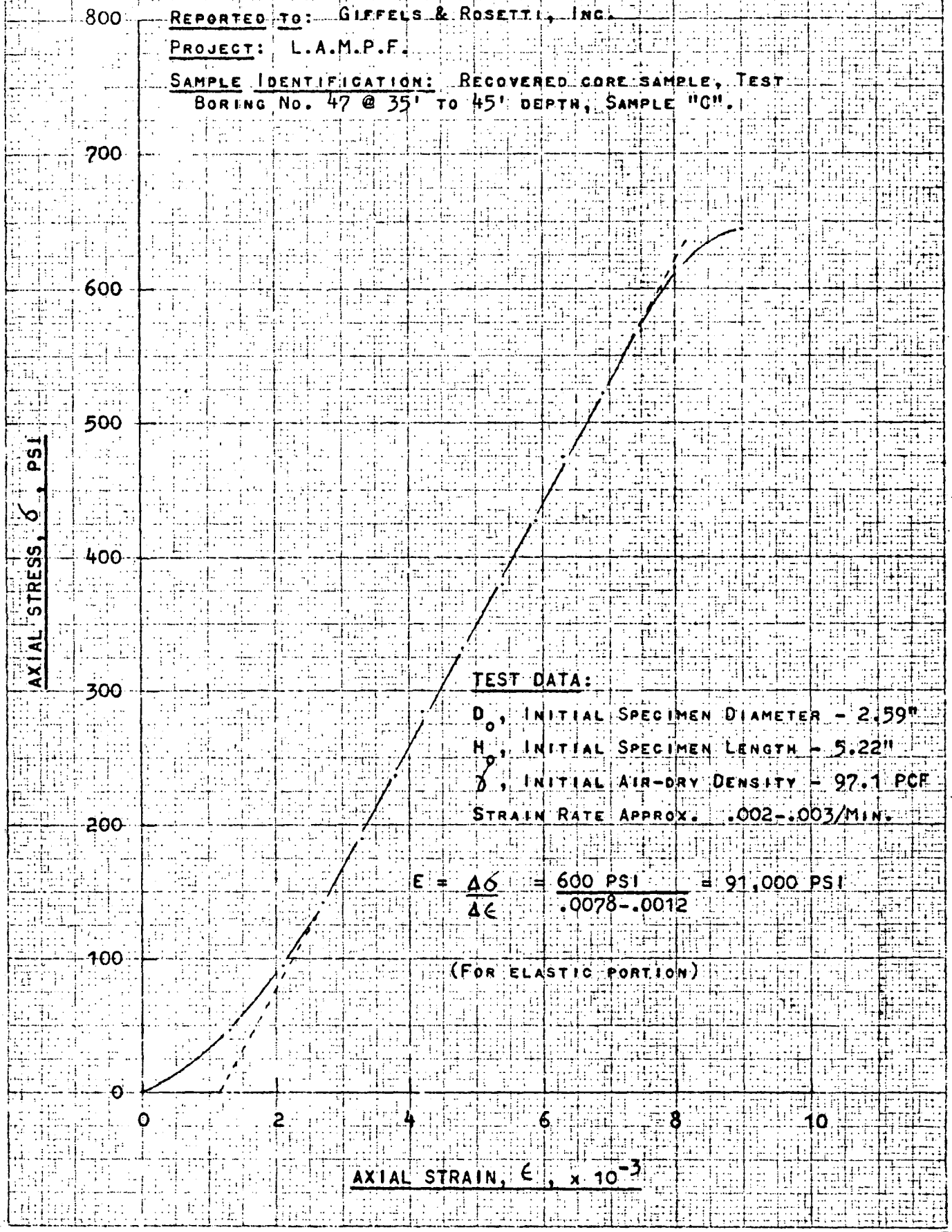


MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING NO. 47 @ 35' TO 45' DEPTH, SAMPLE "C".



TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.59"

H_o, INITIAL SPECIMEN LENGTH - 5.22"

γ, INITIAL AIR-DRY DENSITY - 97.1 PCF

STRAIN RATE APPROX. .002-.003/MIN.

$$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{600 \text{ PSI}}{.0078-.0012} = 91{,}000 \text{ PSI}$$

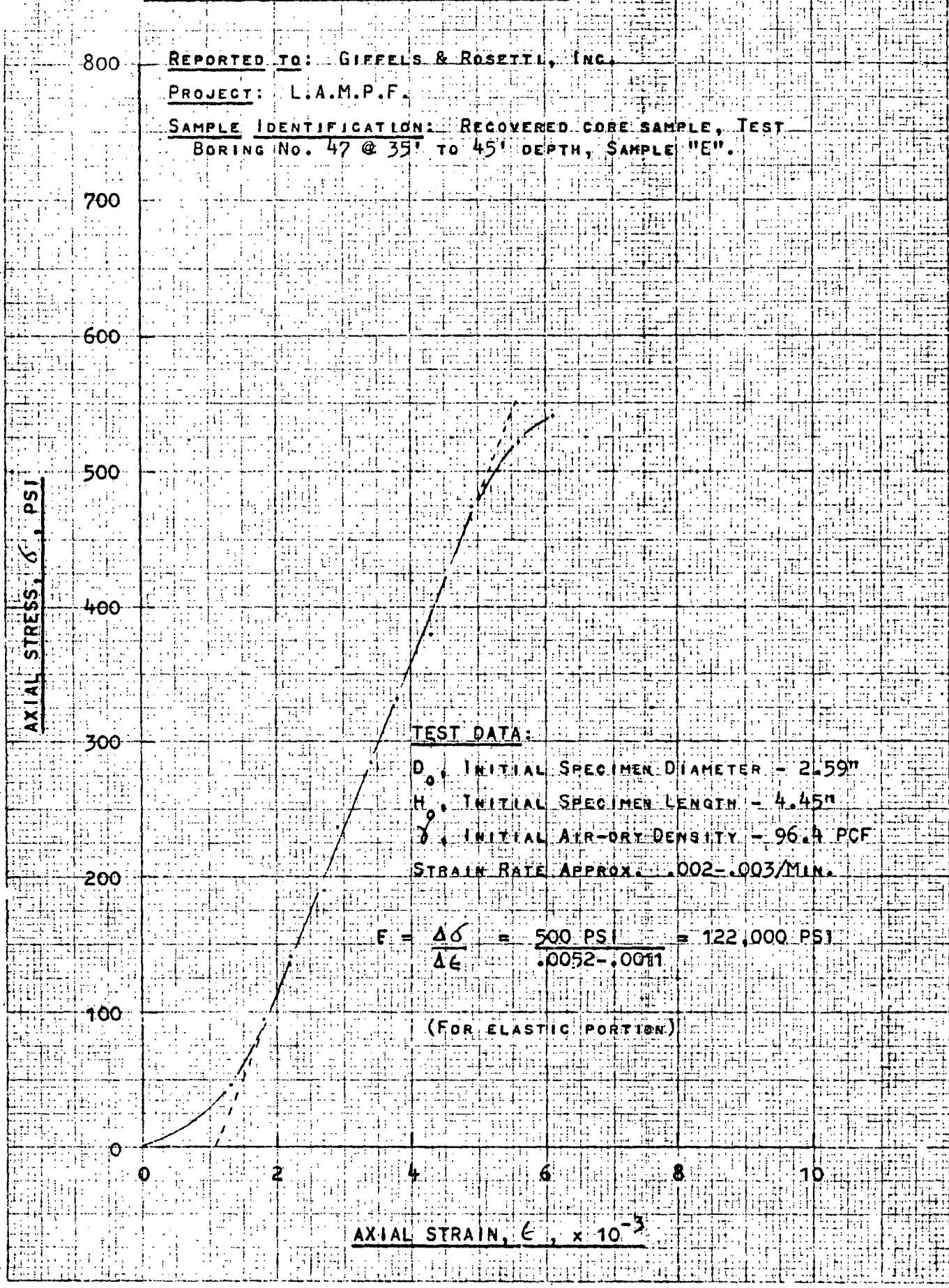
(FOR ELASTIC PORTION)

MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING No. 47 @ 35' TO 45' DEPTH, SAMPLE "E".



TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.59"

H_o, INITIAL SPECIMEN LENGTH - 4.45"

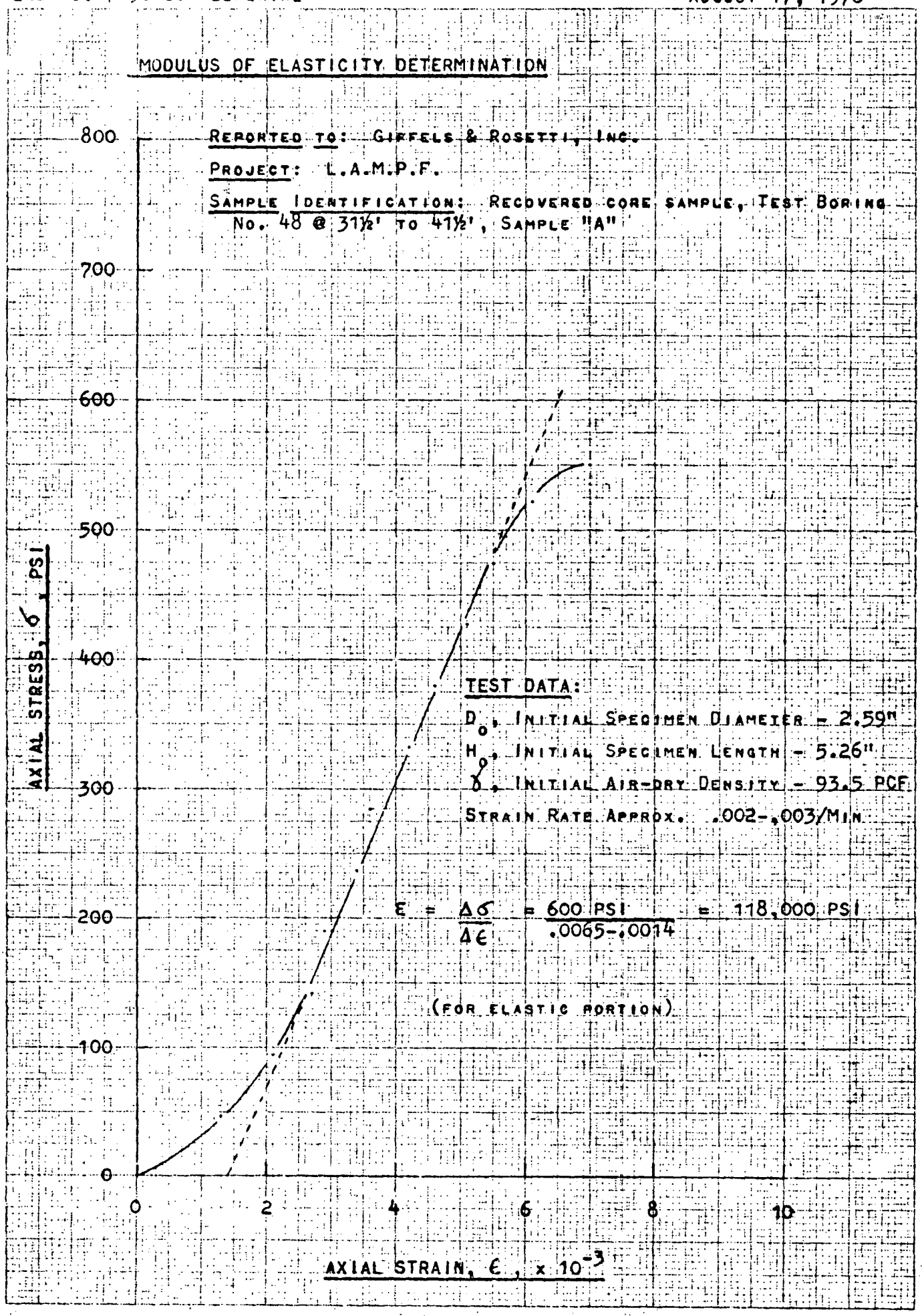
γ_o, INITIAL AIR-DRY DENSITY - 96.4 PCF

STRAIN RATE APPROX. .002-.003/MIN.

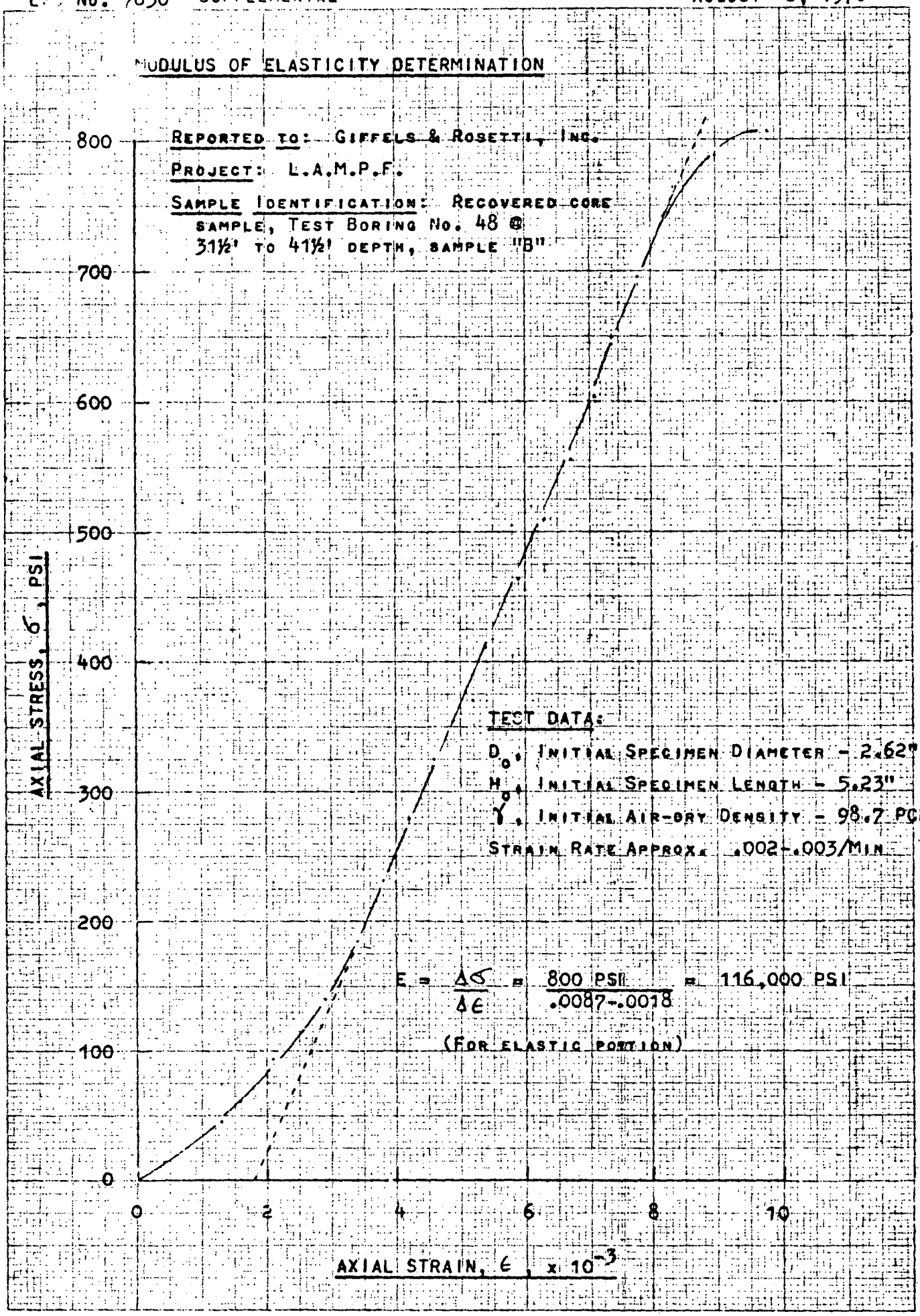
$$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{500 \text{ PSI}}{.0052-.0011} = 122{,}000 \text{ PSI}$$

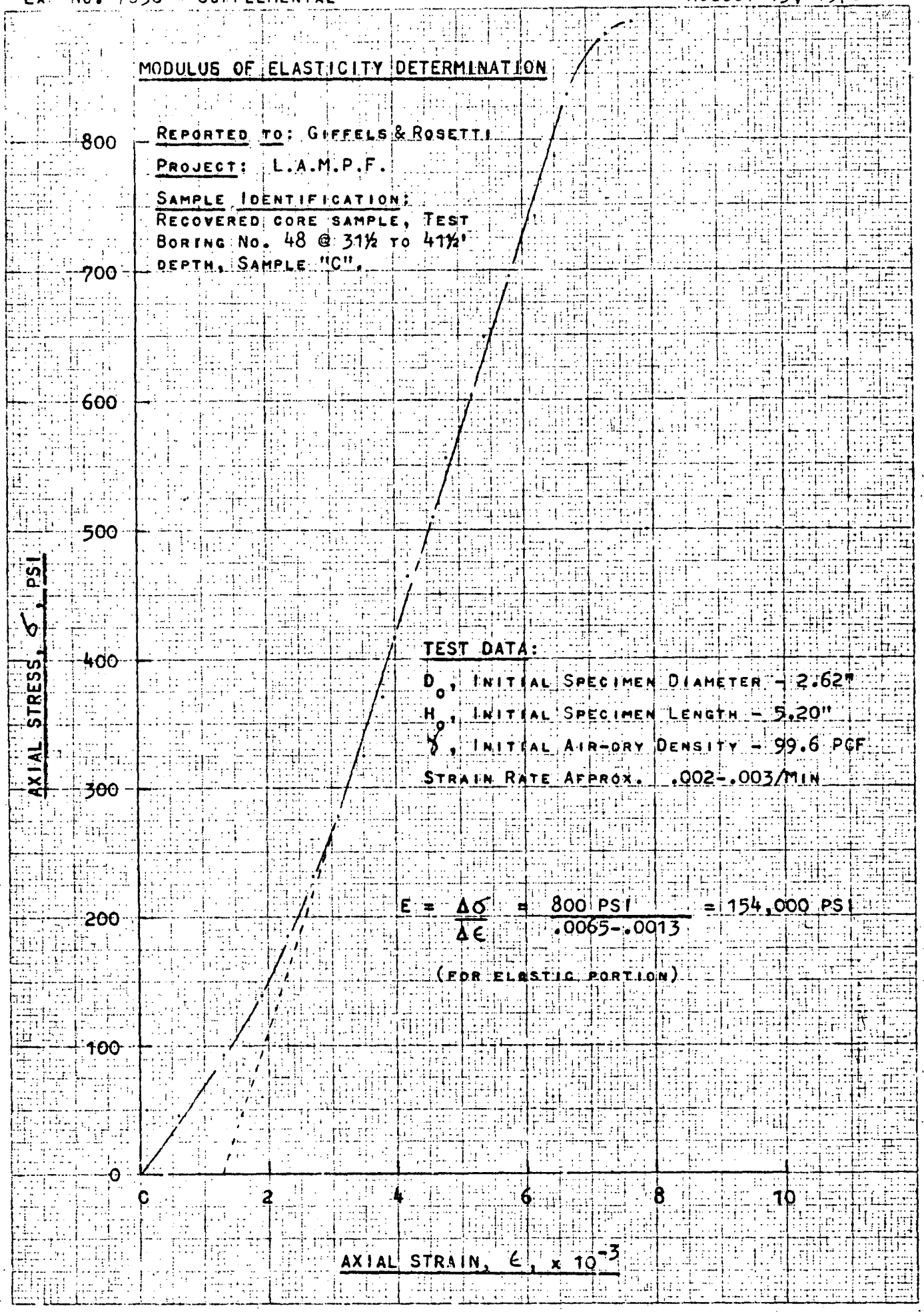
(FOR ELASTIC PORTION)

MODULUS OF ELASTICITY DETERMINATION



MODULUS OF ELASTICITY DETERMINATION




MODULUS OF ELASTICITY DETERMINATION
REPORTED TO: GIFFELS & ROSETTI
PROJECT: L.A.M.P.F.
SAMPLE IDENTIFICATION:
RECOVERED CORE SAMPLE, TEST BORING No. 48 @ 31½ TO 41½' DEPTH, SAMPLE "C".
TEST DATA:
D_o, INITIAL SPECIMEN DIAMETER - 2.62"
H_o, INITIAL SPECIMEN LENGTH - 5.20"
γ_o, INITIAL AIR-DRY DENSITY - 99.6 PCF
STRAIN RATE APPROX. .002-.003/MIN
$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{800 \text{ PSI}}{.0065-.0013} = 154{,}000 \text{ PSI}$
(FOR ELASTIC PORTION)
AXIAL STRESS, σ, PSI
0
100
200
300
400
500
600
700
800
0
2
4
6
8
10
AXIAL STRAIN, ϵ, x 10^{-3}

MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING NO. 49, @ 30'-40' DEPTH, SAMPLE "A".

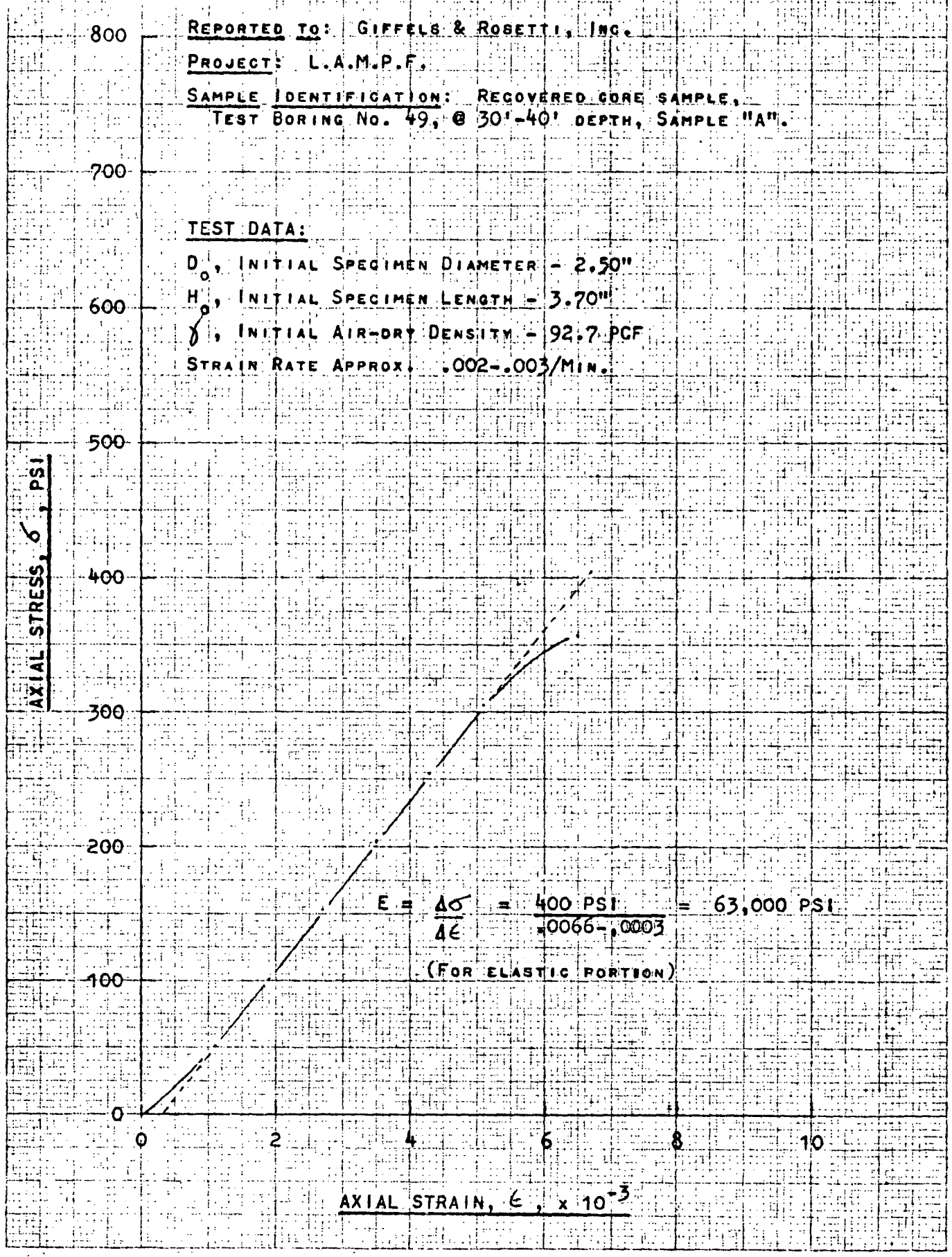
TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.50"

H_o, INITIAL SPECIMEN LENGTH - 3.70"

γ, INITIAL AIR-DRY DENSITY - 92.7 PCF

STRAIN RATE APPROX. .002-.003/MIN.



$$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{400 \text{ PSI}}{.0066-.0003} = 63{,}000 \text{ PSI}$$

(FOR ELASTIC PORTION)

EUGENE DIETZGEN CO. MADE IN U.S.A.

MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING NO. 49, @ 30' TO 40' DEPTH, SAMPLE "B".

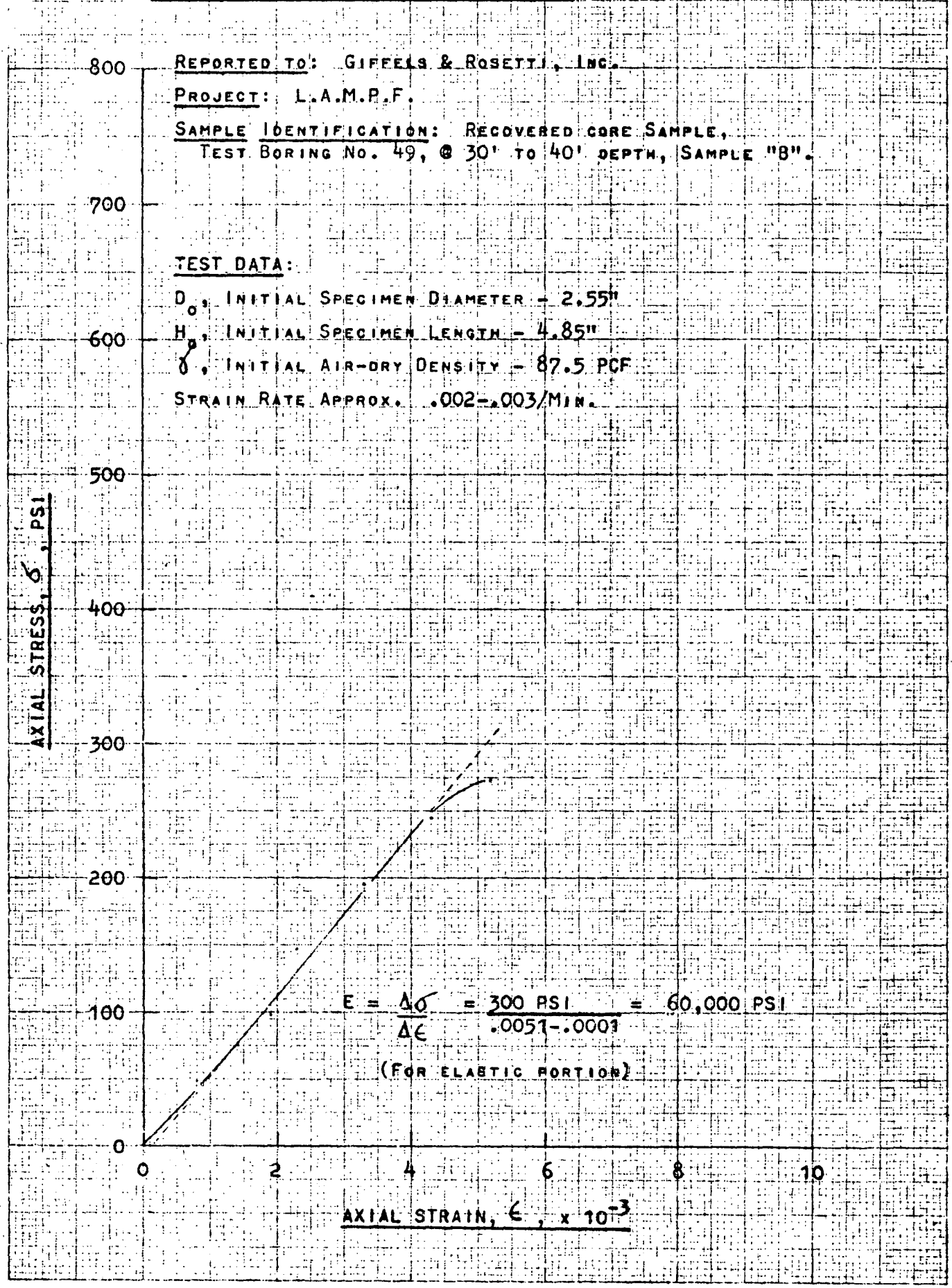
TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.55"

H_o, INITIAL SPECIMEN LENGTH - 4.85"

γ, INITIAL AIR-DRY DENSITY - 87.5 PCF

STRAIN RATE APPROX. .002-.003/MIN.



$$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{300 \text{ PSI}}{.0051-.0001} = 60{,}000 \text{ PSI}$$

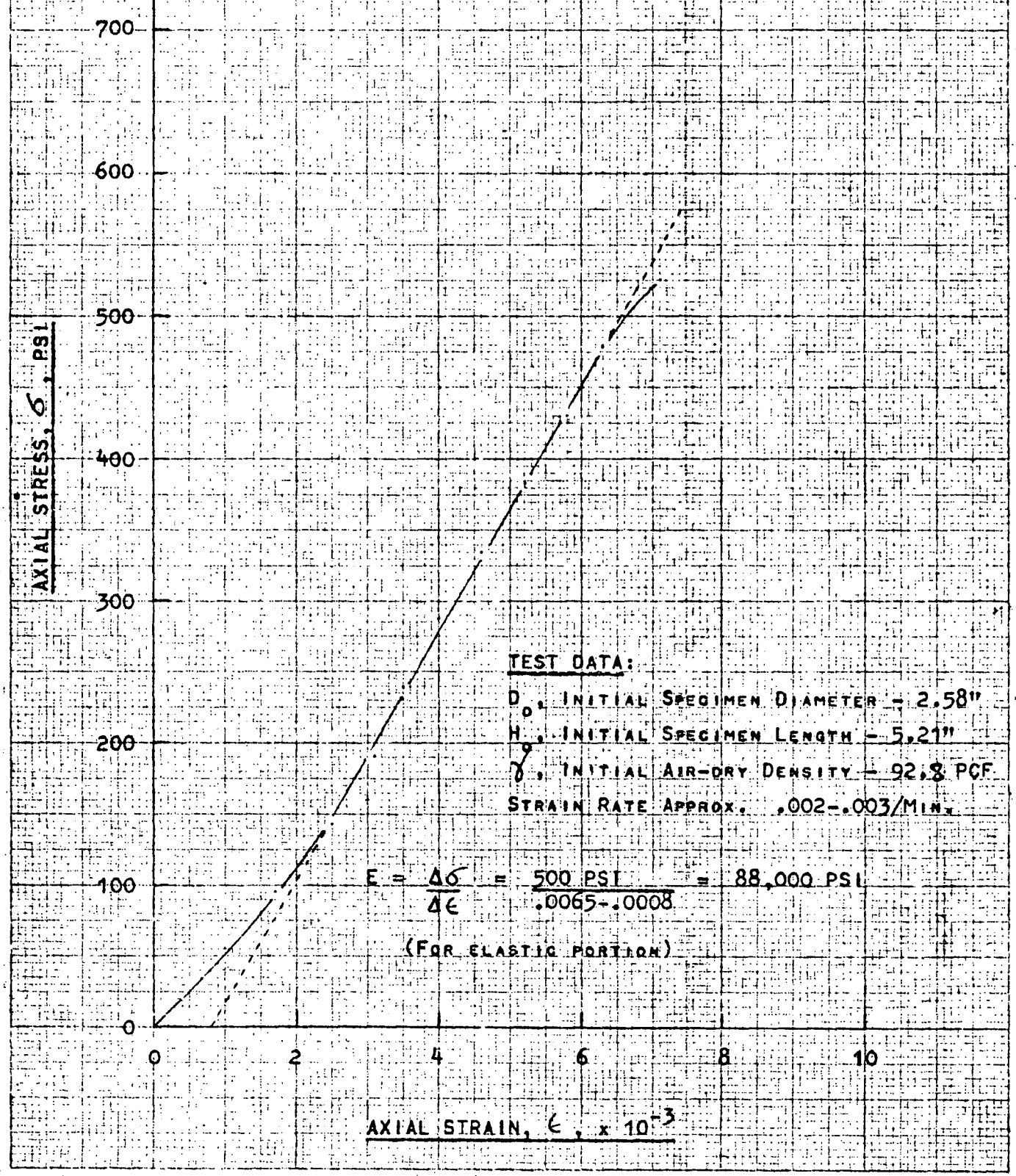
(FOR ELASTIC PORTION)

MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING No. 49 @ 30' TO 40' DEPTH, SAMPLE "C".



TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.58"

H_o, INITIAL SPECIMEN LENGTH - 5.21"

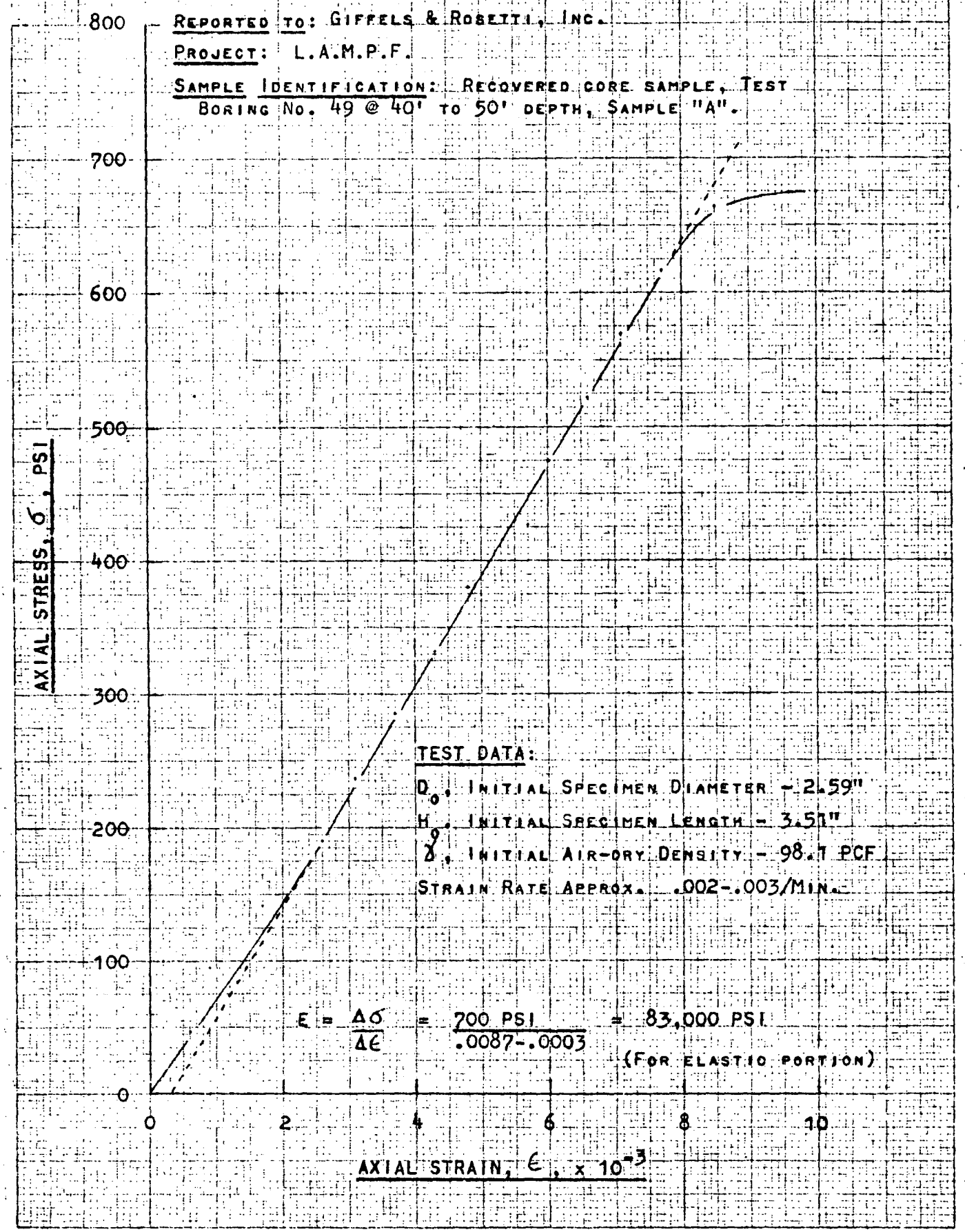
γ, INITIAL AIR-DRY DENSITY - 92.8 PCF

STRAIN RATE APPROX. .002-.003/MIN.

$$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{500 \text{ PSI}}{.0065-.0008} = 88{,}000 \text{ PSI}$$

(FOR ELASTIC PORTION)

MODULUS OF ELASTICITY DETERMINATION



MODULUS OF ELASTICITY DETERMINATION

Reported to: Giffels & Rosetti, Inc.

Project: L.A.M.P.F.

Sample Identification: Recovered core sample, Test Boring No. 49 @ 40' to 50' depth, Sample "B".

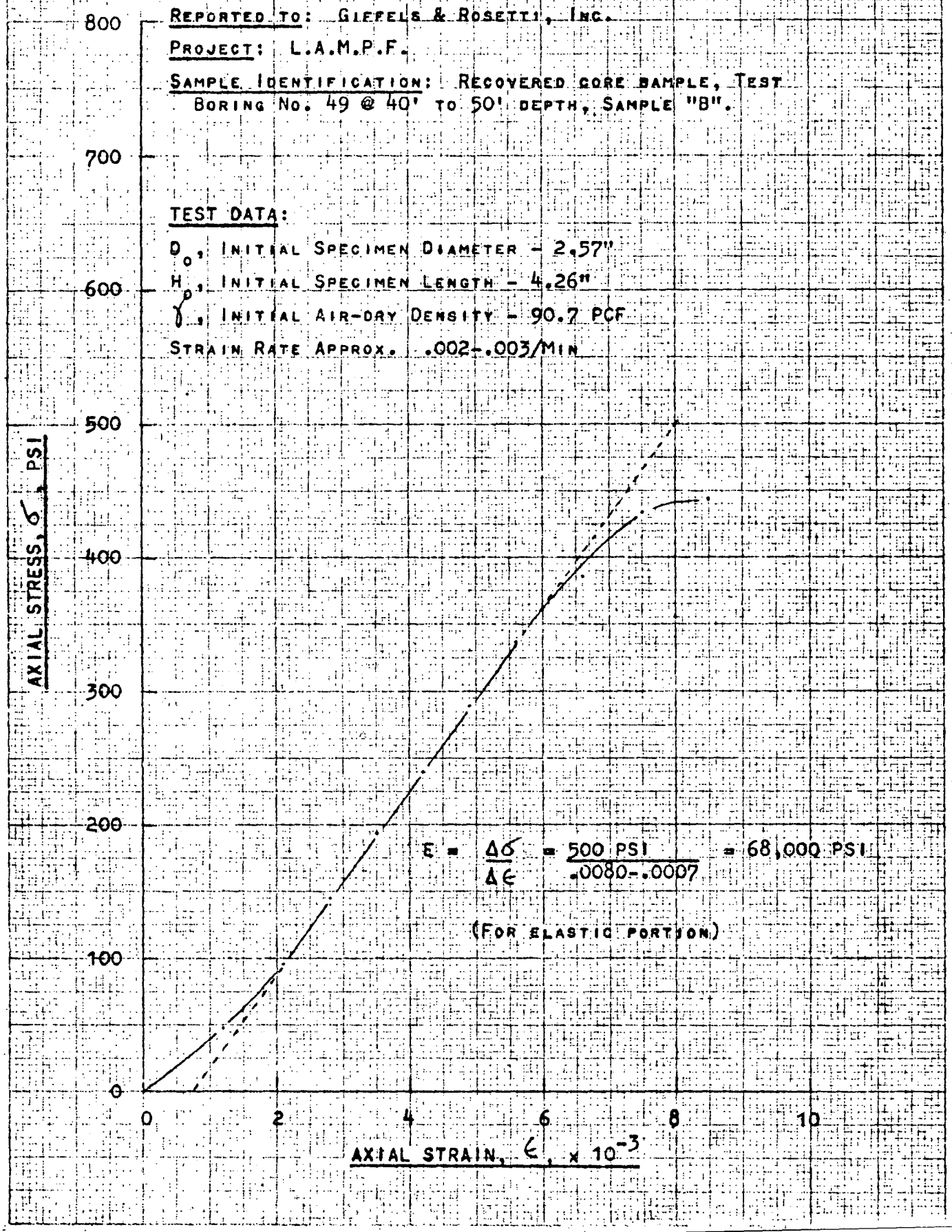
TEST DATA:

D_o, Initial Specimen Diameter - 2.57"

H_o, Initial Specimen Length - 4.26"

γ, Initial Air-Dry Density - 90.7 PCF

Strain Rate Approx. .002-.003/Min



MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING NO. 51 @ 36' TO 40' DEPTH, SAMPLE "B".

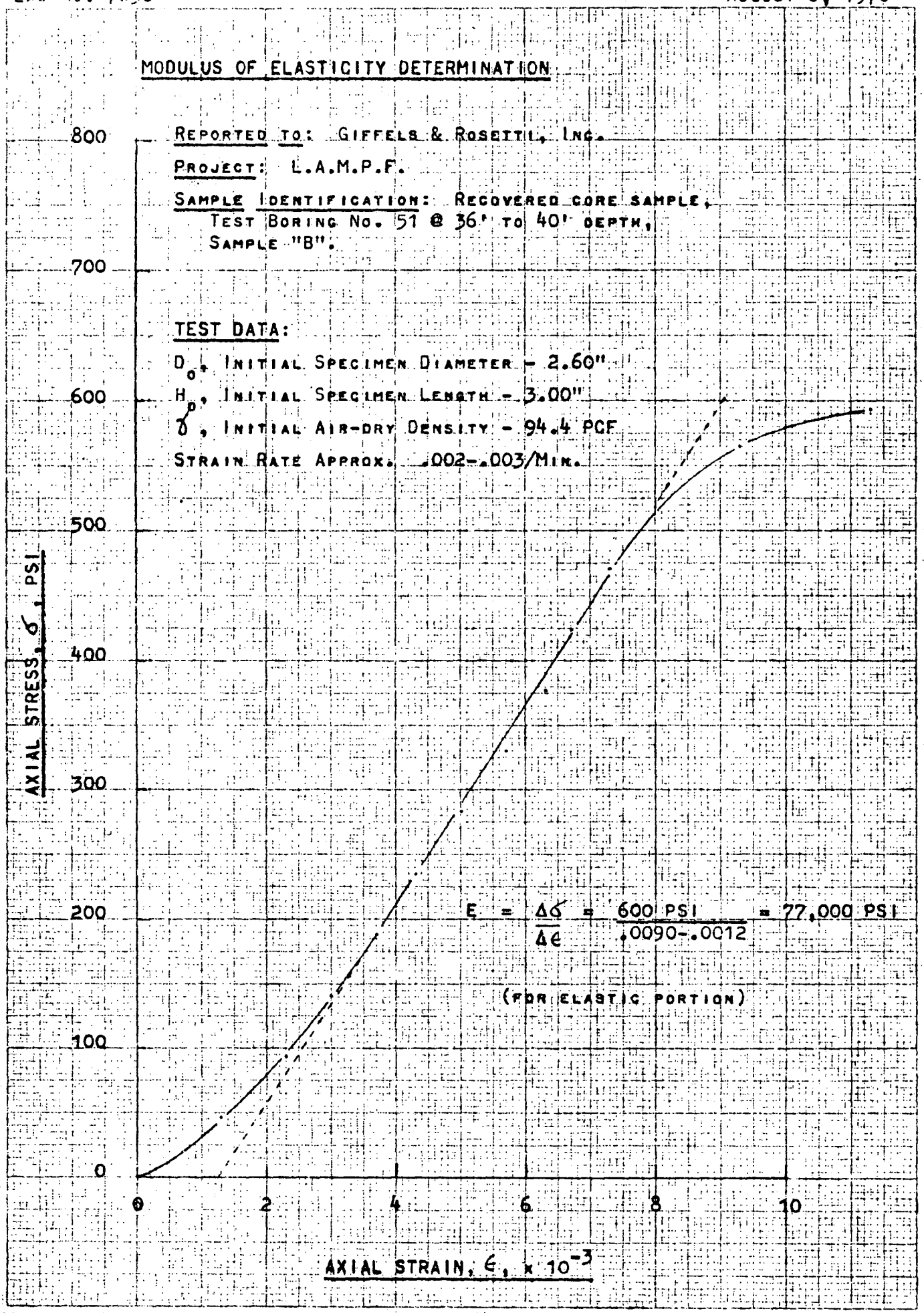
TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.60"

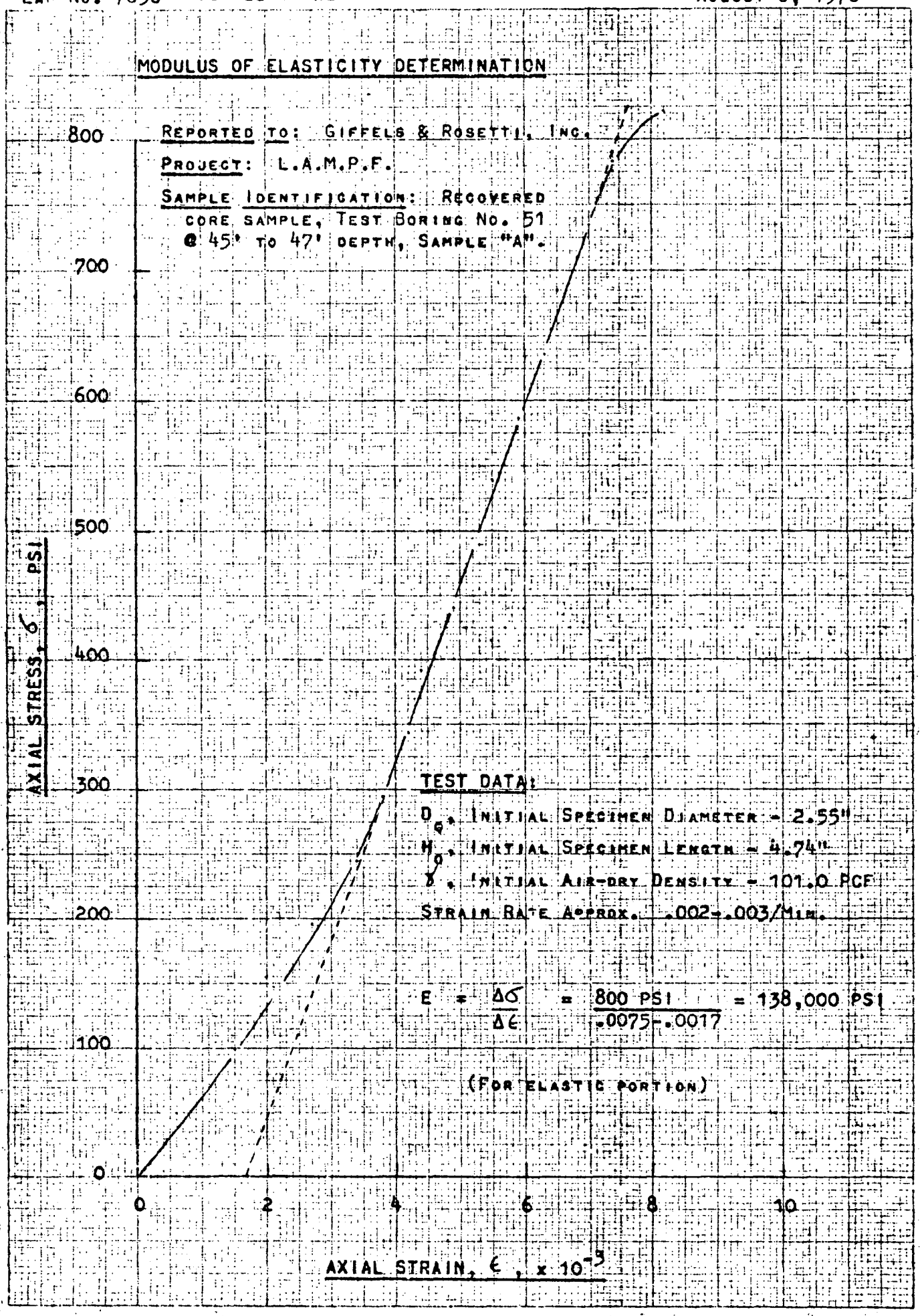
H_o, INITIAL SPECIMEN LENGTH - 3.00"

γ_o, INITIAL AIR-DRY DENSITY - 94.4 PCF

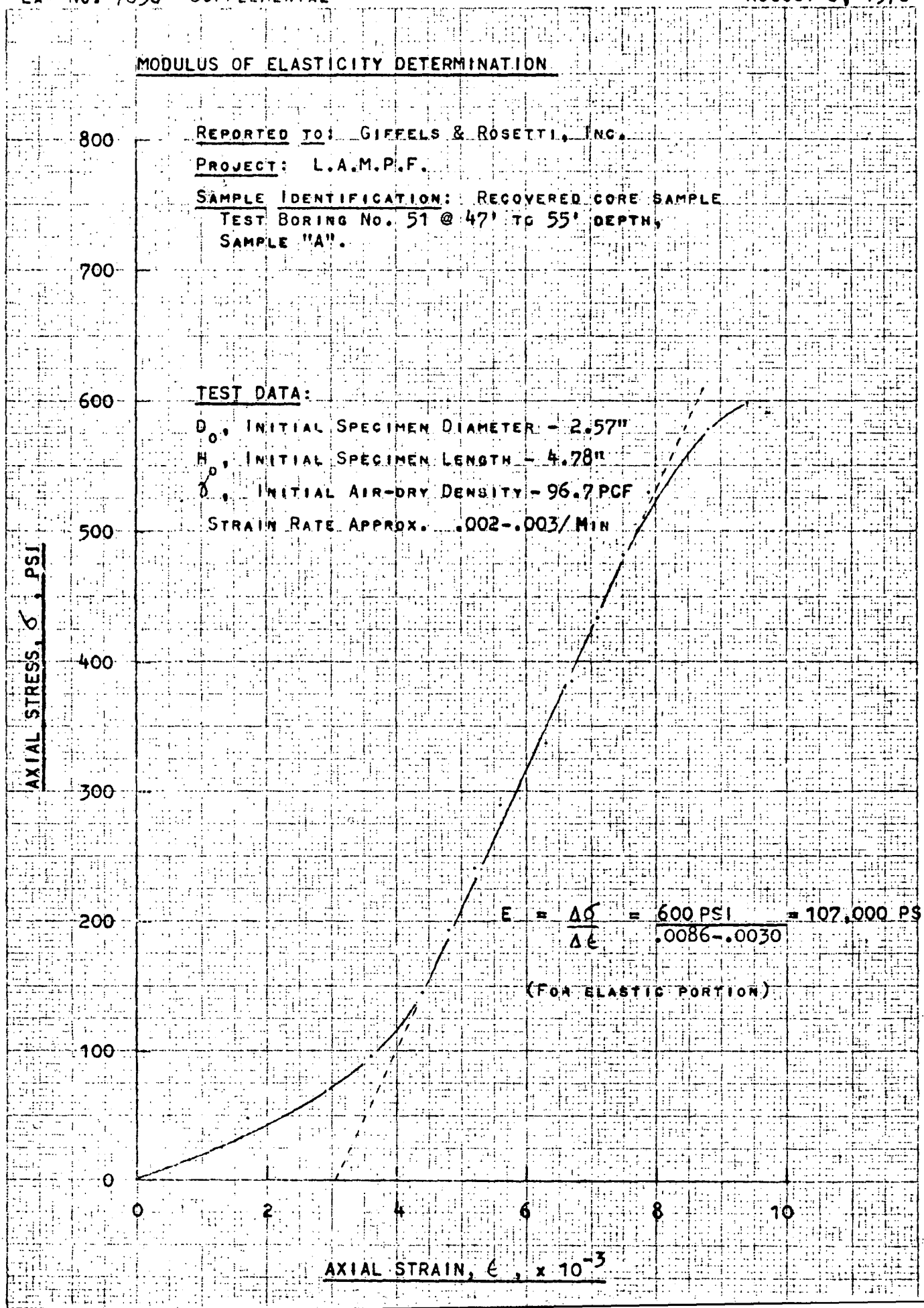
STRAIN RATE APPROX. .002-.003/MIN.



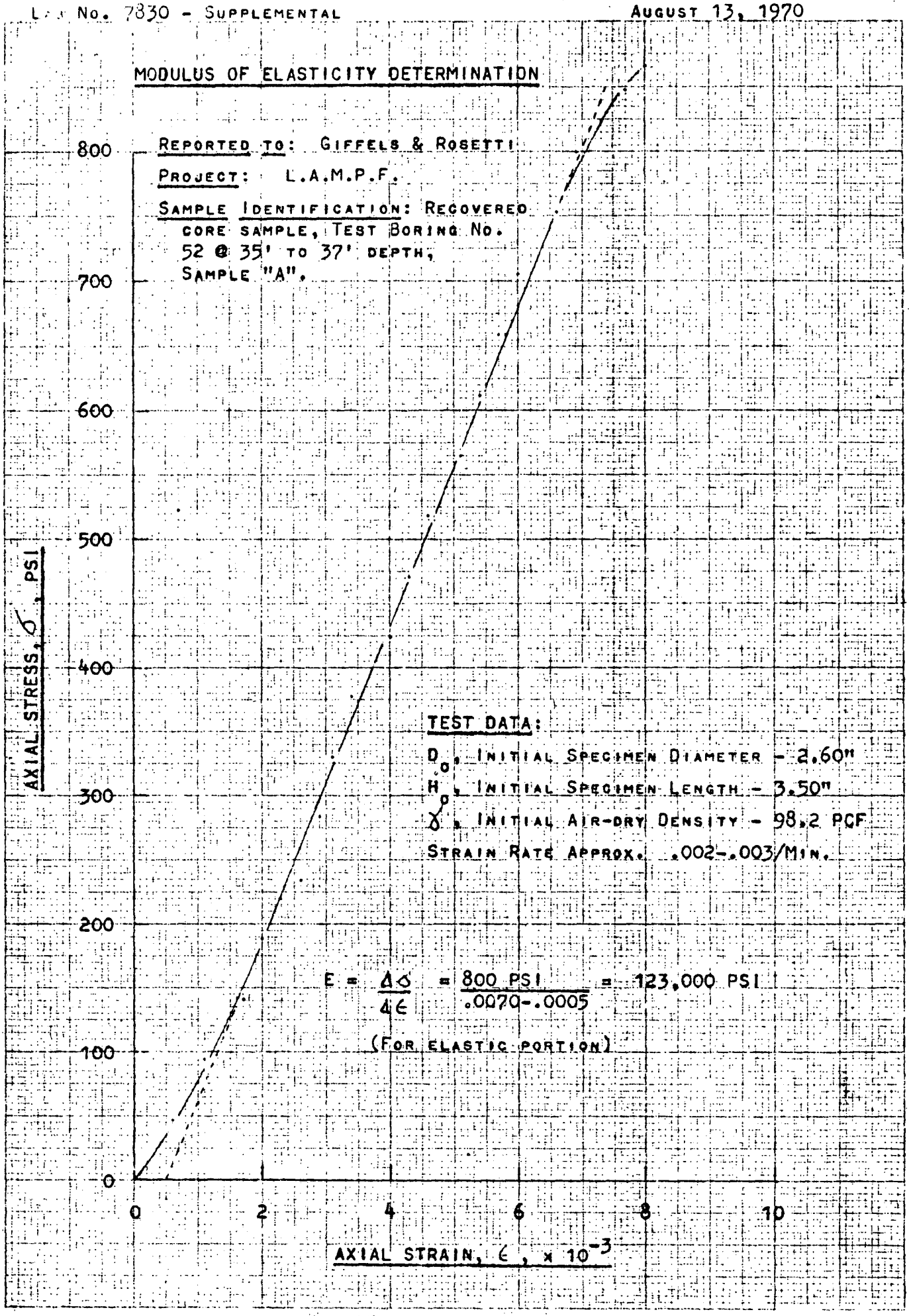
MODULUS OF ELASTICITY DETERMINATION



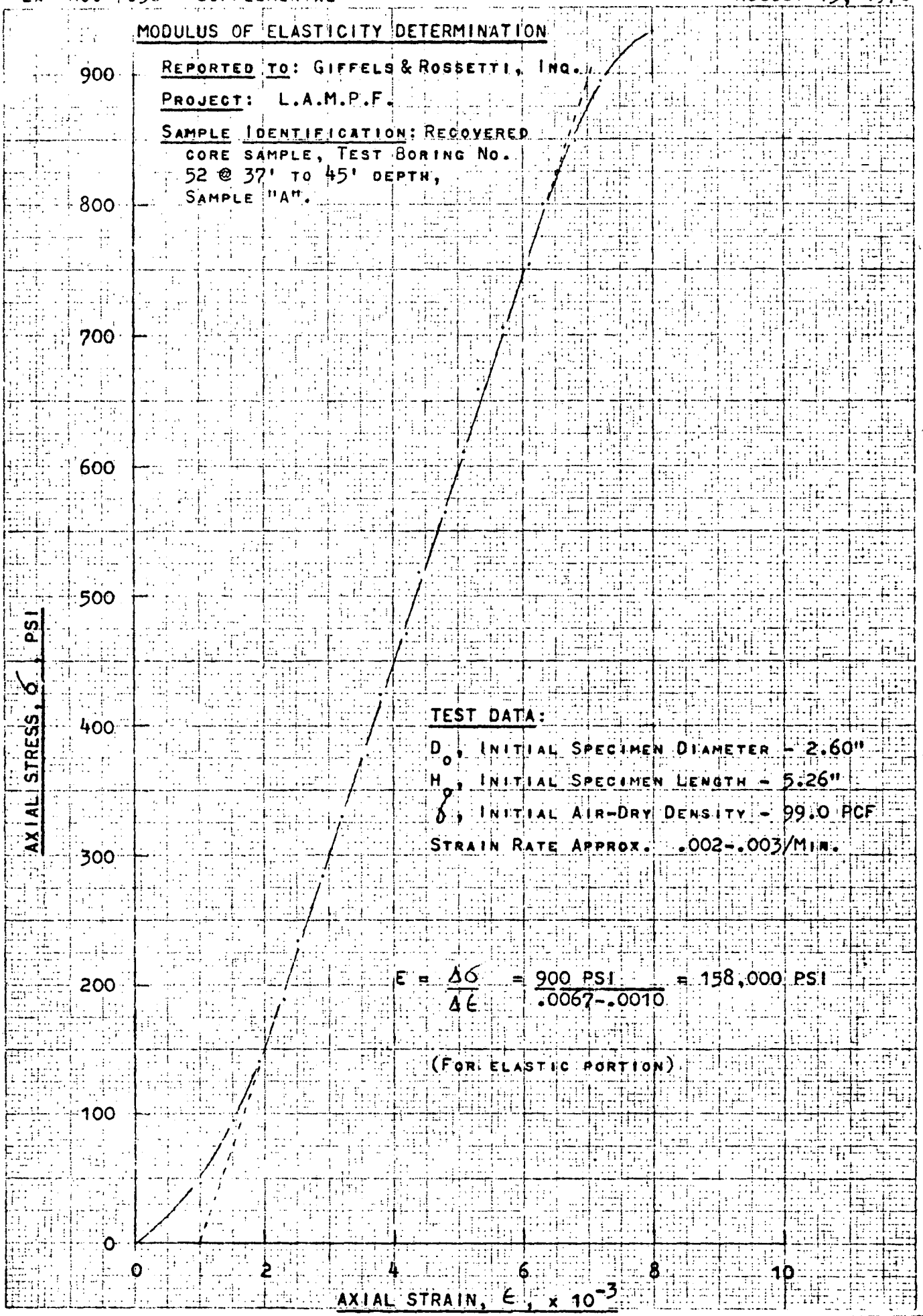
MODULUS OF ELASTICITY DETERMINATION



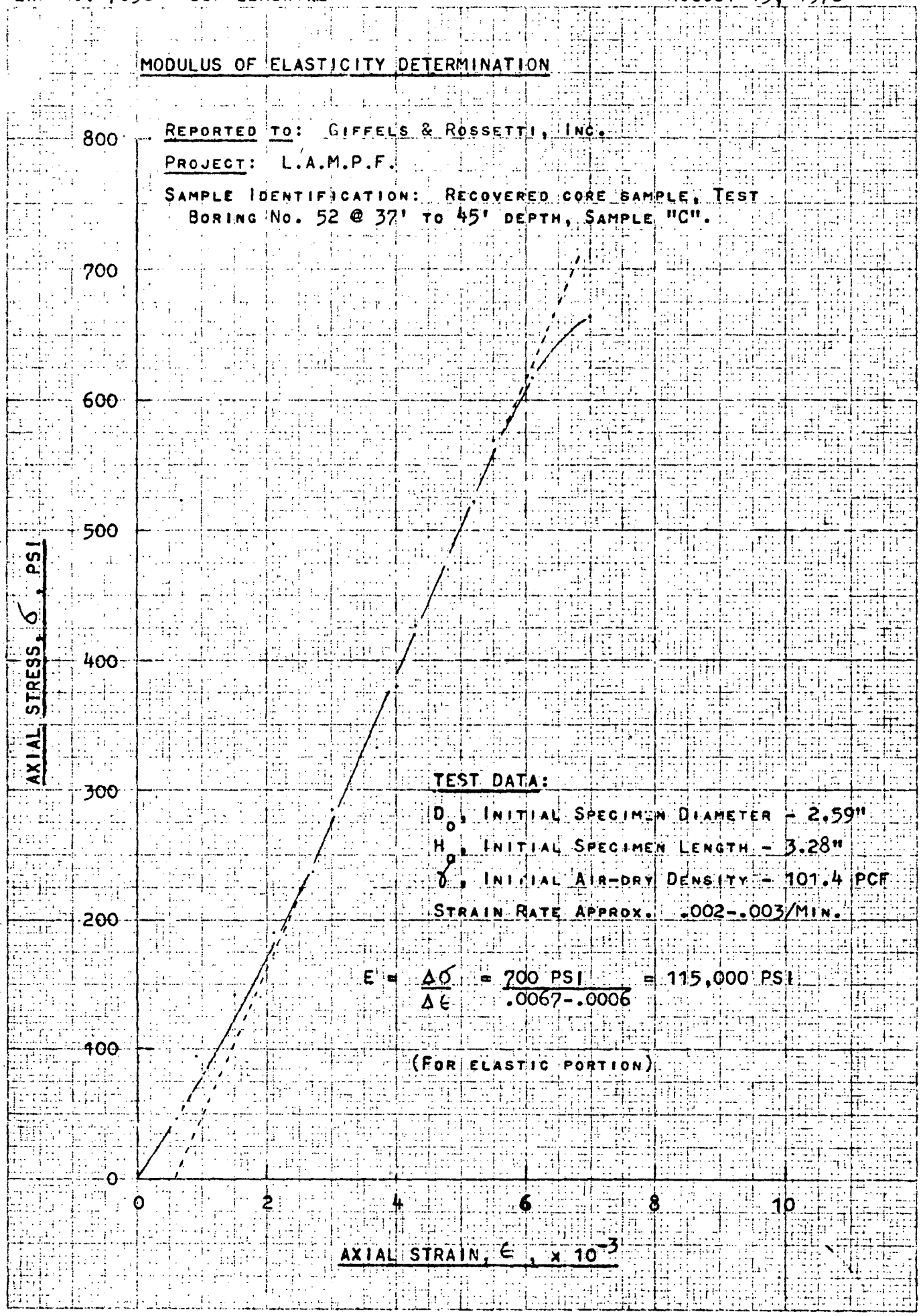
MODULUS OF ELASTICITY DETERMINATION



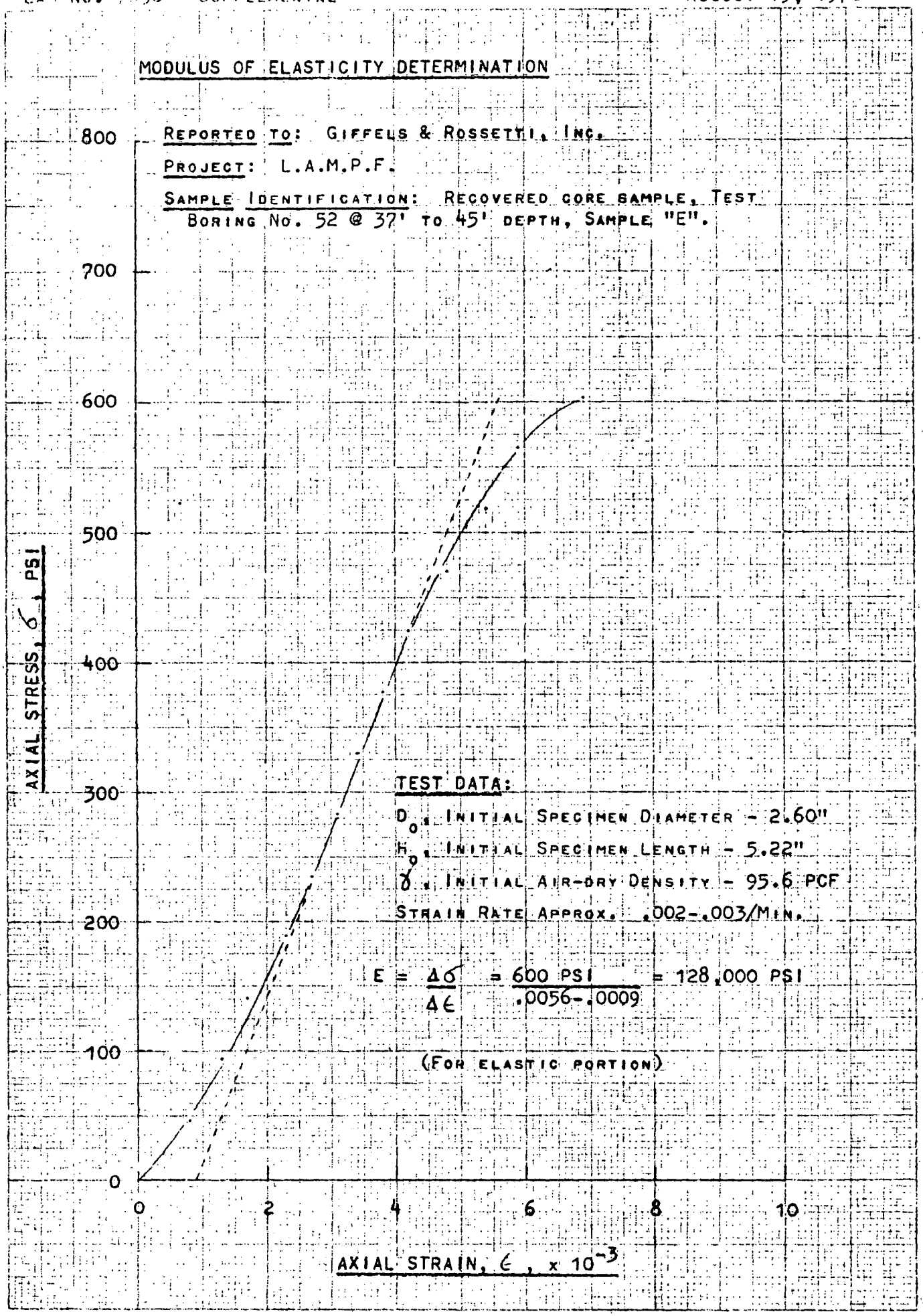
MODULUS OF ELASTICITY DETERMINATION



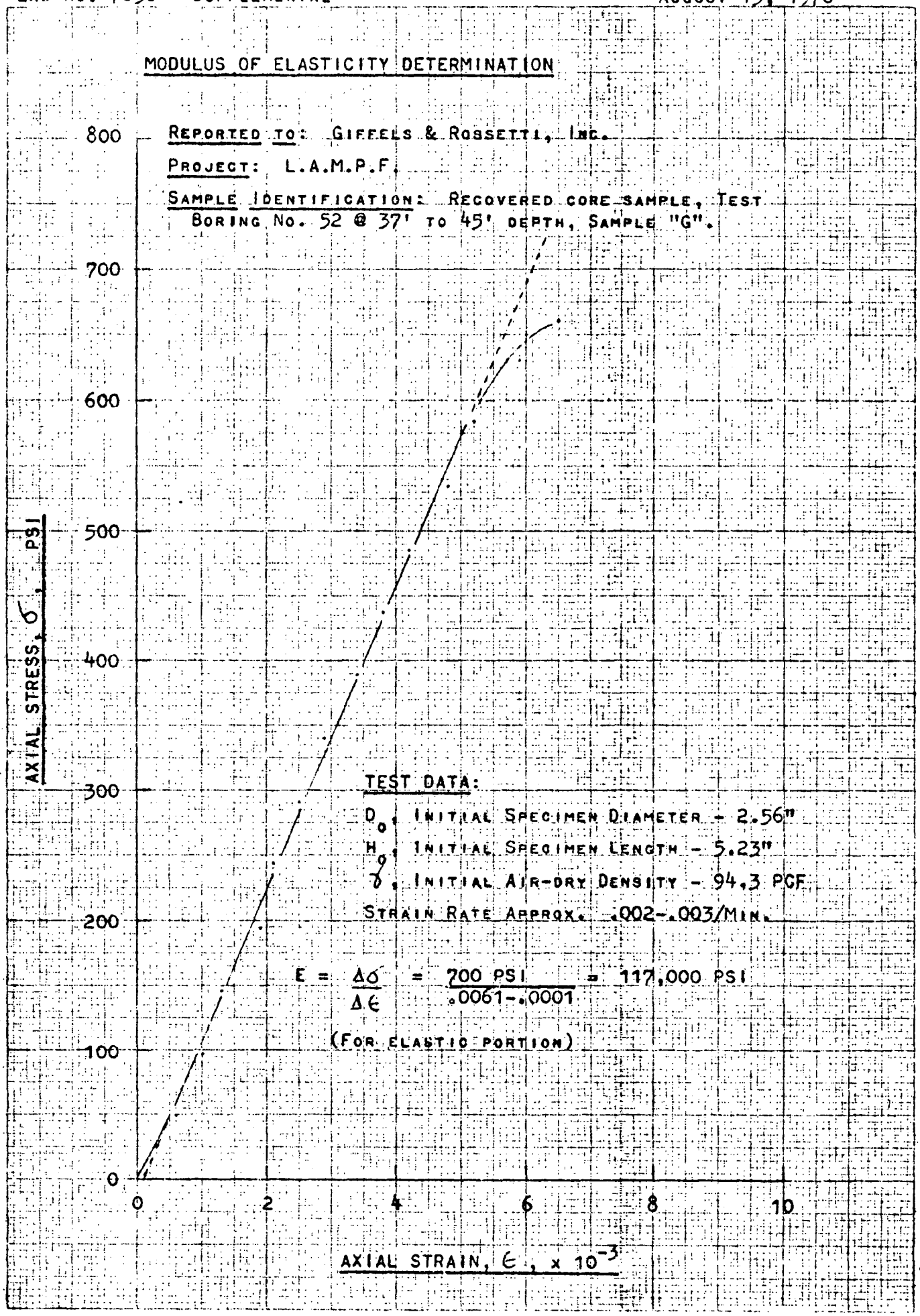
MODULUS OF ELASTICITY DETERMINATION



MODULUS OF ELASTICITY DETERMINATION



MODULUS OF ELASTICITY DETERMINATION

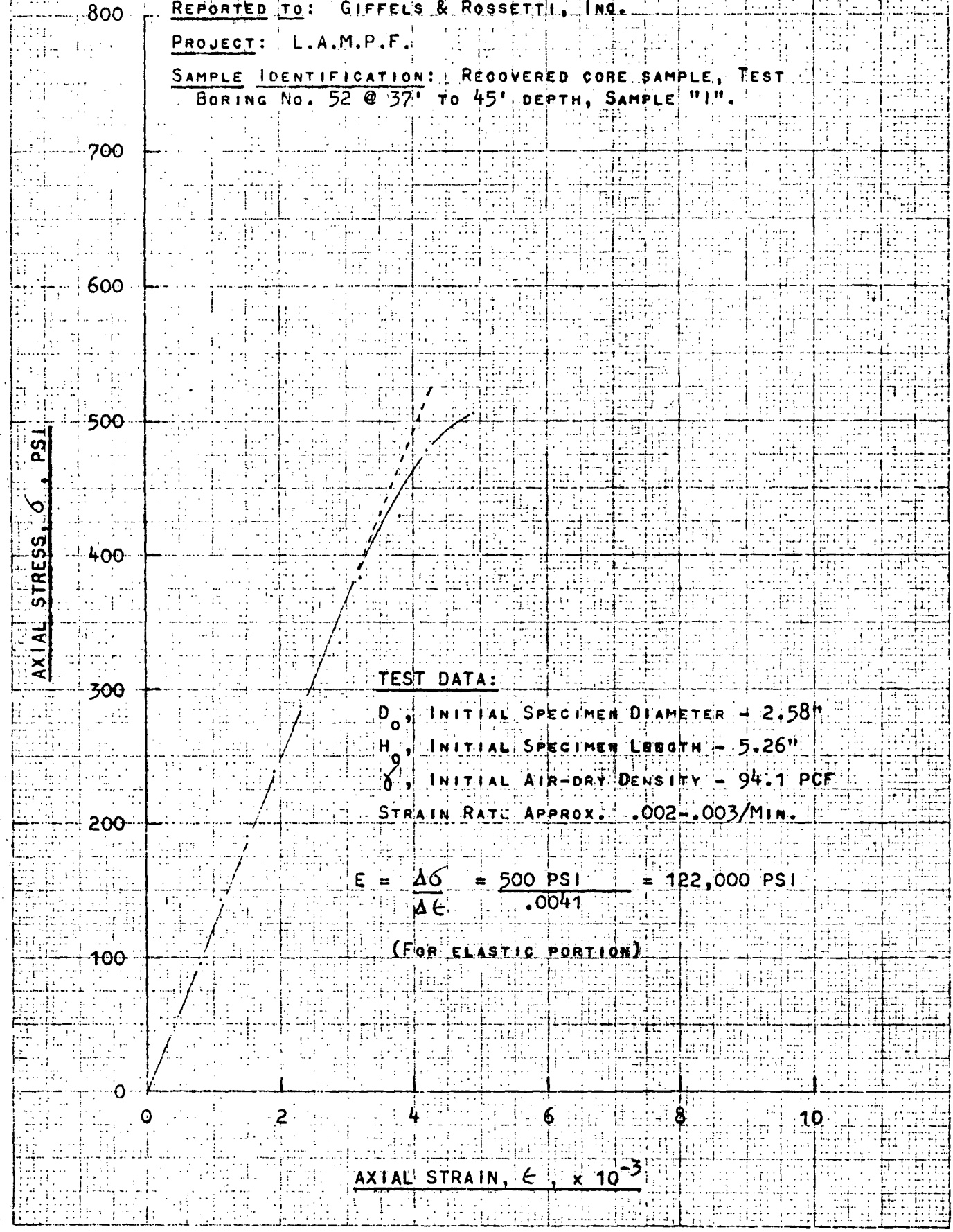


MODULUS OF ELASTICITY DETERMINATION

REPORTED TO: GIFFELS & ROSSETTI, INC.

PROJECT: L.A.M.P.F.

SAMPLE IDENTIFICATION: RECOVERED CORE SAMPLE, TEST BORING NO. 52 @ 37' TO 45' DEPTH, SAMPLE "1".



TEST DATA:

D_o, INITIAL SPECIMEN DIAMETER - 2.58"

H_o, INITIAL SPECIMEN LENGTH - 5.26"

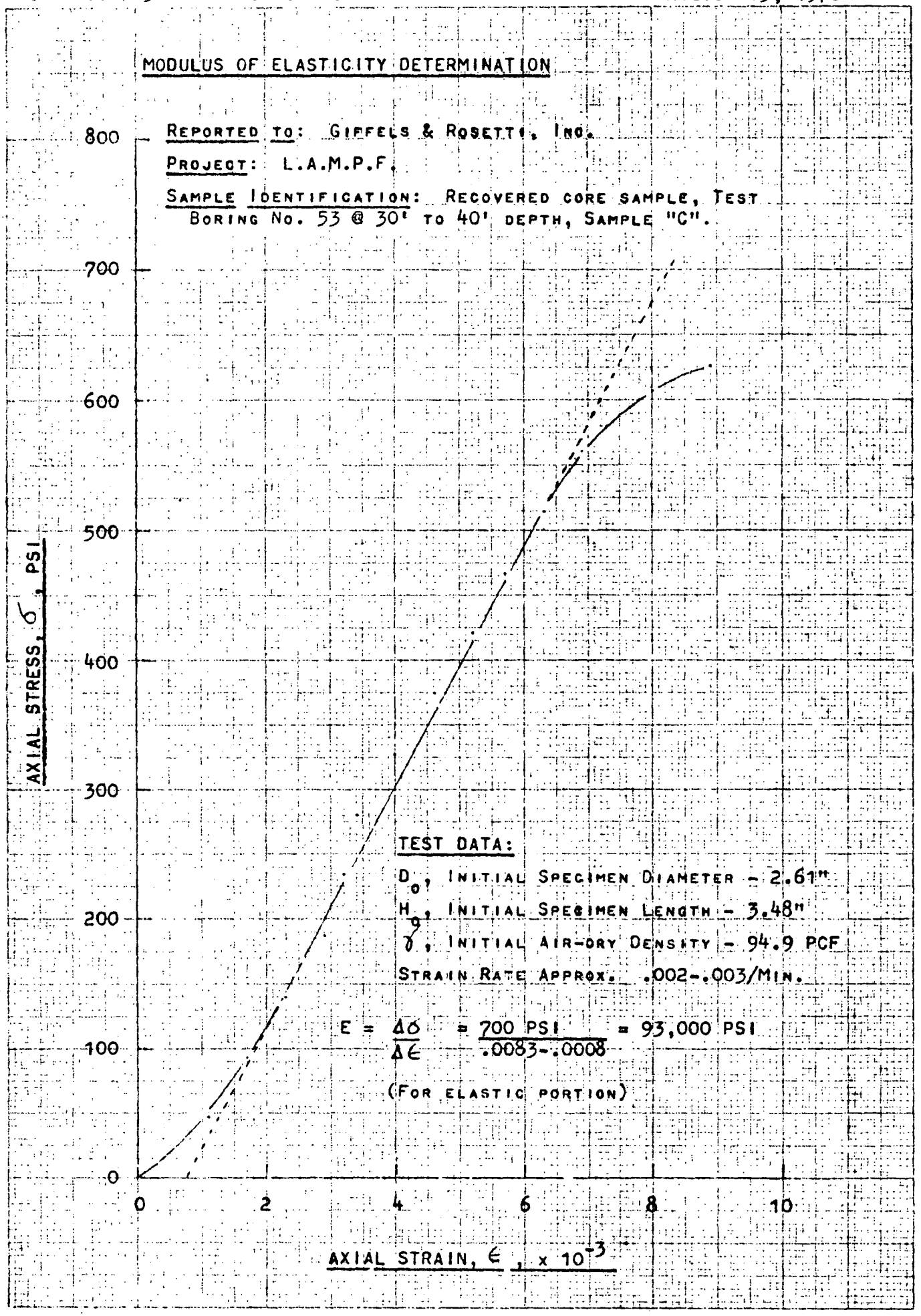
γ, INITIAL AIR-DRY DENSITY - 94.1 PCF

STRAIN RATE APPROX. .002-.003/MIN.

$$E = \frac{\Delta\sigma}{\Delta\epsilon} = \frac{500 \text{ PSI}}{.0041} = 122{,}000 \text{ PSI}$$

(FOR ELASTIC PORTION)

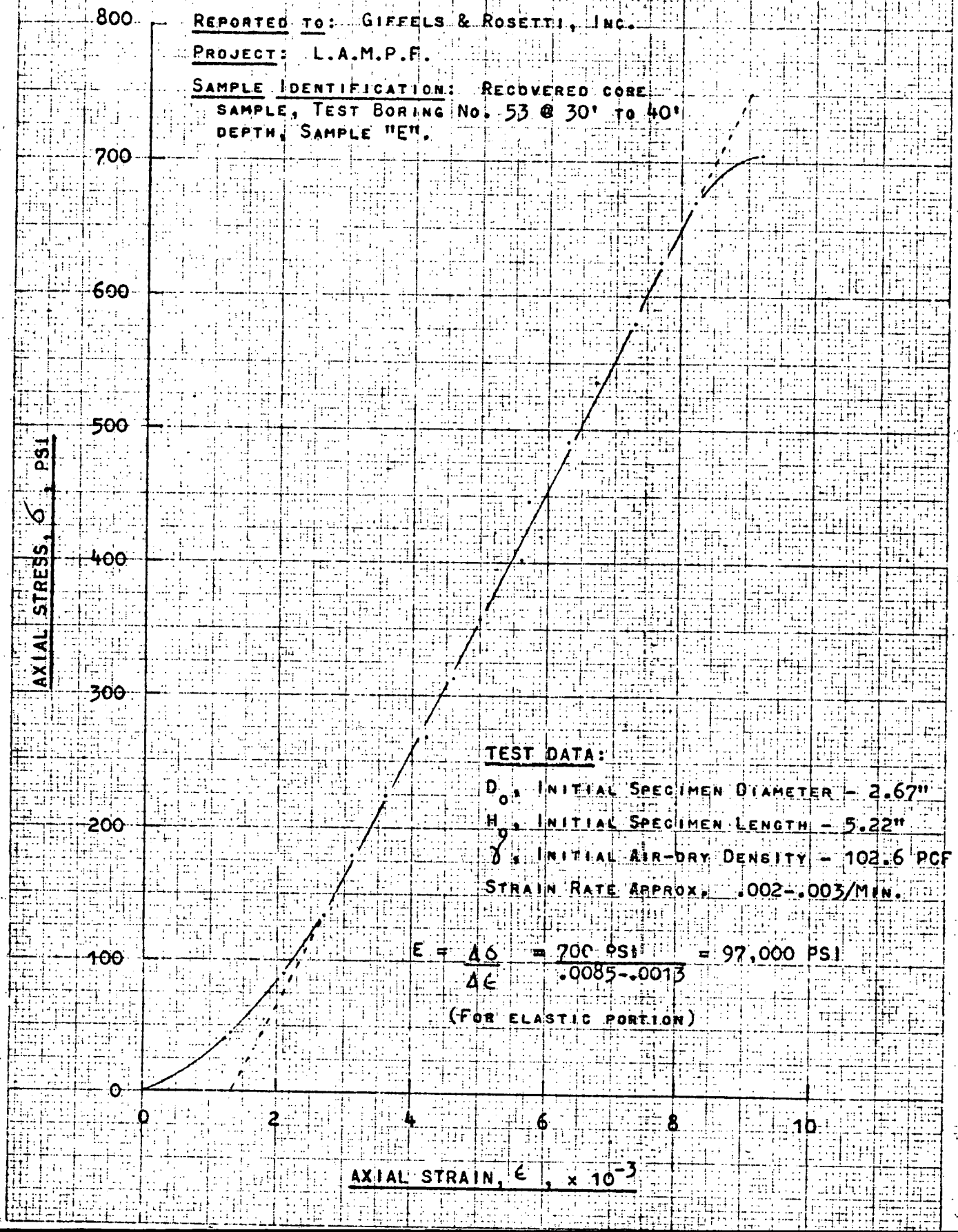
MODULUS OF ELASTICITY DETERMINATION



LAB NO. 7830 - SUPPLEMENTAL

AUGUST 13, 1970

MODULUS OF ELASTICITY DETERMINATION



REPORT OF

FOUNDATION EXPLORATION AND TESTING PROGRAM

Los Alamos, New Mexico

CONTRACT LACI 5-60

To

LOS ALAMOS CONTRACTORS, INC.

Los Alamos, New Mexico

MAY 1960

SPENCER J. BUCHANAN AND ASSOCIATES, INC.

PURPOSE

The purpose of this report is to summarize the results of foundation exploration and laboratory testing of subsurface materials of the U. S. Atomic Energy Commission at several test sites in the vicinity of Los Alamos, New Mexico.

AUTHORIZATION

The data reported herein were obtained for the Los Alamos Laboratory of the University of California through contract with Los Alamos Constructors, Incorporated. Contractural arrangements were made through Mr. Wm. P. Junge, Chief, Supply and Transportation Division, in accordance with Contract No. LACI-5-60 dated December 19, 1959. Our proposal was dated October 26, 1959. Work was initiated on 6 November 1959.

FIELD EXPLORATION

Field exploration consisted of a small diameter pilot hole drilled to a depth of 692.05 ft., and four core borings drilled to varying depths (2 to depths of 500 ft. and 2 to depths of 300 ft.). The pilot hole was initiated on 10 November and was completed on 21 November. The Area 2 core boring was initiated on 22 November and completed on 30 November. The Area 1 core boring was initiated on 1 December and, though coring was completed by 6 December, the additional work was not completed until 28 January 1960. The Area 4 core boring was initiated on 26 January 1960 and completed on 5 February 1960. The Area 3 core boring

was initiated on 28 January and completed on 3 February 1960. All small core boring, except in Area 4, was performed by equipment and personnel of Soil Mechanics Incorporated, our associate company. In order to expedite completion, the Area 4 exploration was performed under our direction using equipment of the Brazos Valley Drilling Company.

All field work was supervised by Mr. N. B. Herring, Manager of Soil Mechanics Incorporated, who is a graduate geologist.

The boring logs indicate the depths of samples which were tested. The report is subdivided by Test Area, for ease in locating data. In addition to the four core borings reported herein, many large diameter borings were drilled by others, from which 5-inch diameter cores were obtained for similar laboratory testing. Test data for laboratory sample numbers, which do not appear on the boring logs, were for the large diameter samples provided by Zia.

LABORATORY TESTING

All laboratory testing was performed under our direction. Exclusive of tests for mineralogical examination, exchange capacity, specific heat and thermal conductivity which were performed by staff members of the A & M College of Texas, spectrographic tests which were performed by Shilstone Testing Laboratory of Houston, and air permeability which was performed by Core Laboratories, Inc. of Houston, all other tests and calculations were performed in the Bryan, Texas laboratory of Soil Mechanics Incorporated using SMI and SJB&A engineers and technicians.

Test scheduling was done primarily by Mr. Herring, with concurrence in most instances by Dr. Newman, in accordance with policies agreed to as a result of conferences and letters in November 1959.

Most tests were of standard type, as described in manuals of ASTM, AASHO, etc., however several special tests such as the 1,000 psi and 5,000 psi lateral pressure triaxial tests were performed by procedures given in "Soil Testing for Engineers" by Wm. T. Lambe, and modified as required for the type of rock tested.

Initially the triaxial specimens were trimmed, were capped with Plaster of Paris, and were then tested, however subsequent tests were not capped since it was determined that capping did not significantly affect test results but did complicate appreciably the membrane sealing procedures necessary for lateral pressure application. At Dr. Newman's request the latter repetitive type compression tests, such as for Samples 7028 and 7029 in Area 2, were capped, however this procedure did not eliminate the concave upward shape of the stress-strain curve. As may be noted from the stress-strain curves for nearly all tuff samples, permanent non-recoverable deformation occurs under load, even if failure is not approached.

Of significant interest were observations of additional tests, which were not requested by Zia, but were performed at no cost as a matter of general interest to us. For example, it was noted that following removal of the softer rock cores from a 5,000 psi lateral load triaxial test the rock had been crushed to a powder. Our curiosity was aroused as to

whether this was caused by lateral pressure, or the combination of lateral plus vertical load. Consequently we set up samples at both 1,000 and 5,000 psi and, prior to applying vertical load, released the lateral pressure and checked the specimen. It was observed that crushing did not occur under 1,000 psi lateral load, but did under 5,000 psi. This phenomenon was not noted for the harder, high strength specimens, but was very evident for the softer tuffs. In addition, it was noted that the softer specimens decreased in mid-diameter by about 4.5% under the 5,000 psi lateral pressure.

It may be noted also that some data for a specific test are incomplete. This is attributed to the discontinuance of testing at the Client's request while some testing was still in progress. If desired, these data can be completed at later date.

The remaining samples on hand in the Bryan Laboratory will be retained for approximately one year from date of procurement, in event other testing may be required.

BORING LOGS

LOG OF BORING

PROJECT FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 1

DATE: 1 Dec. 1959 JOB NO: 59-154 BORING TYPE: 2 7/8" Cont. Air Drilling
DRILLER: Davis & Prator SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.66'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	Scale 1"=5'				Spudded in w/rock bit in soil overburden	Frozen lt. br. sandy clay
	4.0'					
5					Run No. 1 4.0' to 8.85' w/ double tube NX core barrel and insert bit. Drill Time 15 min. Core rec. 2.6' Largest pc. 0.2'	Lt. gr. fine grained volcanic tuff (Bandalier formation) with qtz. xtals. and pumice frags. as inclusions. Highly weathered friable and punky.
	8.8'					
10					Run No. 2 8.85 to 14.6' Drill Time 15 min. Core rec. 1.0' Largest pc. 0.1'	Considerable grinding in C.B. of badly fractured tuff
	14.6'					
15					Run No. 3 Drill Time 5 min. Core rec. 1.9' Largest pc. 0.2'	
20	20.0'					
					Run No. 4 Drill Time 10 min. Core rec. 3.5' Largest pc. 0.3'	No charge in classification
25	25.0'					
					Run No. 5 Drill Time 15 min. Core rec. 2.6' Largest pc. 0.3'	
30	30.0'					
					Run No. 6 Drill Time 15 min. Core rec. 3.4' Largest pc. 0.3'	
	34.3'					
35					Run No. 7 Drill Time 15 min Core rec. 2.8' Largest pc. 0.3'	No change in classification still grinding in core barrel
40	40.2'					
					Run No. 8 Drill Time 15 min. Core rec 4.3' Largest pc. 0.2'	
45	45.3'					

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA 49 Area 1

DATE: 1 Dec 1959 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis & Prator SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7159.66'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	Lab. No. 6786				Run No. 9 Drill Time 15 min. Core rec. 4.3' Largest pc. 0.7'	Unchanged. Same lt. gr. pumaceous tuff w/varying amounts of qtz. xtals. as inclusions. Fractured and friable.
50	50.5'					
	Scale Change 1" = 10'				Run No. 10 Using 20' double tube core barrel and insert bit Drill Time 1 hr. Core rec 13.5' Largest pc. 0.6'	Less fractured
60						
	Lab. No. 6787					
70	70.9					
					Run No. 11 Drill Time 40 min. Core rec 3.1' Largest pc. 0.3'	Softer - becoming lt. gr. sand at 91'
80	Lab. No. 6788					
90	91.1'					
					Run No. 12 Drill Time 40 min. Core rec 1.5' Largest pc. 0.3'	Large core loss due to extreme friability of tuff. Air erosion blows tuff out of hole as dust and qtz. sand
100						
110	111'					
					Run No. 13 Bag sample taken from return air cuttings 121' - 131' Drill time 30 min. Core rec. 0.8'	Probably very poorly cemented
120						
130	131.1					

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 1

DATE: 1-5 Dec. 1959 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis & Prator SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.66'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
140	140.1'				Run No. 14 Bag sample of cuttings 131'-141' Drill Time 8 min. No core recovery	Same Lt. gr. pumaceous groundmass reduced to powder w/v.f. qtz. sand. Air return very poor due to extreme formation porosity.
150					Run No. 15 Bag sample of cuttings 141' - 155' Drill Time 75 min. No core recovery	
	155.7					
160					4" casing set to 170' w/o trying to core due unconsolidated and and uncemented nature of formation	
170	170.0'					
180					Run No. 16 2 Dec. 1959 Drill Time 40 min. Core rec. 0.6' Largest pc. 0.1'	Change in formation 184' to 186' from lt. gr. to red-brown returning to lt. gr at 186' many qtz. xt als. and other glassey minerals
190	191.1'				Run No. 17 Drill Time 15 min. Core rec. 1.5' Largest pc. 0.1'	Lt. gr medium grained volcanic tuff as before Hole caving badly
200	200.2'				Run No. 18 5 Dec. 1959 Drill Time 1 hr, 10 min. Core rec. 8.7' Largest pc. 0.4'	Cave-in stabilized with mud in bottom of hole 205' Change to lt. gr. dense, hard, tuff w/qtz. & sanidine inclusions
210						
220	221.8'					

LOG OF BORING

PROJECT: FOR: The Zia Company

BORING NO: LOCATION: TA-49 Area 1

DATE: 5-6 Dec. 1959 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling

DRILLER: Davis & Prator SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.66'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar

-Core -Penetration Sample -No Recovery

-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 19	Slightly finer grained than previous dense, hard, volcanic tuff with qtz. and sanidine inclusions
					Drill Time 1 hr.	
230						
					Core rec. 10.5' Largest pc 0.4'	
240	241.8'					
					Run No. 20	Same formation
250					Drill Time 1 hr. 10 min.	
260	261.8				Core rec. 12.9' Largest pc 0.5'	
					Run No. 21	Same formation
					Drill Time 1 hr. 17 min.	
270	271.8				Core rec. 8.8' Largest pc 0.5'	
					Run No. 22	Grinding in C. B. due to fractures
					Drill Time 30 min	
280	283.2				Core rec. 2.8' Largest pc 0.1'	
					Run No. 23 6 Dec 1959	-becomes pinkish
					Drill Time 1 hr 20 min	
290						
					Core rec. 6.5' Largest pc 0.1'	
300	301.8					
	Scale Change 1" = 20'				Run No. 24	
					Drill Time 35 min.	
320	321.8'				Core rec 2.1' Largest pc. 0.2'	-becomes soft at 310', very little air return

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 1

DATE: 6 Dec. 1959 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis & Prator SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.06

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 25 Drill Time 2 hrs Overdrilled core barrel length with prior agreement with USGS Bag samples taken at 5' intervals No core recovery	Fine lt. gr. pumaceous dust in air return cuttings becomming lt gr with qtz. sand
340						
360						
	371.8'					
380					Run No. 26 Drill time 1 hr No core recovery	Same
	385.2'					
400					Run No. 27 Drill Time 20 min. Bag samples of air return cuttings taken at 5' intervals No core recovery	Same
420						
440	441.1'					
460					Run No. 28 Drill Time 441' - 451' 30 min. 451' - 461' 30 min. 461' - 471' 25 min. 471' - 481' 25 min. 481' - 491' 15 min. 491' - 501' 40 min. Sack samples of cuttings taken every 5 feet No core recovery	
480						
500	501'					Bottom Of Hole @ 501'

LOG OF BORING

PROJECT FOR: The Zia Company

BORING NO.:
LOCATION: TA-49 Area 2

DATE: 22 Nov. '59 JOB NO: 59-154 BORING TYPE: 2 7/8" Cont. Air Drilling
DRILLER: Davis SOIL ENGINEER Miller & Herring GROUND ELEV.: 7137.47

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	Scale 1"=5'				Spudded in with rock bit in soil overburden	Lt. br. sandy clay overburden
5	5.0'				Run No. 1 Core rec. 2.5' Largest pc. 0.3'	Gray white weathered volcanic tuff, friable and badly broken
10	9.1'				Run No. 2 Drilling Time 3 min. Core rec. 5.0' Largest pc. 1.0'	60° fractures, stained br. on surfaces
15	15.3'				Run No. 3 Drilling Time 3 min. Core rec. 3.0' Largest pc. 0.5'	Same fine grained weathered tuff
20	19.6'				Run No. 4 Drilling Time 2 min. Core rec. 3.0' Largest pc. 0.5'	Same lt gr. weathered tuff
25	25.8'				Run No. 5 Drilling Time 5 min.	Quartz xtals. and pumice inclusions in fine grained groundmass
30	30.1'				Run No. 6 Drilling Time 5 min. Core rec. 4.0' Largest pc. 0.8'	
35	34.8'				Run No. 7 Drilling Time 6 min. Core rec. 3.2' Largest pc. 0.4'	
40	40.1'				Run No. 8 Drilling Time 6 min. Core rec. 2.4' Largest pc. 0.4'	
45	45.4'					

LOG OF BORING

PROJECT: FOR: The Zia Company

BORING NO: LOCATION: TA-49 Area 2

DATE: 22 Nov. 1959 JOB NO: 59-154 BORING TYPE: 2 7/8" Cont. Air Drilling

DRILLER: Davis SOIL ENGINEER: Miller & Herring GROUND ELEV. 7134.47

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar

-Core -Penetration Sample -No Recovery

-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
		Lab Sample No. 6789			Run No. 9 Drilling Time 10 min. Core rec. 4.3' Largest pc. 0.3'	Lt. gr. volcanic tuff of the Bandalier formation w/fine grained qtz. and pumice inclusions
50	50.5'					
		Lab Sample No. 6790			Run No. 10 Drilling Time 10 min. Core rec. 5.0' Largest pc. 0.4'	
55	55.5'					
					Run No. 11 Drilling Time 10 min. Core rec. 2.4' Largest pc. 0.3'	-becoming hard w/ fractures
60	60.5'					
					Run No. 12 Drilling Time 10 min. Core rec. 3.5' Largest pc. 0.4'	
65	65.3'					
					Run No. 13 Drilling Time 10 min. Core rec. 3.0' Largest pc. 0.3'	
70	70.3'					
					Run No. 14 Drilling Time 8 min. Core rec. 4.8' Largest pc. 1.1'	
75		Lab. Sample No. 6791				
					Run No. 15 Drilling Time 8 min Core rec. 1.7' Largest pc. 0.3'	-becoming more friable
80	80.3'					
					Run No. 16 Drilling Time 8 min. No core recovery	Lost air return due to porous formation and caving
85	85.4'					
		Lab. Sample No. 6792			Run No. 17 Drilling Time 3 min. Core rec. 1.9' Largest pc. 0.5'	
90	90.4'					

SOIL MECHANICS INCORPORATED

LOG OF BORING

PROJECT FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 2

DATE: 22-23-25 Nov JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7134.47'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
Core X-Penetration Sample /-No Recovery
▽-Static Water Table ▼-Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 18	
					Drilling Time 5 min.	Air return very poor
					Core rec. 4.2' Largest pc 0.4'	
95	95.5'					
					Run No. 19	Qtz inclusions becoming
					Drilling Time 11 min.	coarse grained sand
					Core rec. 5.2' Largest pc. 0.5'	
100	100.45					
					Run No. 20 Time 11 min.	-becomes pinkish
	105.5'				Core rec. 4.0' Largest pc. 0.3'	
		23 Nov.			Run No. 21 Time 12 min.	
110	110.5'				Core rec. 3.6' Largest pc. 0.6'	
					Run No. 22 Time 8 min.	
	115.3'				Core rec. 3.6' Largest pc. 0.3'	
					Run No. 23 Time 8 min.	-becomes lt. gr.
120	120.6'				Core rec. 3.1' Largest pc. 0.3'	
					Run No. 24 Time 8 min.	Air return very poor in same
	125.3'				Core rec. 4.2' Largest pc. 0.5'	formation
					Run No. 25 Time 5 min.	
130	130.4'				Core rec. 4.5' Largest pc. 0.4'	
					Run No. 26 Time 5 min.	
	135.6'				Core rec. 5.3' Largest pc. 0.5'	
					Run No. 27 Time 5 min.	
140	140.7'				Core rec. 3.0'	
					Run No. 28 Time 5 min.	-becomes sandy or uncemented
	145.3'				No recovery	
					Run No. 29 Time 5 min.	
150	150.7'				No recovery	
					Run No. 30 Time 5 min.	Tools stuck due to cave-in
	155.3				No recovery	Hole cased to 150'
		25 Nov.			Run No. 31 Time 6 min.	
160	160.8'				No recovery	
					Run No. 32 Time 6 min.	
	165.8'				No recovery	
					Run No. 33 Time 6 min.	
170	170.8'				No recovery	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA -49 Area 2

DATE: 27-28-29 Nov. JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7131.17'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
▽-Static Water Table ▼-Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	175.6'				Run No. 34 Time 5 min. No recovery	
180	180.7'				Run No. 35 Time 5 min. No recovery	Air return cuttings become pinkish at 182'
	185.7'				Run No. 36 Time 5 min. No recovery	
190	190.3'				Run No. 37 Time 5 min. No recovery	Hard streak at 186'
	195.6'				Run No. 38 Time 7 min. Core rec 5.6' Largest 0.3'	Lt. gray w/pinkish cast Bandalier tuff. Hard, with quartz and pumice inclusions
200	200.65				Run No. 39 Time 7 min. Core rec 4.3' Largest pc. 0.3'	
	205.2				Run No. 40 Time 10 min. Core rec 2.0' Largest pc. 0.2'	Badly fractured
210	209.5'				Run No. 41 Time 12 min. Core rec 2.0' Largest pc. 0.1	Fractured and broken
	214.8'				Run No. 42 Time 10 min. Core rec 1.7' Largest pc. 0.1'	
220	220.7'				Run No. 43 Core rec. 4.7' Largest pc. 0.3'	Less fractured
	225.5'				Run No. 44 Time 5 min. Core rec. 5.0' Largest pc. 0.3'	
230	230.7'				Run No. 45 Time 5 min. Core rec. 5.1' Largest pc. 0.3'	
	235.7'				Run No. 46 Time 5 min. Core rec. 4.8' Largest pc. 0.3'	
240					Run No. 47 Time 20 min. Using 20' core barrel	Light gray tuff with quartz and pumice inclusions
	29 Nov.				Core rec 9.0' Largest pc 0.2'	
250	251.3'					
	Scale Change 1" = 20'				Run No. 48 Time 30 min.	
270	271.2'				Core rec. 7.5' Largest pc 0.5'	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 2

DATE: 29 & 30 Nov. JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7134.47'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
▽-Static Water Table ▼-Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 49 Time 35 min.	Light gray, hard volcanic tuff with sand size qtz. xtals and pumice inclusions to 1/2 inch.
					Core rec 16.4' Largest pc. 1.0'	
290	291.3'					
					Run No. 50 Time 25 min.	Hole cased to 180' Grinding of fractured pcs. in core barrel
					Core rec 3.8' Largest pc. 0.2'	
310	311.5'					
					Run No. 51 Time 25 min.	Formation change to very fine uncemented and unconsolidated tuff. Fine dust in air return.
					No core recovery	
330	331.5'					
					Run No. 52 Time 30 min.	
					No core recovery	
350	351.5					
					Run No. 53 Time 30 min.	
	30 Nov.				No core recovery	
370	371.5'					
					Run No. 54 Time 30 min.	
					No core recovery	
390	391.5					
					Run No. 55 Time 30 min.	Damp fine sand adhering to core barrel
					No core recovery	
410	411.6'					
					Run No. 56 Time 30 min.	
					No core recovery	
430	431.5'					
					Run No. 57 Time 30 min.	
450	451.5				No core recovery	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-29 Area 2

DATE: 30 Nov. 1959 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Prator SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7134.47'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 58 Drilling Time 20 min. No core recovery	
470	471.5'					
					Run No. 59 Drilling Time 30 min. Overdrilled 20' core barrel length as there was little possibility of obtaining core.	Return air cuttings indicate very fine light gray volcanic tuff or ash
490						
					No core recovery	
500	500.6'					Bottom Of Hole

LOG OF BORING

PROJECT: FOR: The Zia Company

BORING NO: LOCATION: TA-49 Area 3

DATE: 28 Jan. 1960 JOB NO: 59-154 BORING TYPE: 2 7/8" NX Cont. Air Drilling

DRILLER: Davis & Andrews SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.8

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar

-Core -Penetration Sample -No Recovery

-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	Scale 1" = 5'				Spudded in w/rock bit	Soil overburden
5					Run No. 1 Drilling Time 10 min. Core rec. 4.0' Largest pc. 1.0'	Lt. gr. weathered, soft and friable volcanic tuff w/ numerous qtz. phenocrysts and pumice frags to 1/2" size.
10	10.2'				Run No. 2 Drilling Time 12 min. Core rec. 4.5' Largest pc. 1.3'	
15	14.65'				Run No. 3 Drilling Time 10 min. Core rec. 1.8' Largest pc. 0.5'	Badly fractured - pumice inclusions to 1/2" diameter.
20	19.0'				Run No. 4 Drilling Time 10 min. Core rec. 3.0' Largest pc. 0.8'	Grinding in c.b.
25	23.8'				Run No. 5 Drilling Time 15 min. Core rec. 1.1' Largest pc. 0.4'	
30	28.6'				Run No. 6 Drilling Time 15 min. Core rec. 3.0' Largest pc. 0.6'	
35	33.9'				Run No. 7 Time 10 min. Core rec. 3.5' Largest pc. 0.2'	Very friable
40	36.6'				Run No. 8 Drilling Time 15 min. Core rec. 1.0 Largest pc. 0.1'	Damp @ 41'
45	41.9'				Run No. 9 Drilling Time 10 min. Core rec. 3.5' Largest pc. 0.2'	

LOG OF BORING

PROJECT: FOR: The Zia Company

BORING NO: LOCATION: TA-49 Area 3

DATE: 29 Jan. 1960 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling

DRILLER: Davis & Andrews SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7169.8

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar

-Core -Penetration Sample -No Recovery

-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
		46.6'				
50	54.3'				Run No. 10 Drilling Time 20 min. Core rec. 50' Largest pc. 0.2'	Lt. pinkish gray volcanic tuff with v.f. groundmass. Coarse phenocrysts of qtz. and sanidine up to 20% of rock.
55	59.5'				Run No. 11 Drilling Time 15 min. Core rec. 4.2' Largest pc. 0.4'	
60	64.8'	29 Jan.			Run No. 12 Drilling Time 15 min. Core rec. 4.2' Largest pc. 0.2'	
65	70.5'				Run No. 13 Drilling Time 15 min. Core rec. 3.8' Largest pc. 0.2'	Salmon pink tuff - fewer phenocrysts
70	74.8'				Run No. 14 Drilling Time 15 min. Core rec. 3.4' Largest pc. 0.2'	Lt. pinkish gray tuff more phenocrysts of qtz. and sanidine
75	80.8'				Run No. 15 Drilling Time 15 min. No core recovery	
80	85.0'				Run No. 16 Drilling Time 15 min. Core rec. 0.3'	
85	90.9'				Run No. 17 Drilling Time 15 min. Core rec. 2.0'	
90						

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 3

DATE: 29 Jan. 1960 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis & Andrews SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.5

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 18 Drilling Time 15 min. Core rec. 0.8' Largest pc.frag	
95	94.8'					
					Run No. 19 Drilling Time 10 min. Core rec. 5.0' Largest pc. 0.4'	
100	100.8'					-becomes harder @ 100'
					Run No. 20 Drilling Time 15 min. Core rec. 3.0' Largest pc. 0.4'	
105	104.9'					
					Run No. 21 Drilling Time 15 min. Core rec. 5.6' Largest pc. 1.6'	
110	110.5'					
					Run No. 22 Drilling Time 15 min. Core rec. 2.8' Largest pc. 0.4'	
115	115.2'					
					Run No. 23 Drilling Time 6 min. No core recovery	-becomes softer, no air return to surface due to porous formation
120	120.8'					
					Run No. 24 Drilling Time 5 min. Core rec. 0.3' Largest pc.frags.	
125	125.1'					
					Run No. 25 Drilling Time 5 min. No core recovery	Very soft
130	130.8'					
					Run No. 26 No core recovery	
135	135.7'					

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 3

DATE 29 Jan.- 1 Feb.'60 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis & Andrews SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7169.5

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	137.9'				Run No. 27 Took "Po Boy" Sample	Lt. gr. very fine volcanic tuff crushed in sampler
140					Run No. 28 Drilling Time 10	
	143.7				No core recovery	
145					Run No. 29 No core recovery	
	147'					
	148'				Sampled With "PoBoy"	Same very fine tuff crushed in sample
150					Run No. 30 Drilling Time 10 min.	
	151.5				No recovery	
155					No attempt made to core to depth of 191'. Soft and unstable formation made it necessary to case hole. Casing placed to 191 feet with considerable difficulty. Samples of return air cuttings were taken every five feet during reaming for casing.	
160						
175					Hole reamed and cased placed during period 30 Jan. to 1 Feb.	
180						

SOIL MECHANICS INCORPORATED

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 3

DATE: 1 Feb. 1960 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Davis & Andrews SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.5'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
190	191					
		1 Feb '60			Run No. 31 Sampled with "Po Boy"	
	193.7				Run No. 32 Time 15 mi Rec. 1.4'	
195	195.1				Run No. 33 Drilling Time 15 min	Light purplish gray volcanic tuff. Dense and welded
200	201.1				Core rec. 4.7' Largest pc 1.5'	
					Run No. 34 Drilling Time 15 min. Core rec. 4.7' Largest pc. 1.5'	
205	206.1'					
					Run No. 35 Drilling Time 10 min.	
210	211.1'				Core rec. 5.0' Largest pc. 1.8'	
					Run No. 36 Drilling Time 2 hrs Core rec. 4.0' Largest pc. 1.3'	
215	215.9'					
					Run No. 37 Drilling Time 2 hrs Core rec. 4.6' Largest pc. 1.2'	
220	220.7'					
					Run No. 38 Drilling Time 2 hrs Core rec. 5.1' Largest pc 1.0'	
225	225.7'					
					Run No. 39 Drilling Time 2 hrs	
230	230.3'				Core rec. 5.1' Largest pc. 0.6'	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 3

DATE: 1 Feb. 1960 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drillig
DRILLER: Davis & Andrews SOIL ENGINEER: Miller & Herring GROUND ELEV.: 7169.5'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 40 Drilling Time 2 hrs Core rec. 4.2' Largest pc. 0.8'	Lt. purplish gray volcanic tuff - dense and welded
235	235.3'					
					Run No. 41 Drilling Time 1 hr Core rec. 12.5' Largest pc. 2.0'	
240						
	Scale Change 1" = 10'					
250	250.2'					
					Run No. 42 Drilling Time 45 min. Core rec. 20.0' Largest pc. 2.0'	
260						
270	270.2'					
					Run No. 43 Drilling Time 20 min. Core rec. 18.3' Largest pc. 0.5'	
280						
290	290.2					
					Run No. 44 Drilling Time 20 min. Core rec. 9.2' Largest pc. 0.5'	
300	300.2					Bottom of Hole @ 300.2'

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4

DATE: 26 Jan '60 JOB NO: 59-154 BORING TYPE: 2 7/8" NX Cont. Air Drilling
DRILLER: Hatfield & Fisk SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7116.2'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
▽-Static Water Table ▼-Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	1" = 5'					
	2.0'				Run No. 1	Imported crushed tuff
5	5.0'				Run No. 2 Drill Time 5 min	Lt. gr. tuff w/fine groundmass, punky
10	10.0'				Run No. 3 Drilling Time 10 min.	Abundent pumice frags
15	15.0'				Run No. 4 Drilling Time 15 min.	Qtz. phenocrysts becoming coarser
	18.0'				Run No. 5 Drilling Time 10 min.	Latite fragments becoming larger
20					Run No. 6 Drilling Time 15 min.	
25	25.0'					
30					Run No. 7 Drilling Time 15 min.	Less pumice fragments
	32.5'					
35					Run No. 8 Drilling Time 15 min.	
40						
45						

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4

DATE: 26 Jan. 1960 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Hatfield & Fisk SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7116.7'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 8 (continued)	Lt pinkish-gray tuff with abundant qtz. phenocrysts and some sanidine
50						
	52.5'					
55					Run No. 9 Drilling Time 20 min. Core rec. 2.0'	
	57.0'					
60					Run No. 10 Drilling Time 1 hr.	Clay alteration along joint @ 57.5'. Abundant phenocrysts of qtz. and sanidine. Intervals of sand and weathered tuff.
65					Core rec. 1.0' Largest pc. 0.2'	
70						
75						
	77.0'					
80					Run No. 11 Drilling Time 15 min. Core rec. 0.3' Fragments	
	82.1'					
	84.0'				Run No. 12 Core rec. 3.0' Largest pc. 0.2'	
85					Run No. 13 Drilling Time 30 min.	-becoming light purplish gray w/v. f. groundmass. Up to 50% qtz. and sanidine.
90					Core rec 3.5' Largest pc. 0.4'	

LOG OF BORING

PROJECT: FOR: The Zia Company

BORING NO: LOCATION: TA-49 Area 4

DATE: 26-27 Jan. '60 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling

DRILLER: Hatfield & Fisk SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7116.7

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar

-Core -Penetration Sample -No Recovery

▽-Static Water Table ▼-Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
					Run No. 14	
					Drilling Time 30 min.	Same formation
95						
	96.7'				Core rec 4.5'	
		27	Jan.		Run No. 15	
100					Drilling Time 15 min.	
					Core rec. 1.0' Largest pc. 0.1'	
	104.0'					
105					Run No. 16	
					Drilling Time 15 min.	
	109.0'				Core rec. 5.0'	
110					Run No. 17	
					Drilling Time 15 min.	
	114.0				Core rec 5.0'	
115					Run No. 18	
					Drilling Time 20 min.	
	119.0'				Core rec. 3.6' Largest pc. 0.4'	
120					Run No. 19	Twisted off bit in hole and could not recover it. Abandoned hole No. 4 and move 7' North and restarted on hole 4 B
	124.0'				No recovery	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4 (B)

DATE: 28-29 Jan. '60 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Hatfield & Fisk SOIL ENGINEER: Herring & Miller GROUND ELEV.: 7116.7

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	No Scale				Reamed hole 4 B to depth of 121' w/6 3/4 in rock bit before resuming coring.	
120	121.0'					
	Scale 1" = 5'				Run No. 1 Drilling Time 15 min. Core rec. 2.3' Largest pc. 0.4'	
125	126.0'					
					Run No. 2 Drilling Time 15 min. No core recovery	
130	131'					
	133'				Run No. 3 Took "Po Boy" Sample	No sample recovered in very soft formation
					Run No. 4 Drilling Time 10 min No core recovery	
135	136.5'					
	29 Jan				Run No. 5 Drilling time 15 min.	Due to poor core recovery this hole had to be abandoned. Hole 4 C to be started 5' North of Hole 4 B
140						
145						
150						
	153.5'					Bottom of Hole @ 153.5'
155						

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4 (C)

DATE: 29 Jan. '60 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: SOIL ENGINEER: GROUND ELEV.: 7116.7

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	No Scale				Due to poor core recovery hole 4 B was abandoned. Hole 4 C was drilled to a depth of 121' w/ 6 3/4 inch rock bit before coring was resumed.	
120	121'					
	Scale 1" = 5'				Run No. 1 Drilling Time 15 min. Core rec. 2.7' Largest pc. 0.3'	Friable lt. gr. volcanic tuff with qtz. phenocrysts and divitrified pumice frags.
125	126'					
					Run No. 2 Drilling Time 15 min. No core recovery	
130	131'					
	133'				Run No. 3 "Po Boy" Sample - No rec.	Hole caving badly in friable or sandy formation
135	No Scale				Not possible to continue coring due to nature of formation. Decision to set 170' of casing before resuming coring. Drilling w/ 6 3/4" rock bit Drilling rate: 2 to 2½ feet per minute Continuous sack samples taken from air return cuttings.	
170'	31 Jan				Run No. 4 Drilling Time 15 min. No recovery	Formation still very friable and sandy. Hole coving below casing
175	175'					
	177'				Run No. 5 "Po Boy" Sample - No rec.	
180	182'				Run No. 6 Drilling Time 15 min. No recovery	Hole caving badly
185	1 Feb.				In attempting to clean hole and stabilize with mud, hole over-drilled to 188 feet. Casing set to 190'	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4 (C)

DATE: 29 Jan. '60 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: SOIL ENGINEER: GROUND ELEV.: 7116.7

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
▽-Static Water Table ▼-Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	No Scale				Due to poor core recovery hole 4 B was abandoned. Hole 4 C was drilled to a depth of 121' w/ 6 3/4 inch rock bit before coring was resumed.	
120	121'					
	Scale 1" = 5'				Run No. 1 Drilling Time 15 min. Core rec. 2.7' Largest pc. 0.3'	Friable lt. gr. volcanic tuff with qtz. phenocrysts and divitrified pumice frags.
125	126'					
					Run No. 2 Drilling Time 15 min. No core recovery	
130	131'					
	133'				Run No. 3 "Po Boy" Sample - No rec.	Hole caving badly in friable or sandy formation
135	No Scale				Not possible to continue coring due to nature of formation. Decision to set 170' of casing before resuming coring. Drilling w/ 6 3/4" rock bit Drilling rate: 2 to $2\frac{1}{2}$ feet per minute Continuous sack samples taken from air return cuttings.	
170'	31 Jan				Run No. 4 Drilling Time 15 min. No recovery	Formation still very friable and sandy. Hole coving below casing
175	175'					
	177'				Run No. 5 "Po Boy" Sample - No rec.	
180	182'				Run No. 6 Drilling Time 15 min. No recovery	Hole caving badly
185	1 Feb.				In attempting to clean hole and stabilize with mud, hole over-drilled to 188 feet. Casing set to 190'	

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4 (C)

DATE: 31 Jan. 3 Feb. JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Hatfield SOIL ENGINEER: Herring GROUND ELEV.: 7116.7'

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	184'					
185	185.2'				"Po Boy" Sple. inside casing	Lt. gr. v.f. volcanic tuff crushed inside sampler
					Run No. 8 "Po Boy" Sample taken inside casing	
	188.2'					
190					Run No. 9 Drilling Time 15 min. Core rec. 1.7'	Lt. gr. tuff, welded. Sanidine phenocrysts, ryolite zenoliths, pumice frags. to 1" dia. 50% qtz. and sanidine.
	193.5'					
195					Run No. 10 Drilling Time 19 min. Core rec. 4.0	-becoming harder -becoming lt. purplish gray
	198.6'					
200					Run No. 11 Drilling Time 20 min. Core rec. 4.5'	
	203.6'					
205					Run No. 12 Drilling Time 20 min. Core rec. 4 5.0'	
	208.8'					
210	3 Feb. Scale Change 1" = 10'				Run No. 13 Drilling Time 30 min. Core rec. 3.5'	45° Fractures
	219.1'					
220					Run No. 14 Drilling Time 11 min. Core rec. 11.9'	
230	231.4'					
					Run No. 15 Drilling Time 30 min.	
240						

LOG OF BORING

PROJECT:
FOR: The Zia Company

BORING NO:
LOCATION: TA-49 Area 4 (c)

DATE: 3 Feb 1960 JOB NO: 59-154 BORING TYPE: NX Cont. Air Drilling
DRILLER: Hatfield SOIL ENGINEER: Herring GROUND ELEV.: 7116.7

LEGEND

S-Shelby Tube D-Denison Barrel P-Penetration Test J-Jar
-Core -Penetration Sample -No Recovery
-Static Water Table -Hydrostatic Water Table

Depth in Feet	Sample Type & No.	Symbol	Elevation in Feet	Blows / Foot	DESCRIPTION OF STRATUM	
	245.7'				Run 15 (continued) Core rec. 14.3'	Dark gray ryolite frags. as inclusions.
250					Run No. 16 Drilling Time 36 min. Core rec. 14.0'	
260	265.6'					
270	277.5'				Run No. 17 Drilling Time 20 min. Core rec. 13.0'	Lt. purplish pink, dense welded tuff w/qtz. and sanidine phenocrysts. Ryolite and pumice fragments
280					Run No. 18 Drilling Time 20 min. Core rec. 10.1'	
290	290.5'					
300	302.9'				Run No. 19 Drilling Time 15 min. Core rec. 4.0'	Bottom @ 302.9'

AREA ONE

SOIL MECHANICS INCORPORATED

SUMMARY OF LABORATORY TESTS

Lab No.	Boring	Depth, ft	Confine-ment, psi	Max. Stress psi	Nat. Moist. Content, %	Nat. Density pcf	Dry Density pcf	Porosity Dry, %	Wet Density pcf	Vert. Perm. to Air, Millidarcys
*6786	Area 1	46.5-47.5	1000	2930	0.78	86.7	86.1	47.2	103.0	136
*6787	Area 1	64.5-66.0	1000	3570	2.90	105.5	102.6	35.7	120.3	38
*6788	Area 1	78.0-84.0	1000	2570	0.20		97.2	39.9		249

Lab No.	Specific Gravity
6786	2.615
6787	2.560
6788	2.545

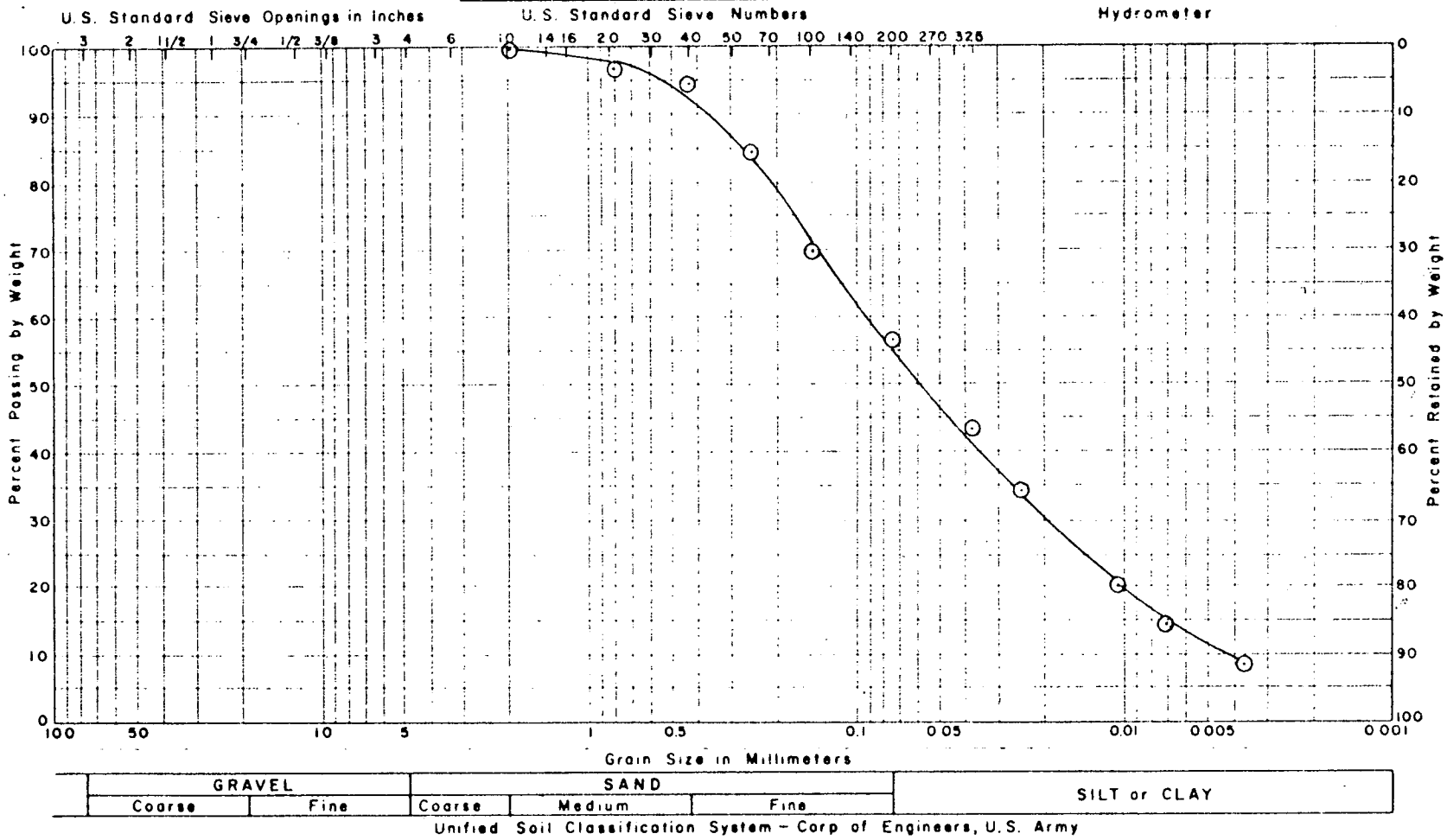
*_ Chemical Analysis, Mechanical Analysis and Mineralogical Analysis Data Attached.

SEMI-QUANTITATIVE SPECTOGRAPHIC ANALYSIS

AREA ONE

Sample No.	6786	6787	6783 ~~6792~~
Depth	46.5 - 47.5	64.5 - 66.0	78.0 - 84.0
Element		Approx. %	
Silicon	33.	33.	36.
Copper	0.05	0.09	0.07
Iron	0.6	0.7	0.6
Manganese	0.06	0.08	0.06
Chromium	0.002	0.004	0.003
Calcium	3.	2.	1.
Aluminum	7.	8.	7.
Magnesium	0.2	0.2	0.1
Titanium	0.1	0.1	0.1
Sodium	2.	2.	2.
Barium	Trace	Trace	Trace
Potassium	2.	2.	2.
Strontium	Trace	Trace	Trace
Zirconium	0.02	0.03	0.03

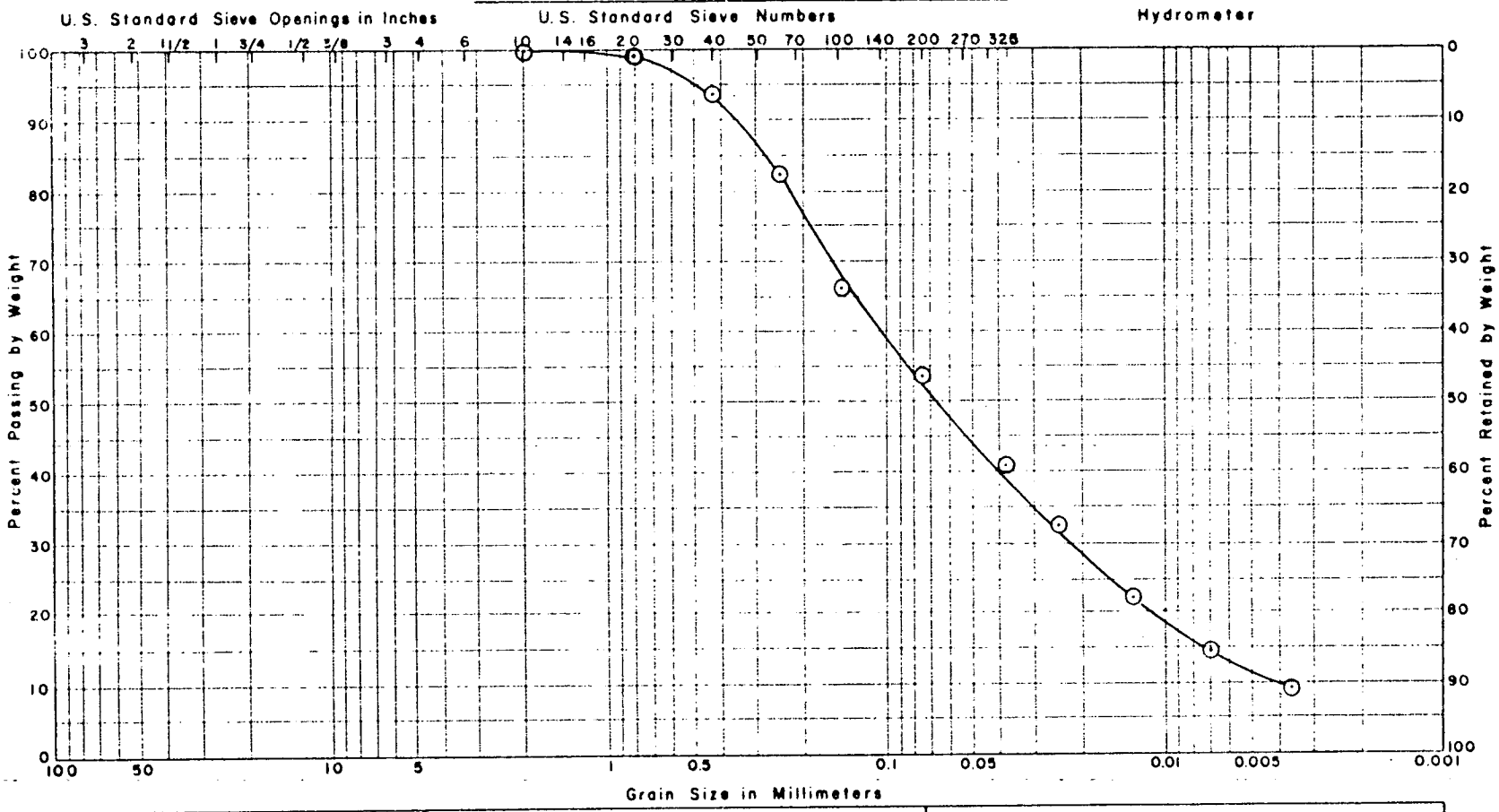
MECHANICAL ANALYSIS CHART



THE ZIA COMPANY
Job No. 59-154
Lab No. 6786

Tuff Area 1

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Job No. 59-154
Lab No. 6787

Tuff

Area 1

SAMPLE NO. 6786 - Area 1

This rock is a rhyolitic tuff, consisting of mineral fragments and a few rock fragments in a fine-grained matrix of volcanic glass shards, crystalline grains, and dust.

Its composition is approximately as follows (These figures represent merely a visual estimate from thin sections and are not to be considered accurate):

	%	%	%
Fragments			30
Mineral fragments		28	
Orthoclase	22		
Quartz	2		
Augite (pale green, probably sodic)	2		
Albite	1		
Magnetite	1		
Rock fragments (rhyolitic lava and partly devitrified brown glass)		2	
Matrix			70
Orthoclase, tridymite, and cristobalite in crystalline grains and fragments		35	
Glass shards, partly devitrified to a very fine-grained mineral aggregate		20	
Other volcanic glass and dust		15	
Alteration Products			Less than 1%
Limonite, on some of the rock and on magnetite			
Clay minerals, on some of the orthoclase			

Some of the mineral fragments show partial to nearly complete crystal outlines, but many are merely broken pieces of crystals and some even appear to be corroded. The largest fragments are quartz and orthoclase; the smallest are magnetite. The rock fragments appear to consist of fine-grained and glassy igneous rocks of much the same composition as the rest of the material.

The matrix consists of a mixture of straight and curved, narrow shards of volcanic glass with much fine granular material and considerable isotropic dust. The shards have the low index of refraction indicative of a rhyolitic or trachytic composition. Many of them are partly devitrified to an extremely fine-grained mineral aggregate of low

birefringence. The fine granular material consists of small rectangular grains of orthoclase interspersed with tiny hexagonal grains of tridymite and square grains of cristobalite. However, identification is difficult on such fine material, and some of that considered orthoclase may possibly be one of the zeolite minerals, and the grains considered cristobalite may possibly be analcime.

The optical properties of some of the orthoclase fragments, and the green color of the augite, suggest a higher-than-average sodium content for the rock.

SAMPLE NO. 6787 - Area 1

This rock is a rhyolitic tuff very similar to Sample No. 6786 (see report on that sample). It consists of mineral fragments and a few rock fragments in a matrix composed of volcanic glass shards, very fine-grained crystalline material, and structureless volcanic glass.

Its approximate composition is as follows (figures are merely visual estimates from examination of thin sections and are not to be considered accurate):

	%	%	%
Fragments			20
Mineral fragments		19	
Orthoclase	12		
Quartz	3		
Augite (green, Probably sodic)	1		
Albite	2		
Magnetite	1		
Rock fragments (fine-grained lava)		1	
Matrix			80
Fine granular orthoclase, tridymite, and cristobalite		20	
Volcanic glass shards, partly devitrified		25	
Structureless volcanic glass, crowded with microlites		35	
Alteration products			Less than 1%
Limonite, more than in Sample No. 6786			

The thin sections examined show somewhat fewer fragments than did those of Sample 6786, and a larger proportion of structureless glass in the matrix. This structureless glass is crowded with very tine needle-like microlites, incipient crystals of unidentifiable minerals. The "dust" of Sample 6786 may be the same thing in still finer texture.

The identification of orthoclase, tridymite, and cristobalite in the finer granular material of the matrix is subject to the same difficulties and uncertainties as in Sample 6786.

The glass shards, which in Sample 6787 are more obviously parts of the walls of broken and flattened bubbled, are partly devitrified to an extermely fine aggregate of crystalline minerals, as in Sample 6786.

Limonite is more abundant than in No. 6786, and it is more widely distributed throughout the specimen.

Samples nos.. 6786 and 6787 may be considered identical rocks. In a rock of this nature much more variation in composition from point to point may be expected than was actually found.

No. 6787

SAMPLE NO. 6788 - Area 1

This rock, like Samples Nos. 6786 and 6787, is a rhyolitic tuff, consisting of mineral fragments and few rock fragments in a matrix of volcanic glass shards and very fine-grained crystalline material.

Its approximate composition is as follows (estimate only, from microscopic examination of thin section):

	%	%	%
Fragments			25
Mineral fragments		24	
Orthoclase	3		
Quartz	20		
Augite (green, probably sodic)	Less than 1		
Magnetite	Less than 1		
Rock fragments (fine-grained lava)		1	
Matrix			75
Fine granular tridymite, orthoclase, and possibly zeolites		40	
Volcanic glass shards, largely devitrified		35	
Alteration		Very slight	

Unlike Samples 6786 and 6787, in the mineral fragments of this sample quartz is more abundant than feldspar. The feldspar has properties suggestive of a high sodium content and may even be anorthoclase, although the grid twinning sometimes shown by that mineral was not observed.

The rock fragments consist of brown to black, fine grained to glassy igneous rocks, some of which are almost opaque.

Examination of the matrix under high magnification shows that the glass shards are almost completedy devitrified to an aggregate of minute, weakly birefringent, feathery grains, which may be feldspar or zeolites. The granular material between the shards appears to consist of tridymite, small fragments or orthoclase, and a few prismatic grains which may be zeolites. As always, microscopic identification is uncertain on such fine-grained material.

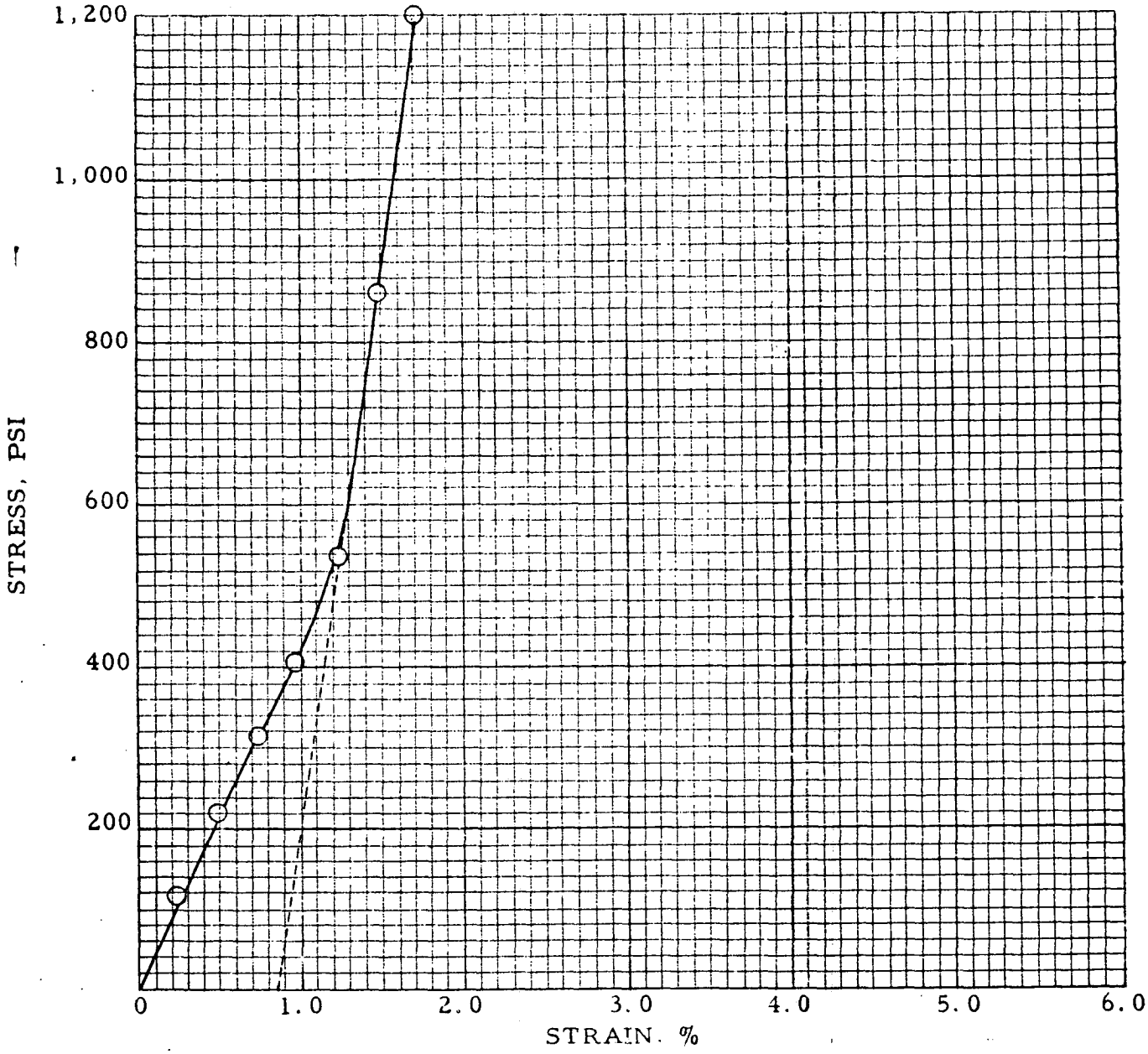
Alteration in this sample is practically negligible, having formed only traces of clay minerals and limonite.

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6943 Boring 1 - A Depth, ft. 55' E



MODULUS OF ELASTICITY, PSI

Elastic Range 146,591

At Failure 146,591

POISSON'S RATIO

Elastic Range .612

At Failure .612

BULK MODULUS, PSI

At Failure 146,712

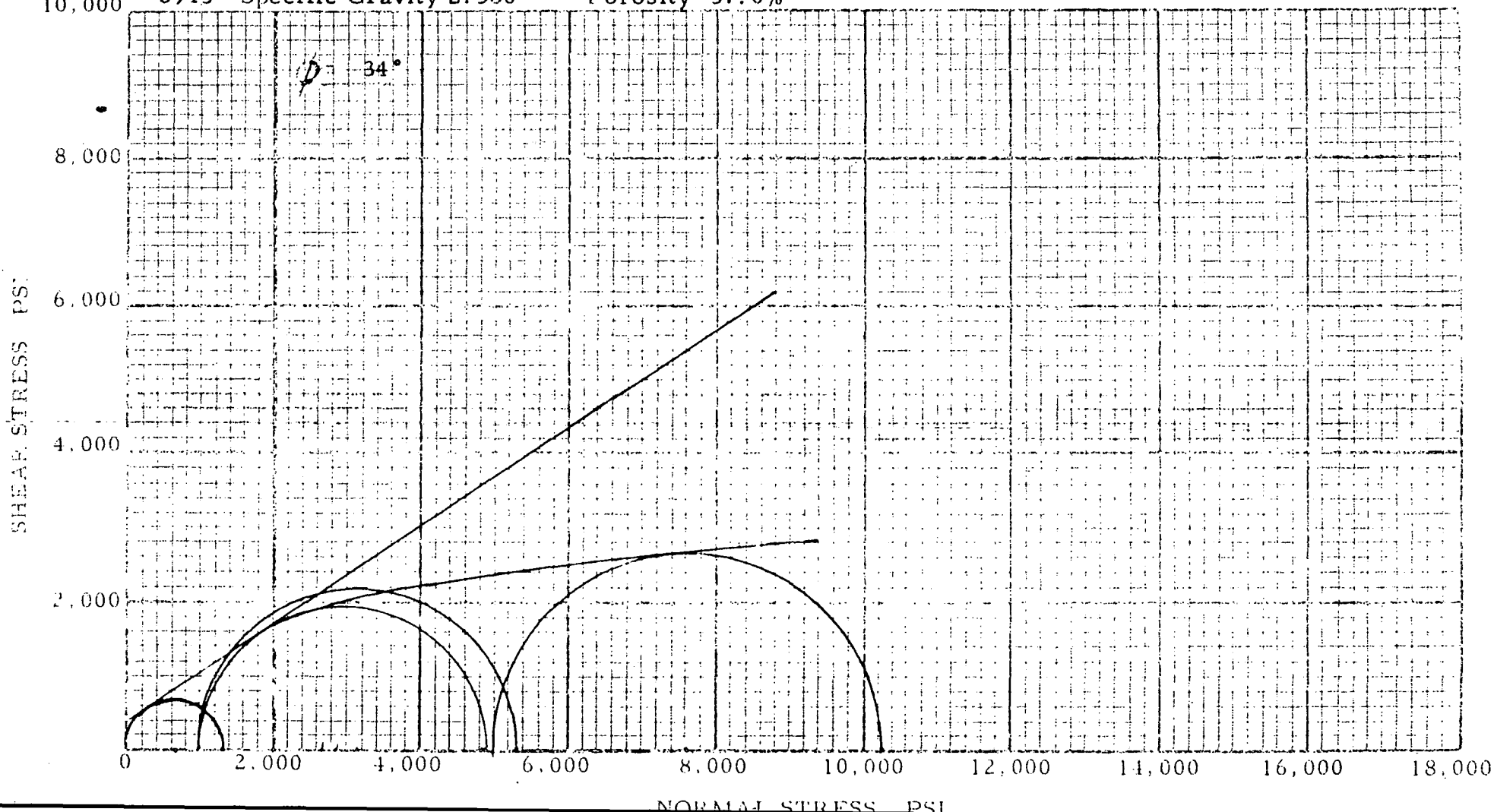
SOIL MECHANICS INCORPORATED

TRIAXIAL C M ESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 1 - A Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6943	0	1290	101.3	1.9		Dry	1.78	4.03
6941-1	1,000	3910		2.4	99.4	"	1.78	4.06
6941-2	1,000	4310		2.4	98.1	"	1.74	4.06
6945	5,000	5240		1.7	101.1	"	1.78	4.03

6943 Specific Gravity 2.580 Porosity 37.0%



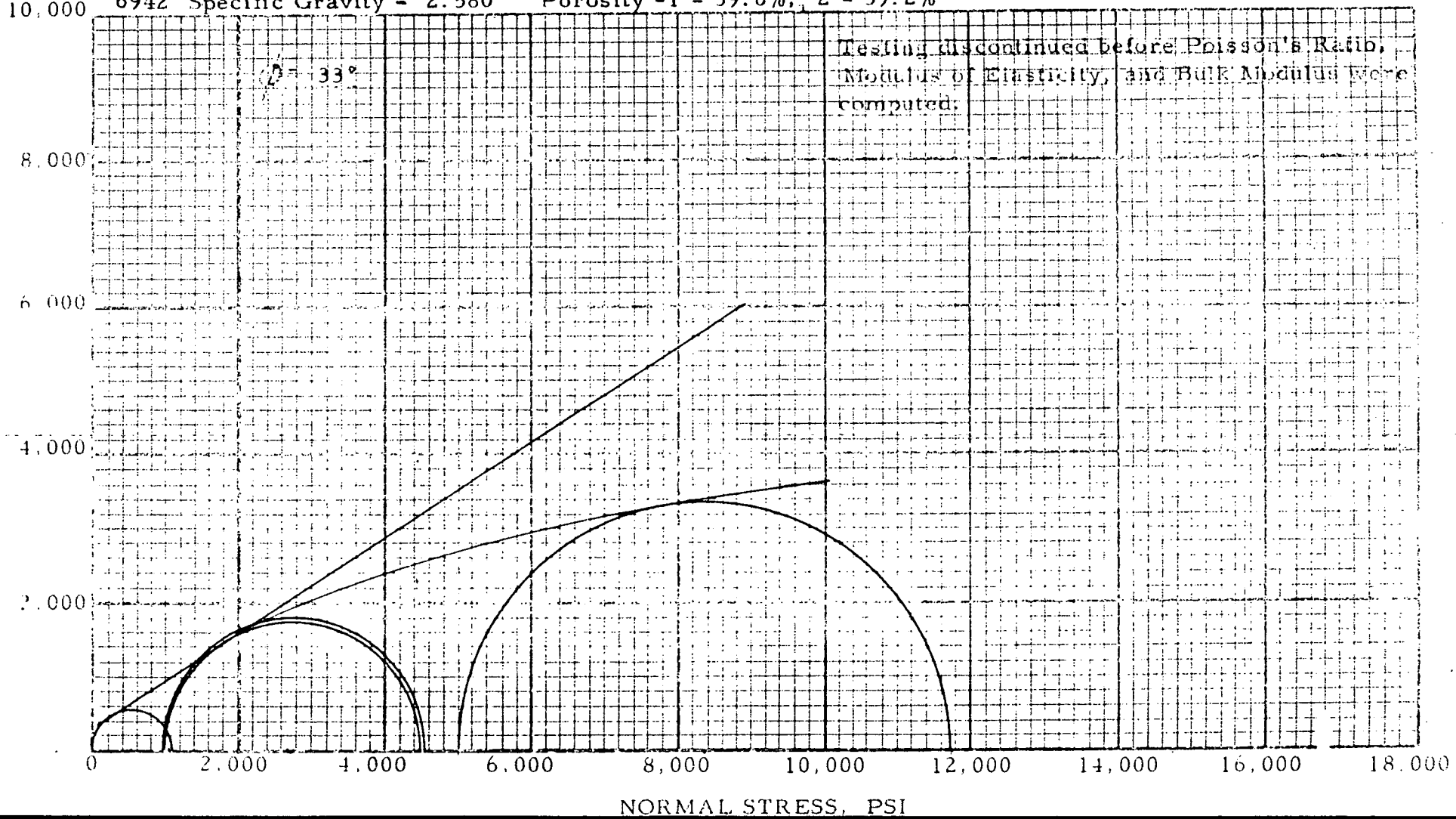
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 1 - A Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6944	0	1078		3.0	99.6	5.0	1.78	4.06
6942 - 1	1,000	3580		2.2	97.2	5.0	1.73	4.08
6942 - 2	1,000	3455		2.2	97.8	5.0	1.78	4.09
6940	5,000	6750		2.2	101.0	5.0	1.78	4.03

6942 Specific Gravity = 2.580 Porosity -1 = 39.6%, 2 = 39.2%



THERMAL CONDUCTIVITY & SPECIFIC HEAT DATA

AREA ONE

Sample No. 6750

Depth: 44.5' Boring No. 1-C

Thermal Conductivity: 0.33 BTU/hr ft °F at 117°F average temperature and Bulk Density of 93.1 lb/cu ft, air dried sample.

Specific Heat: 0.202 BTU/lb °F at 145° F (average temperature) air dried sample crushed and passing No. 200 sieve.

Sample No. 6751

Depth: 45.5' Boring No. 1-C

Thermal Conductivity: 0.31 BTU/hr ft °F at 116° F average temperature and bulk density of 92.7 lb/cu ft, air dried sample.

Specific Heat: 0.201 BTU/lb °F at 145° F (average temperature) air dried sample crushed and passing No. 200 sieve.

Sample No. 6752

Depth: 49 ft Boring No. 1-C

Thermal Conductivity: 0.31 BTU/hr ft °F at 120° F average temperature and bulk density of 92.5 lb/cu ft, air dried sample.

Specific Heat: 0.207 BTU/lb °F at 145° F average temperature, air dried sample passing No. 200 sieve.

Sample No. 6753

Depth 50 ft Boring No. 1-C

Thermal Conductivity: 0.38 BTU/hr ft °F at 117°F average temperature and a bulk density of 94.3 lb/cu ft, air dried sample.

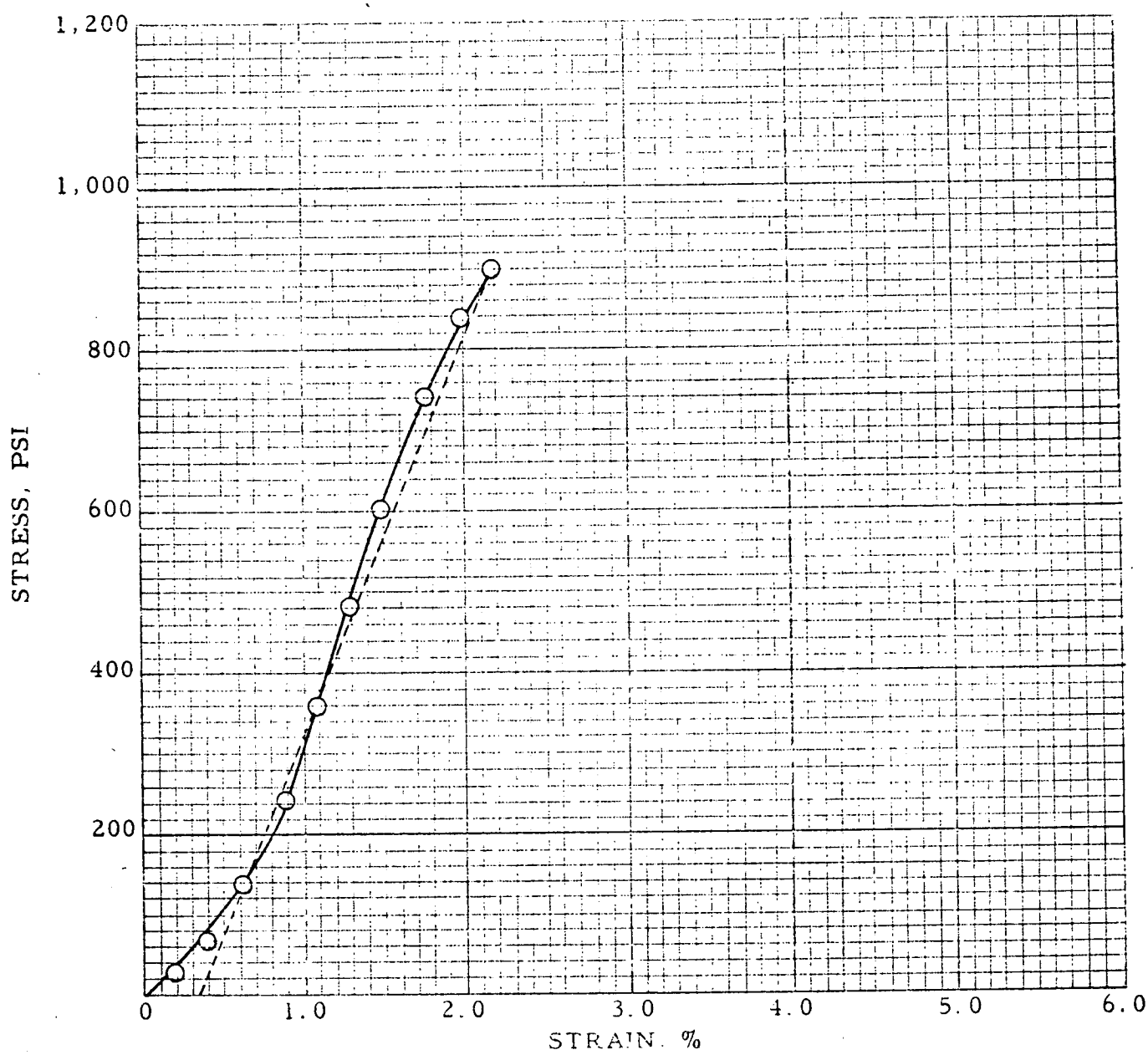
Specific Heat: 0.198 BTU/lb °F at 144° F average temperature, air dried sample crushed and passing No. 200 sieve.

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6757 Boring 1 - U Depth, ft. 59' W



MODULUS OF ELASTICITY, PSI

Elastic Range 52,034

At Failure 48,704

POISSON'S RATIO

Elastic Range .072

At Failure .130

BULK MODULUS, PSI

At Failure 46,792

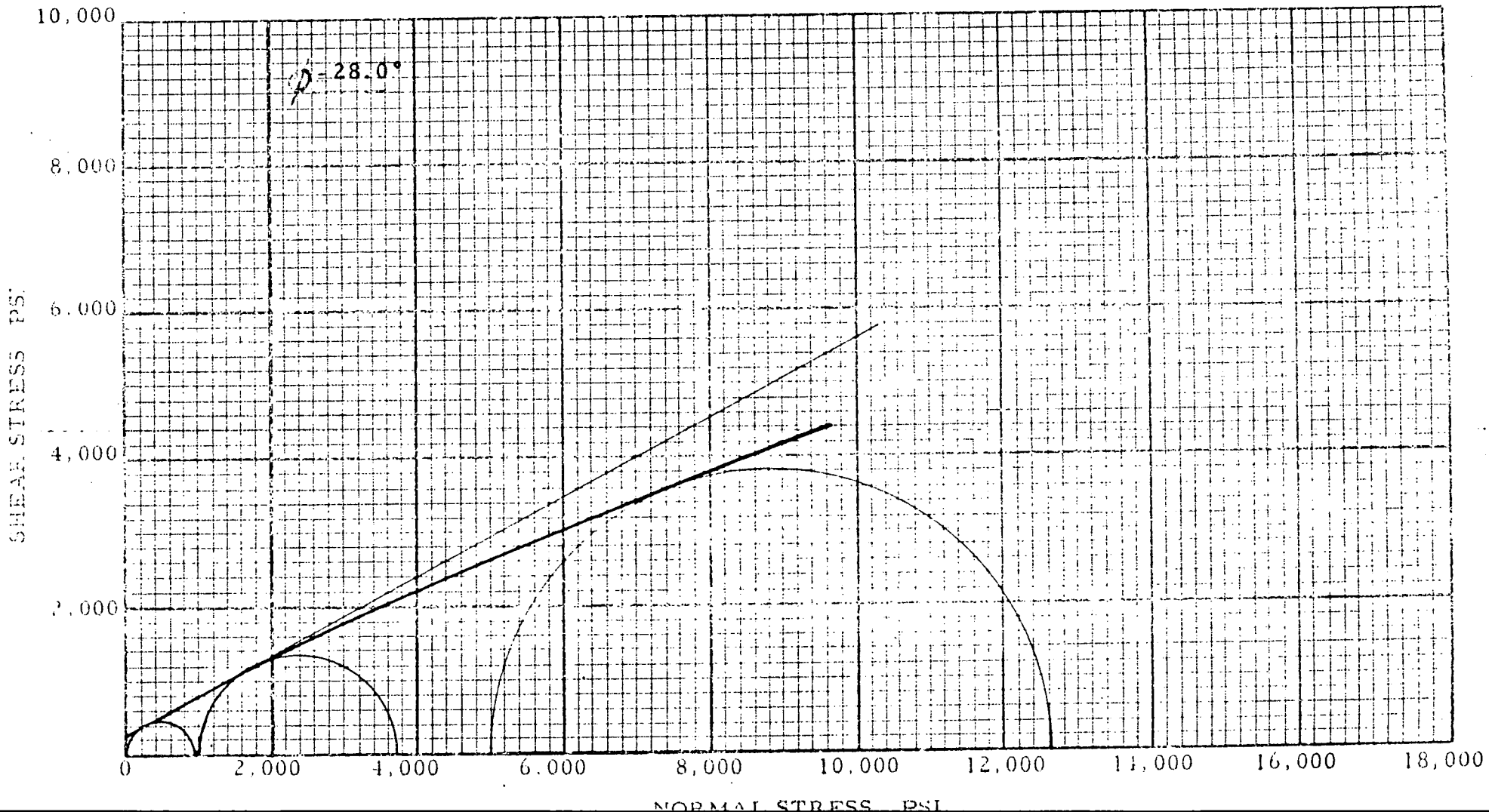
SOIL MECHANICS INCORPORATED

TRIAXIAL C M RESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 1 u Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6757	0	905		2.50	95.0	5.0	1.782	4.031
6759 (1)	1.000	2,690	95.0	1.78	93.4	5.0	1.782	4.031
6759 (2)	1.000	2,700	94.5	1.78	92.9	5.0	1.782	4.031
6761	5.000	7,620		2.44	97.1	5.0	1.782	4.031

6759 Porosity = 43.4% Specific Gravity = 2.640

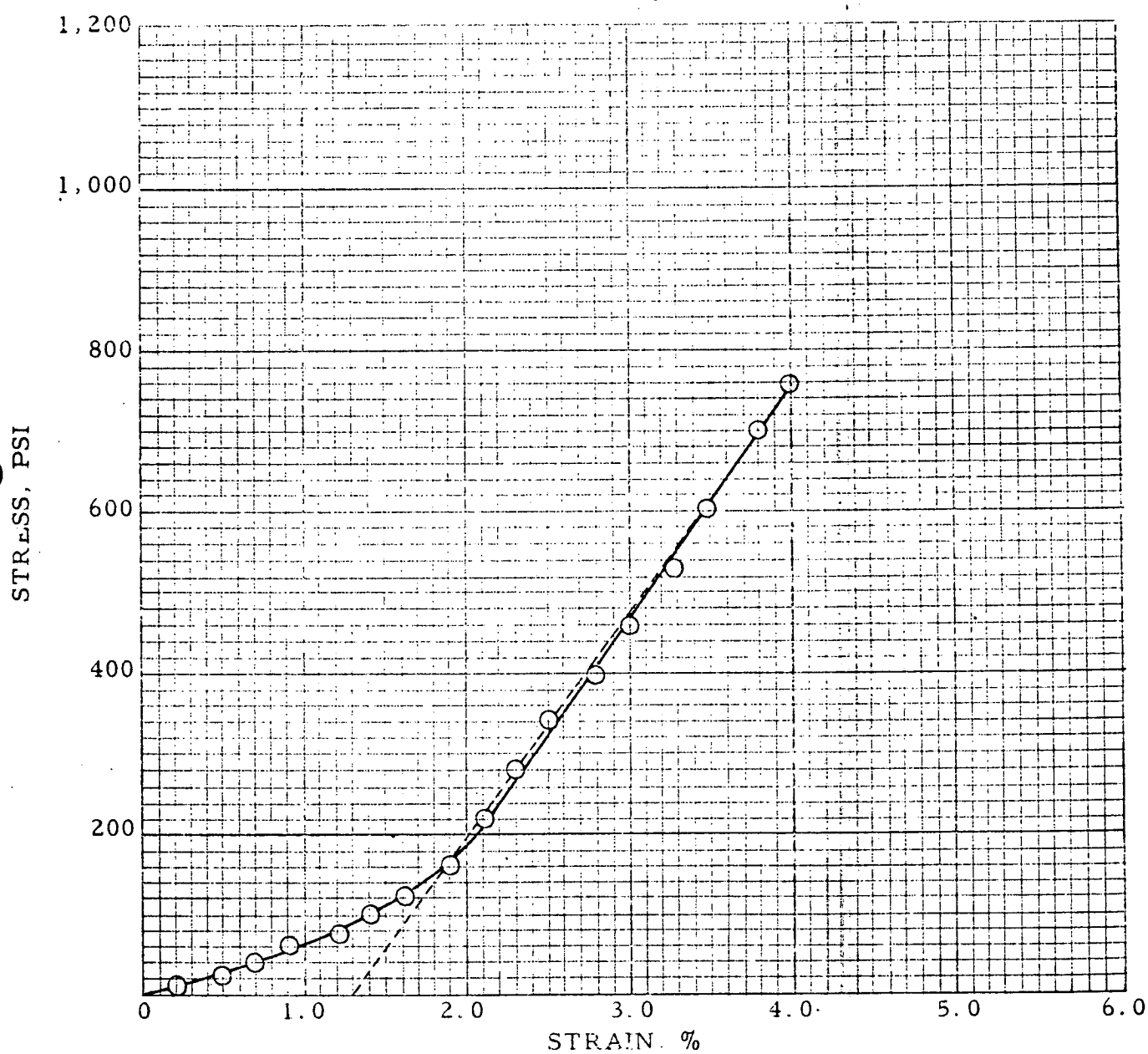


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 6758 Boring 1 - U Depth, ft. 57' E



MODULUS OF ELASTICITY, PSI

Elastic Range 27,059

At Failure 28,111

POISSON'S RATIO

Elastic Range .046

At Failure .178

BULK MODULUS, PSI

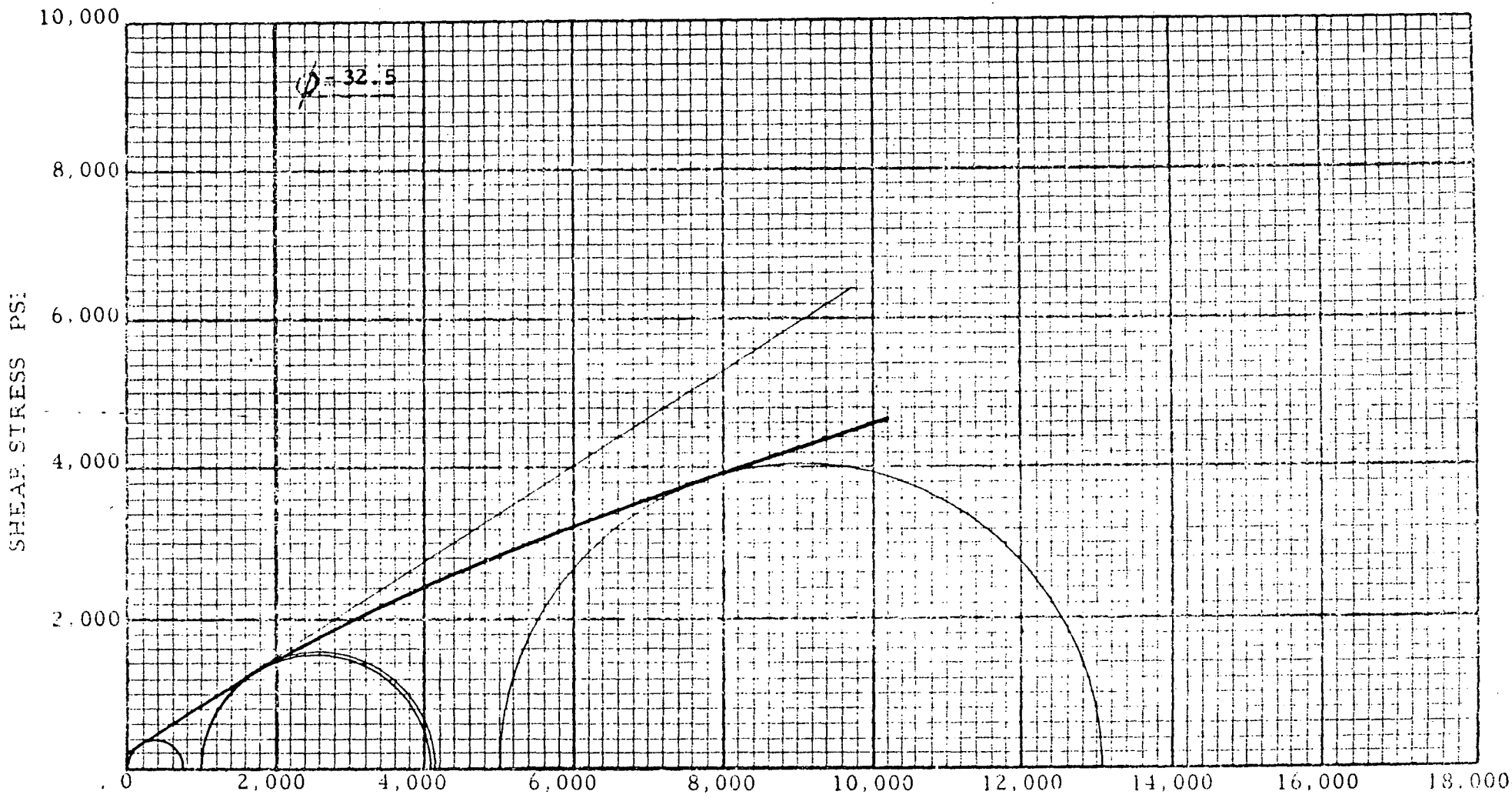
At Failure 33,335

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 1 u Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6758	0	760		2.45	94.4	5.0	1.750	4.031
6760 (1)	1,000	3,070		2.35	93.4	5.0	1.782	4.031
6760 (2)	1,000	3,040		2.35	93.4	5.0	1.782	4.031
6762	5,000	8,220		2.18	90.9	5.0	1.782	4.031



AREA TWO

SOIL MECHANICS INCORPORATED

SUMMARY OF LABORATORY TESTS

Lab No.	Boring	Depth, ft	Confinement, psi	Max. Stress psi	Nat. Moist Content, %	Nat. Density pcf	Dry Density pcf	Porosity Dry, %	Wet Density pcf	Vert. Perm. to Air, Millidarcys
*6789	Area 2	44.5-46	1000	3275	1.72	87.8	86.5	44.6	108.2	75-147
6790	"	53.5-55	1000	2050	0.18		87.9	45.0		81
6791	"	74.5-75.5	1000	3000	0.41		99.1	37.0		
**6792	"	85.0-89	1000	3320	1.54	105.0	103.3	35.0	119.9	170

Lab No.	Specific Gravity
6789	2.510
6790	2.560
6791	2.505
6792	2.550

* Chemical Analysis and Mineralogical Analysis Data Attached.

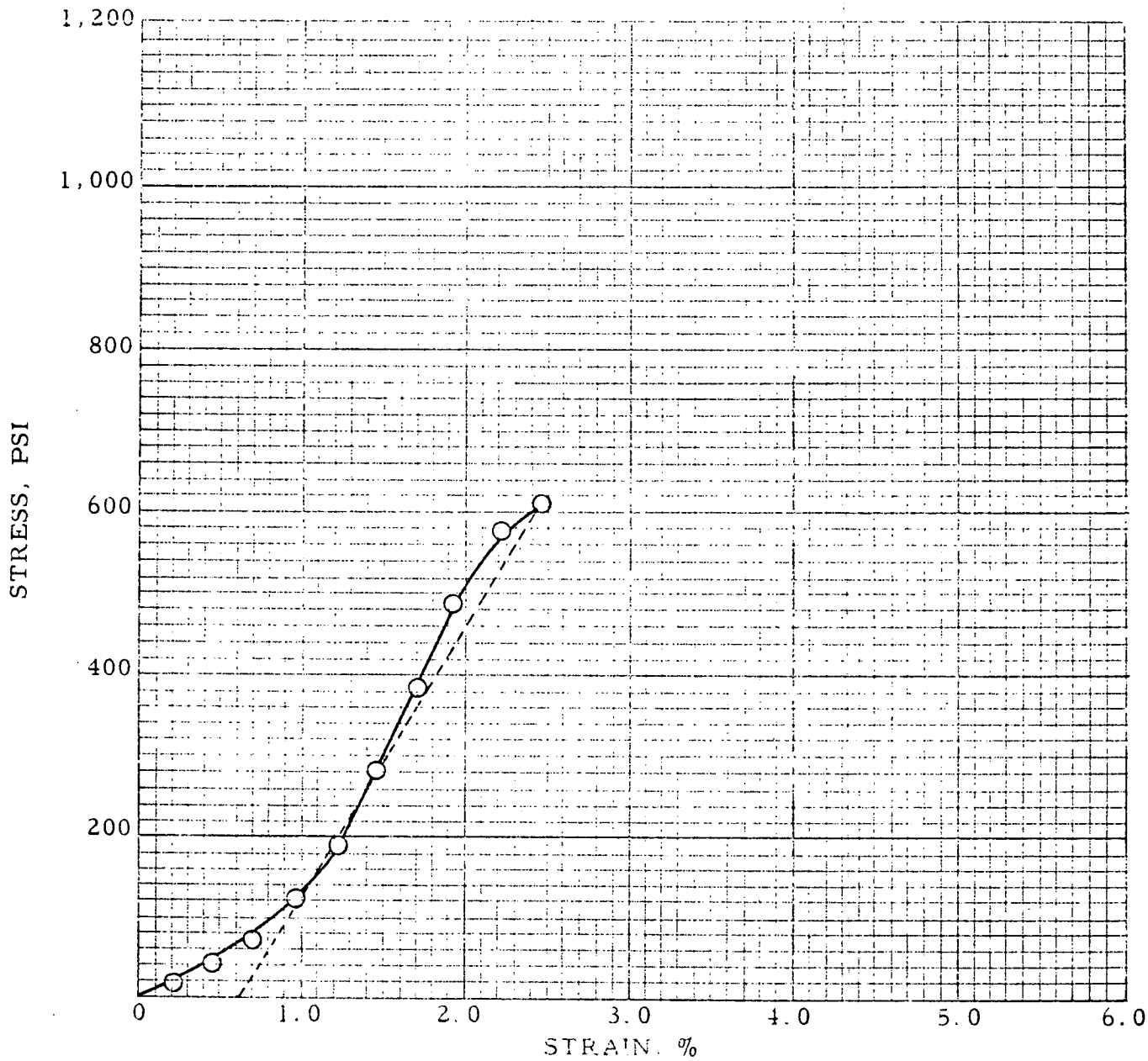
** Chemical Analysis, Mechanical Analysis and Mineralogical Analysis Data Attached.

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 6767 Boring 2-A Depth, ft. 56' E



MODULUS OF ELASTICITY, PSI

Elastic Range 32,500

At Failure 32,567

POISSON'S RATIO

Elastic Range .110

At Failure .078

BULK MODULUS, PSI

At Failure 36,466

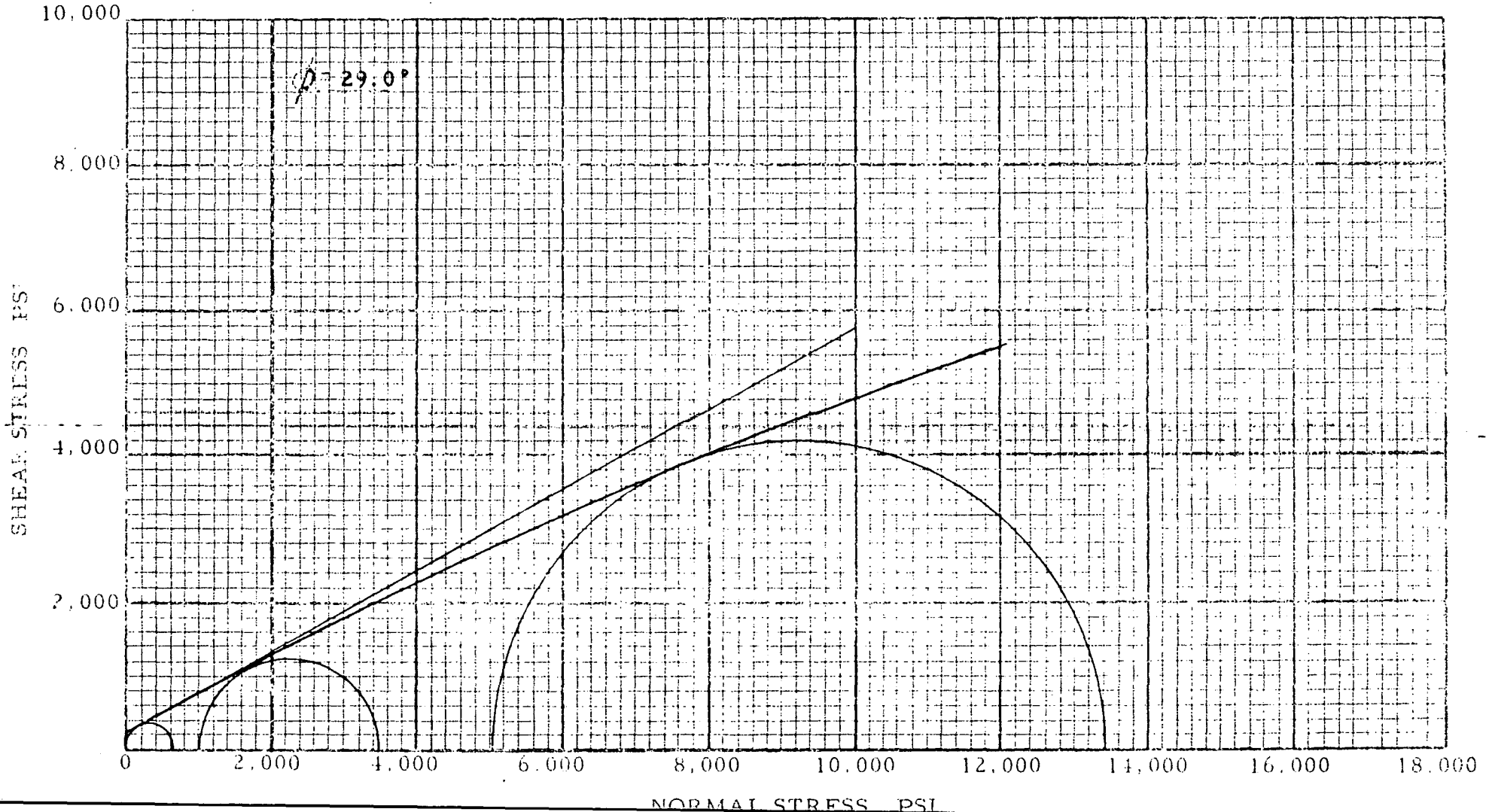
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 A Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6767	0	609		1.62	89.2	5.0	1.688	4.031
6769 (1)	1,000	2,540	93.1	2.54	90.8	5.0	1.750	4.031
6769 (2)	1,000	2,580	90.0	2.54	87.7	5.0	1.750	4.031
6771	5,000	8,450		2.64	87.7	5.0	1.720	4.031

6769 Porosity = 44.0% Specific Gravity = 2.500

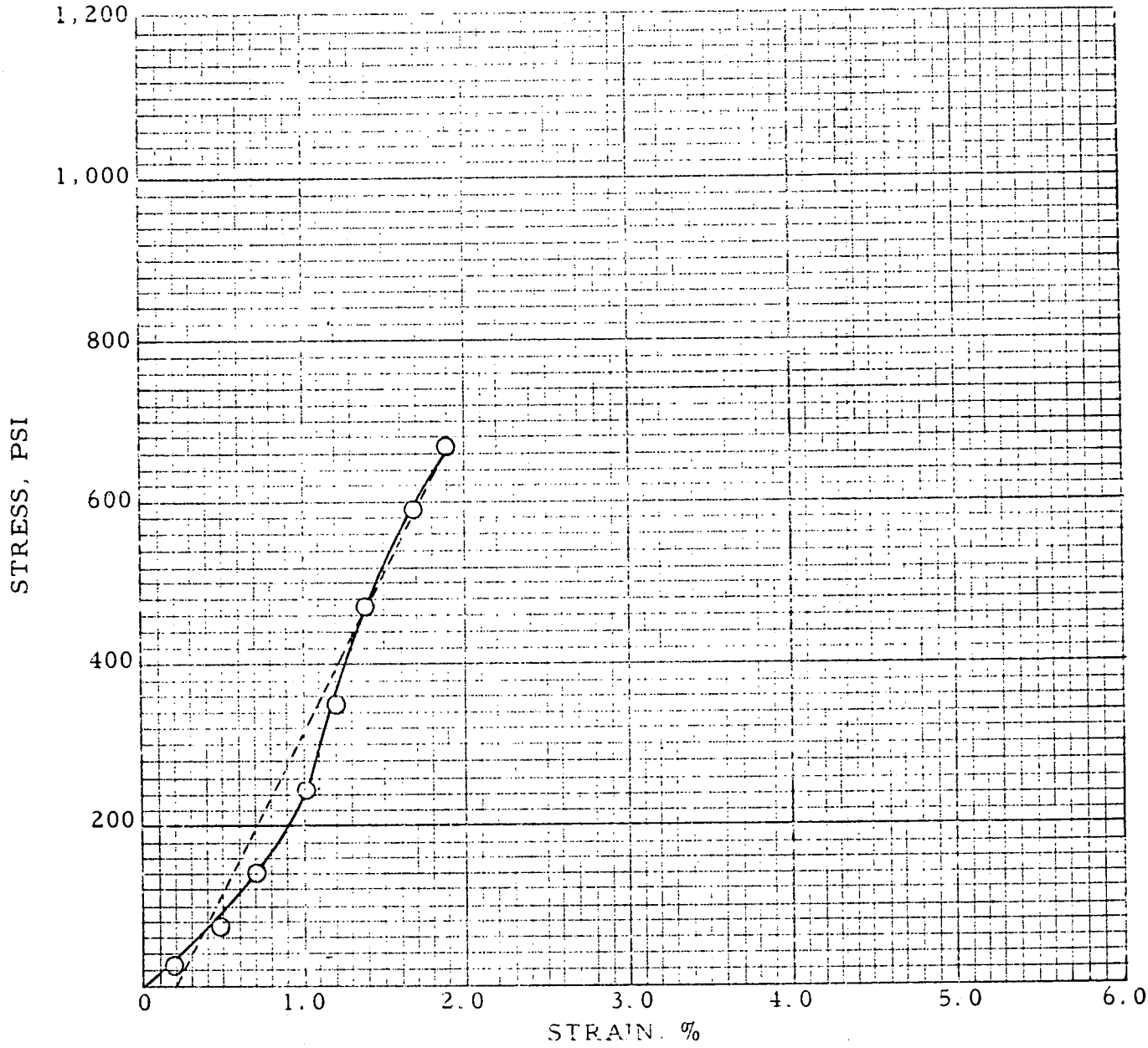


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 6768 Boring 2 - A Depth, ft. 56' W



MODULUS OF ELASTICITY, PSI

Elastic Range 39,650

At Failure 39,347

POISSON'S RATIO

Elastic Range .094

At Failure .436

BULK MODULUS, PSI

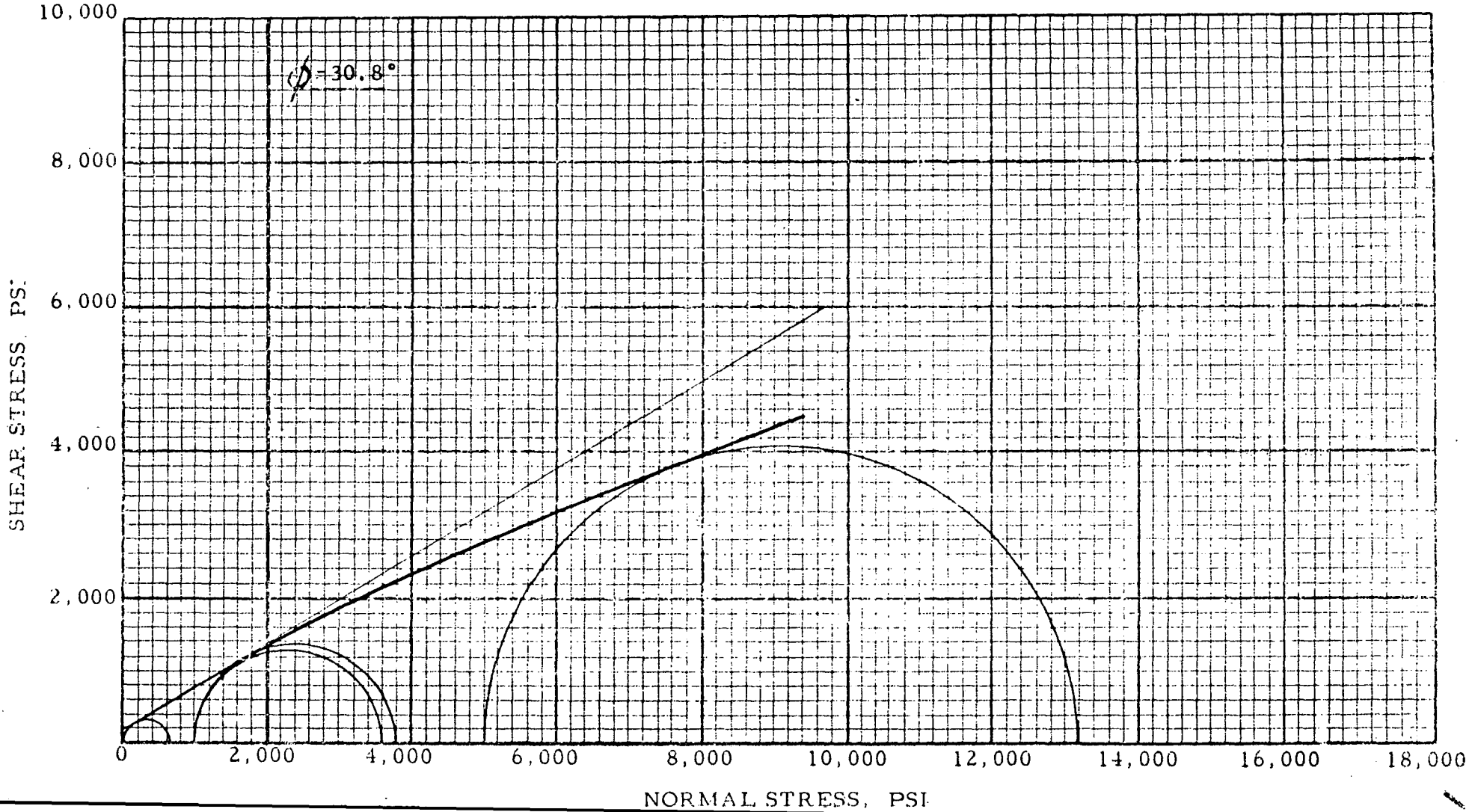
At Failure 64,781

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 A Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6768	0	670		2.48	91.3	5.0	1.687	4.031
6770 (1)	1,000	2,540		1.95	86.9	5.0	1.750	4.031
6770 (2)	1,000	2,750		1.95	86.1	5.0	1.750	4.031
6772	5,000	8,200		2.48	85.4	5.0	1.750	4.250

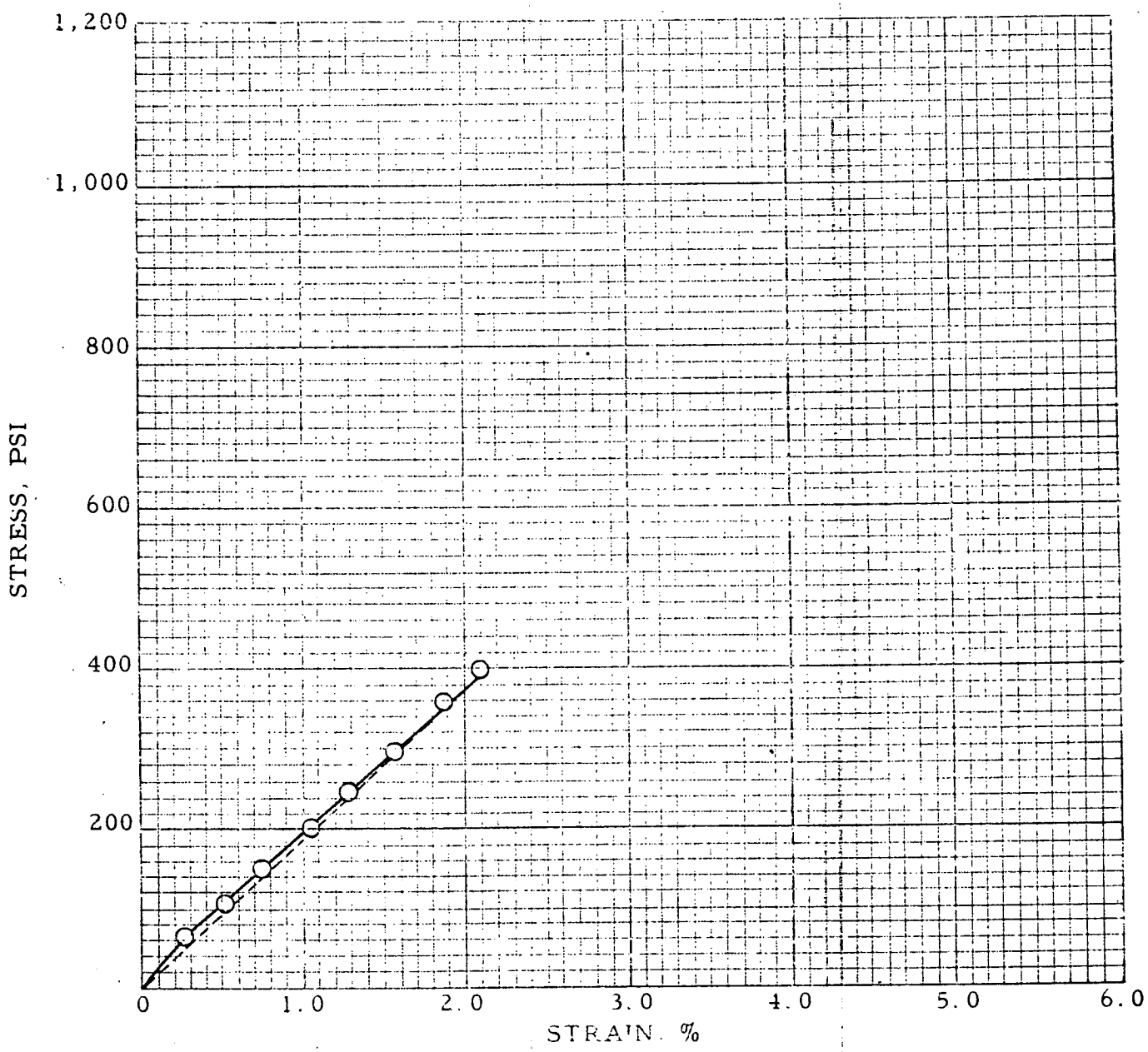


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6915 Boring 2 - D Depth, ft. 55' W



MODULUS OF ELASTICITY, PSI

Elastic Range 19,279

At Failure 19,279

POISSON'S RATIO

Elastic Range .262

At Failure .262

BULK MODULUS, PSI

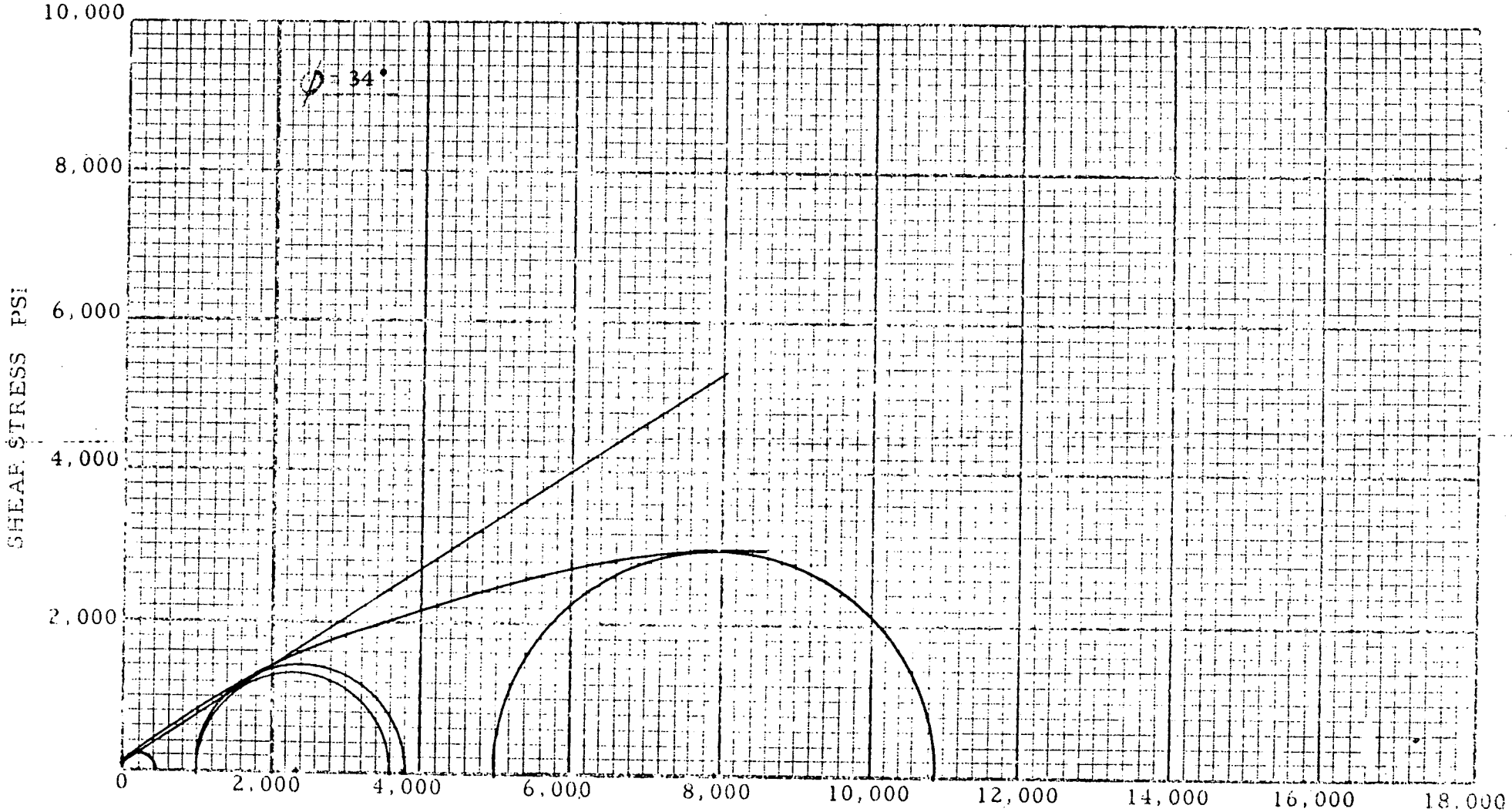
At Failure 20,871

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2-D Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6915	0	401		5.2		Dry	1.75	3.84
6913-1	1,000	2595		3.7		"	1.75	4.02
6913-2	1,000	2775		3.7		"	1.72	4.02
6911	5,000	5880		3.5		"	1.75	4.16

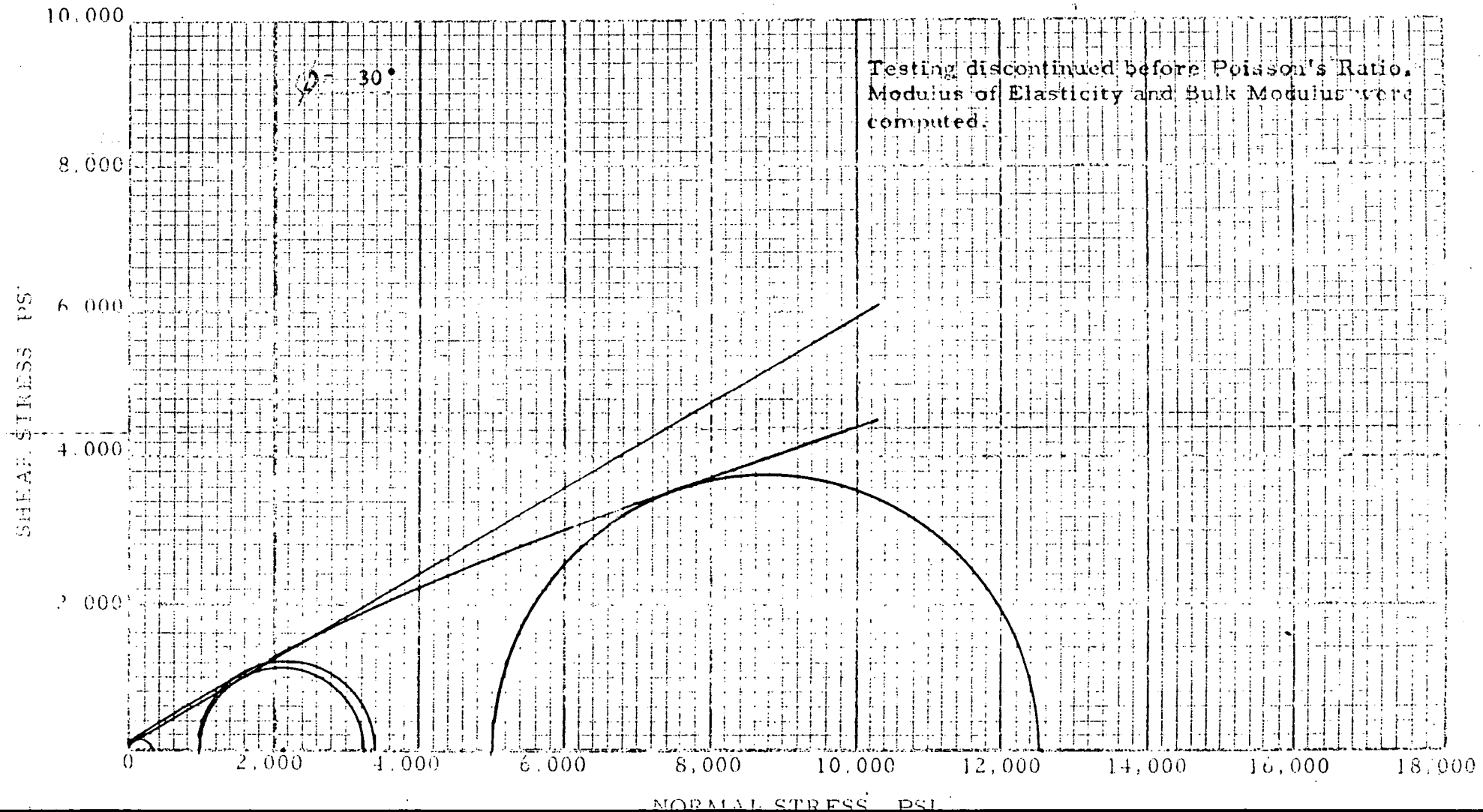


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 - D Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6916	0	321		5.5		5.0	1.75	3.78
6914 (1)	1,000	2230		2.5		5.0	1.75	4.02
6914 (2)	1,000	2370		2.5		5.0	1.73	4.06
6912	5,000	7550		2.3		5.0	1.72	4.00

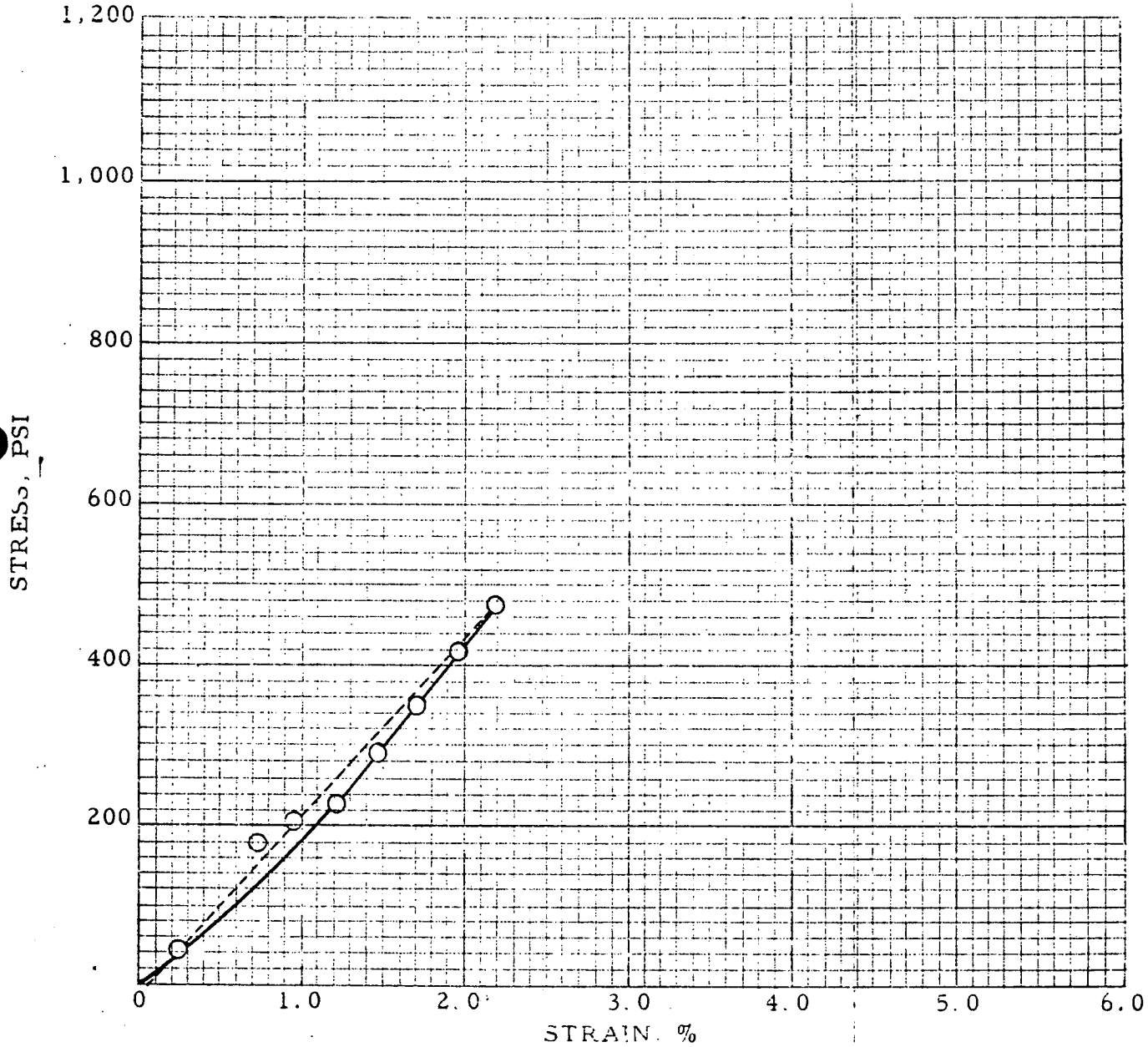


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 6801 Boring 2-E Depth, ft. 52' E



MODULUS OF ELASTICITY, PSI

Elastic Range 21,906

At Failure 21,944

POISSON'S RATIO

Elastic Range .042

At Failure .024

BULK MODULUS, PSI

At Failure 23,246

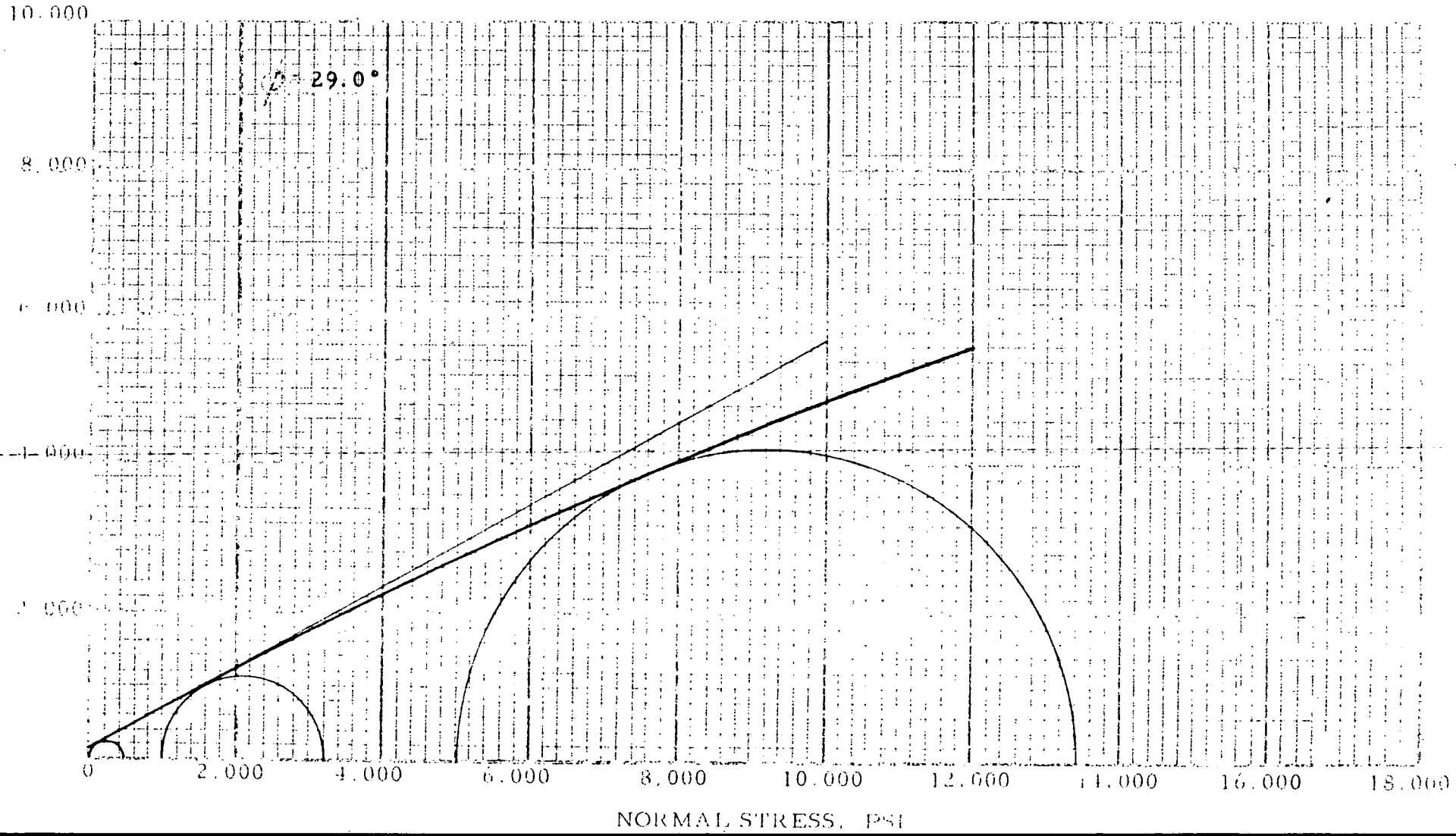
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY, Los Alamos, N. M. Boring 2E Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6801	0	472		1.81	87.5	5.0	1.720	4.078
6799 (1)	1.000	2,350	84.5	1.61	83.2	5.0	1.734	4.031
6799 (2)	1.000	2,130	83.7	1.61	82.4	5.0	1.734	4.047
6797	5.000	8,540		1.70	88.4	5.0	1.625	4.083

6799 - Porosity = 49.7%, Specific Gravity 2.625

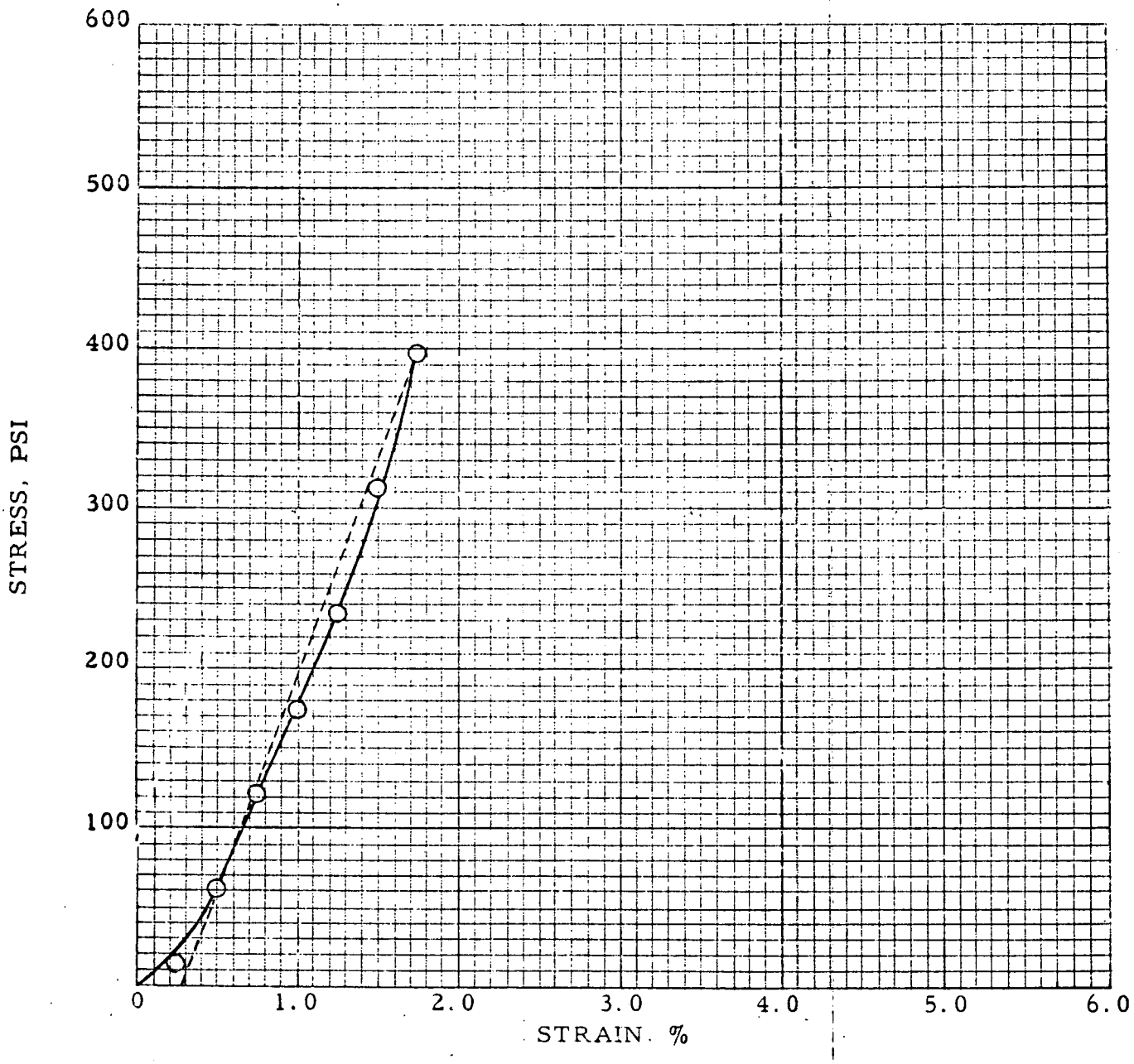


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6802 Boring 2 - E Depth, ft. 51' W



MODULUS OF ELASTICITY, PSI

Elastic Range 24,593

At Failure 27,171

POISSON'S RATIO

Elastic Range .036

At Failure .044

BULK MODULUS, PSI

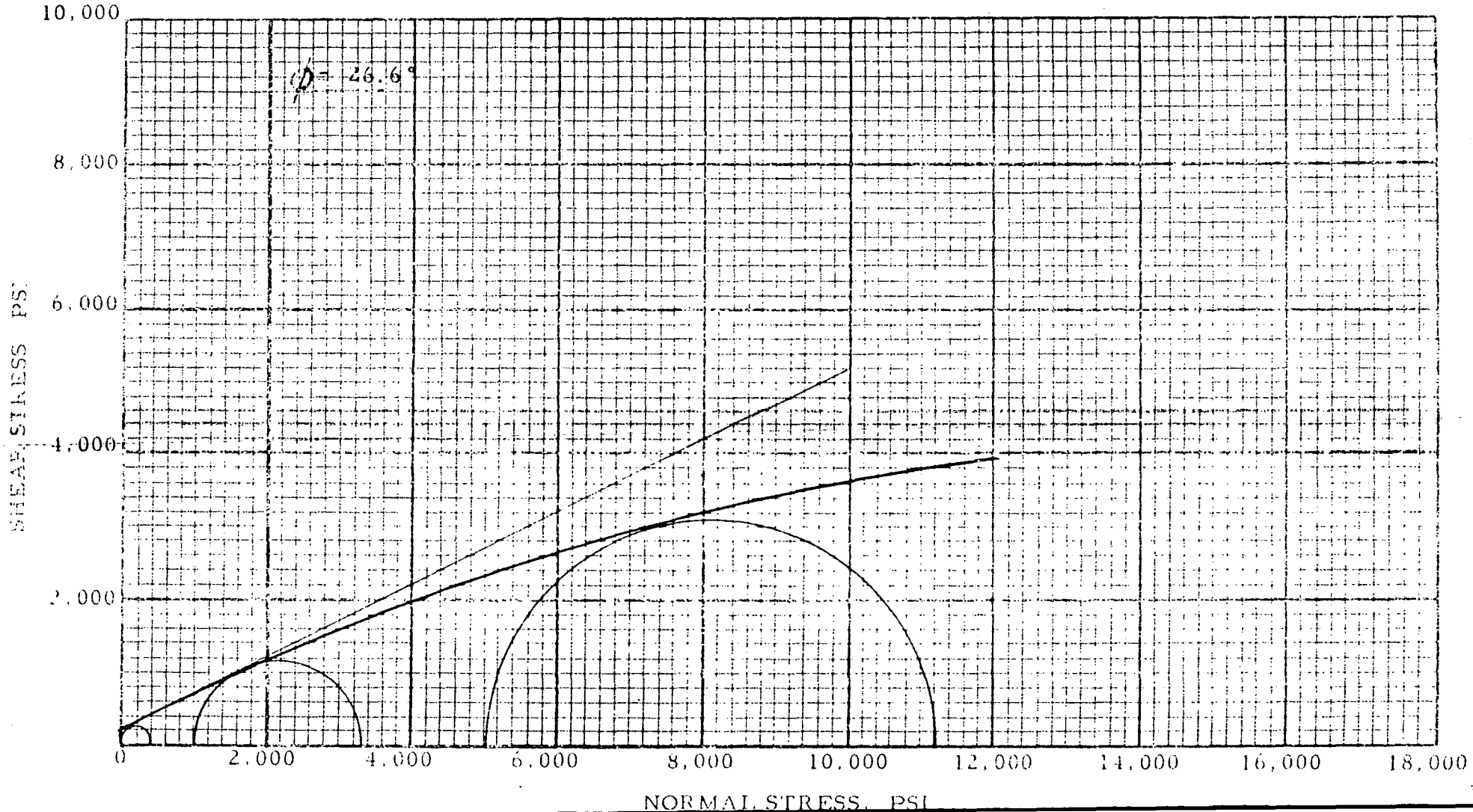
At Failure 29,272

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 E Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6802	0	397		1.53	83.5	5.0	1.750	4.031
6800 (1)	1,000	2,200		1.94	83.0	5.0	1.750	4.031
6800 (2)	1,000	2,265		1.94	81.7	5.0	1.745	4.031
6798	5,000	6,180		1.29	79.1	5.0	1.730	4.031

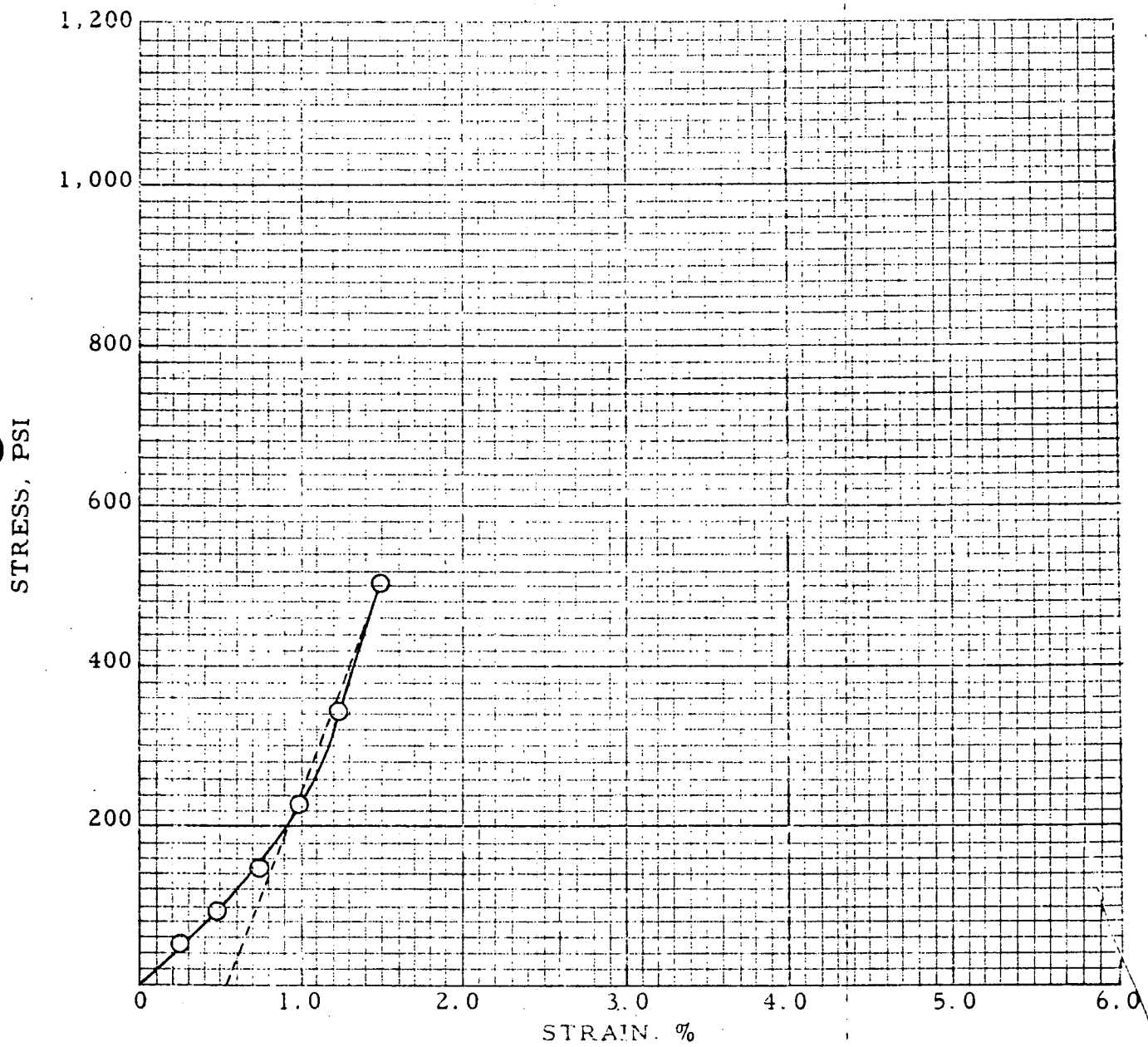


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 6905 Boring 2 - F Depth, ft. 55' E



MODULUS OF ELASTICITY, PSI

Elastic Range 53,829

At Failure 53,829

POISSON'S RATIO

Elastic Range .140

At Failure .140

BULK MODULUS, PSI

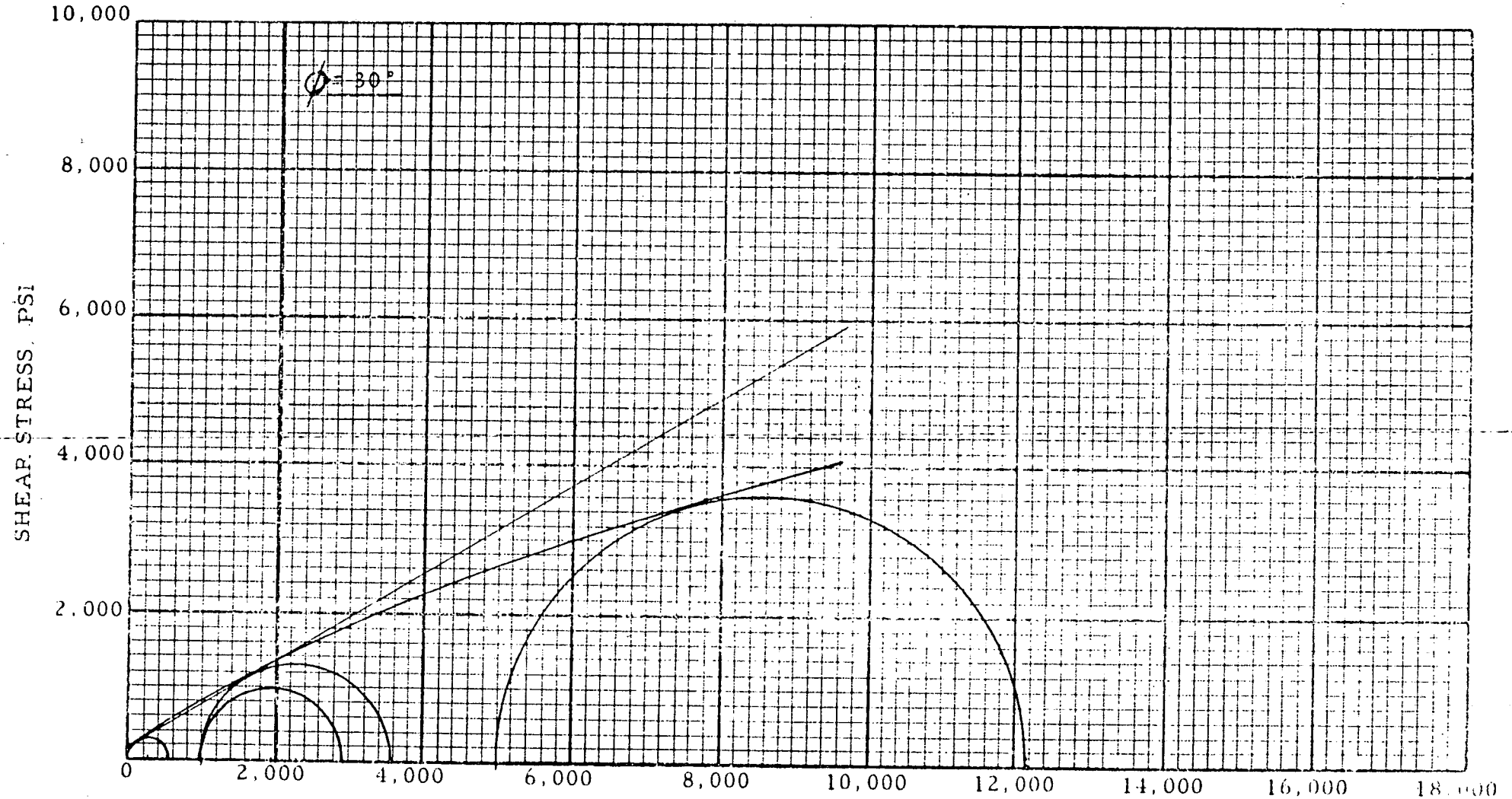
At Failure 56,260

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 F Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6905	0	506		1.4		Dry	1.75	4.03
6903-1	1,000	1930		0.7		"	1.69	4.03
6903-2	1,000	2582		0.7		"	1.69	4.08
6901	5,000	7190		4.1		"	1.72	4.03

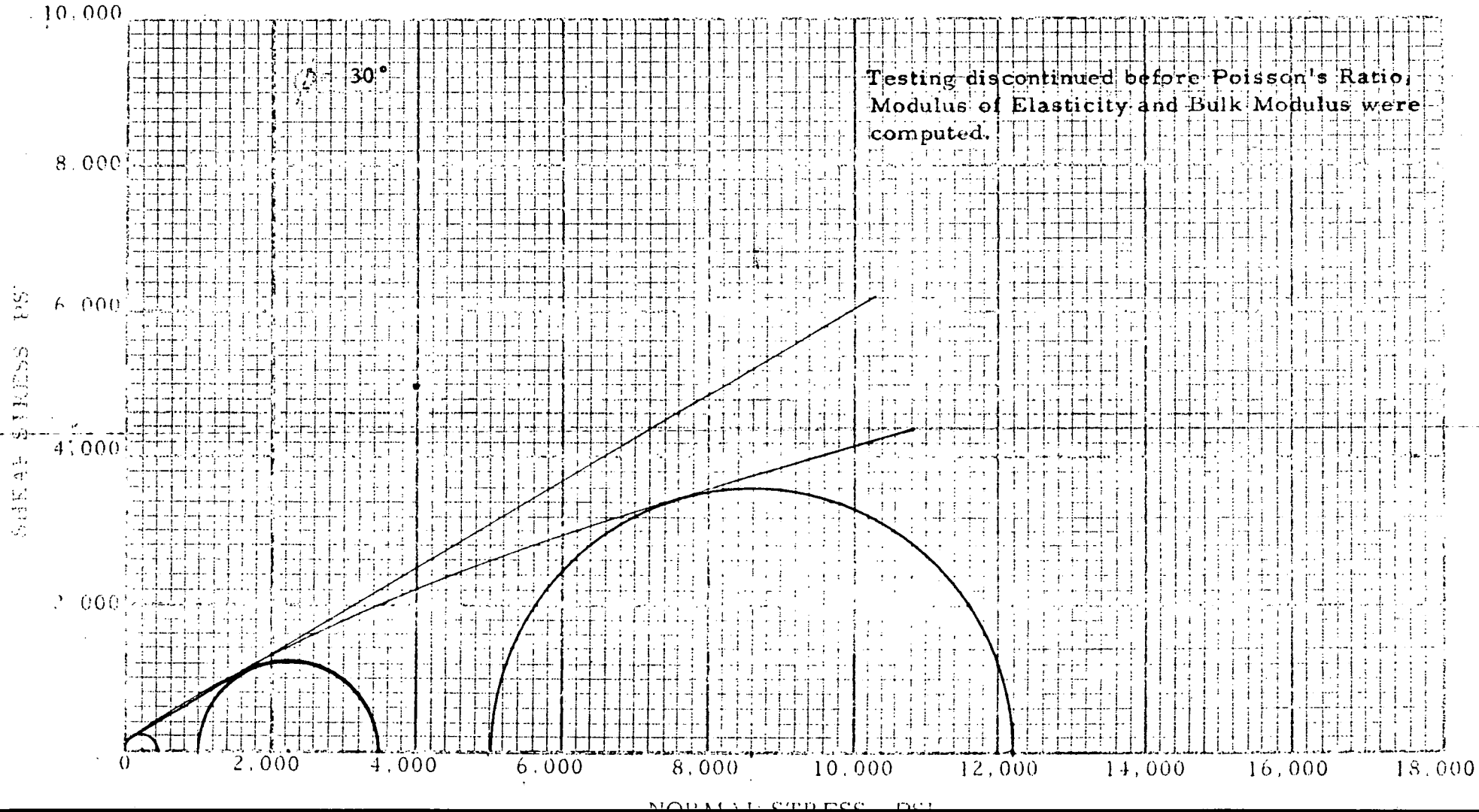


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 - F Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6906	0	427		2.0		5.0	1.75	4.03
6904 (1)	1.000	2460		2.5		5.0	1.72	3.86
6904 (2)	1.000	2500		2.5		5.0	1.72	4.06
6902	5.000	7200		1.7		5.0	1.75	3.38



SOIL MECHANICS INCORPORATED

SUMMARY OF LABORATORY TESTS

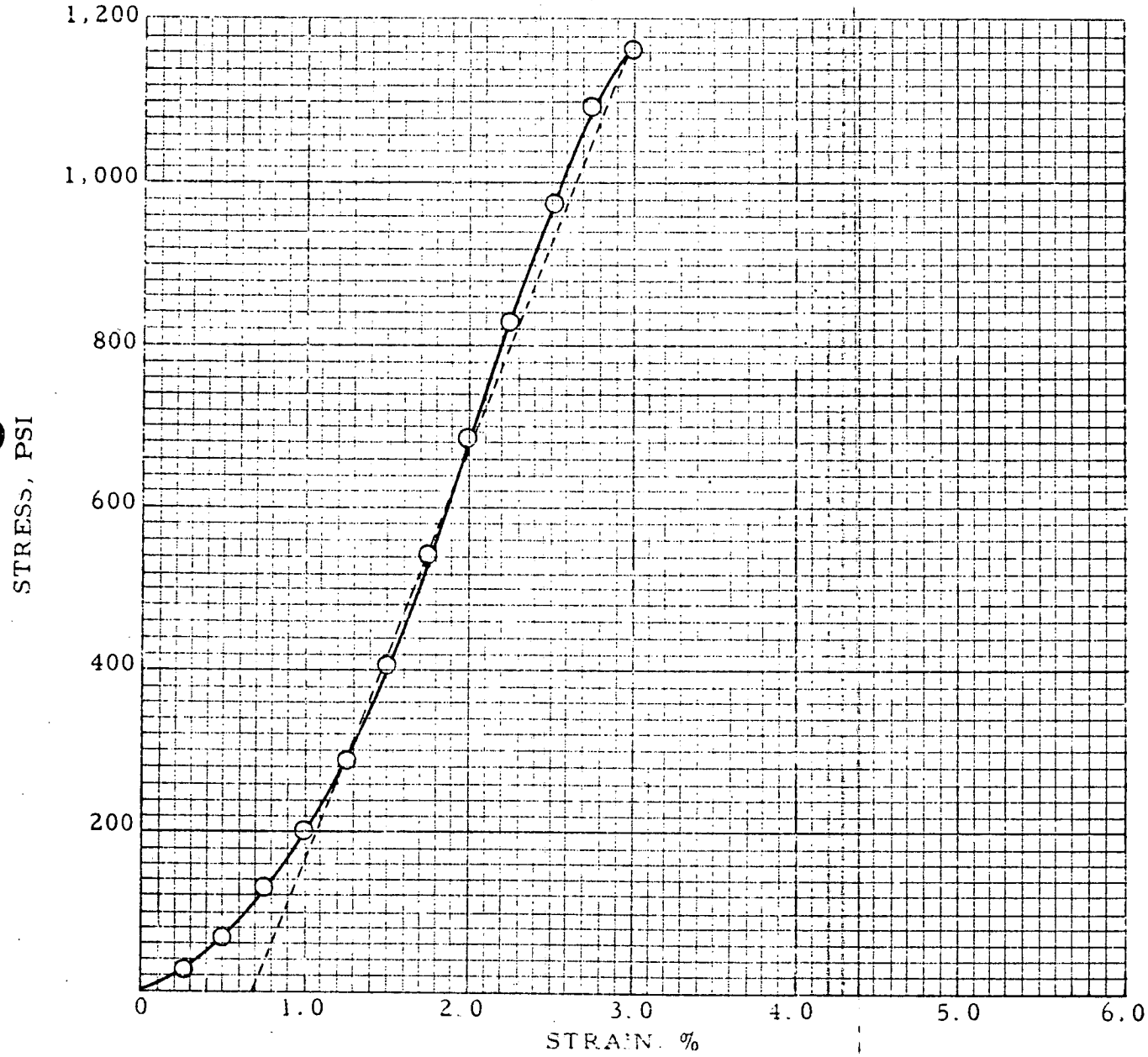
Lab. No.	Boring No.	Depth, ft	Natural Moisture Content, %
6972	2H	55' W	2.5
6973	2H	56' W	5.3
6974	2H	56' E	0.2
6975	2H	57' E	0.9
6976	2H	58' E	1.1
6977	2H	58' W	0.6
6979	2J	53' E	0.5
6980	2J	54' W	0.2
6981	2J	54' E	0.4
6982	2J	55' E	0.2
6983	2J	55' E	0.2
6984	2J	56' W	0.2

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6827 Boring 2 - K Depth, ft. 66 E



MODULUS OF ELASTICITY, PSI

Elastic Range 53,333

At Failure 48,223

POISSON'S RATIO

Elastic Range .074

At Failure .062

BULK MODULUS, PSI

At Failure 22,055

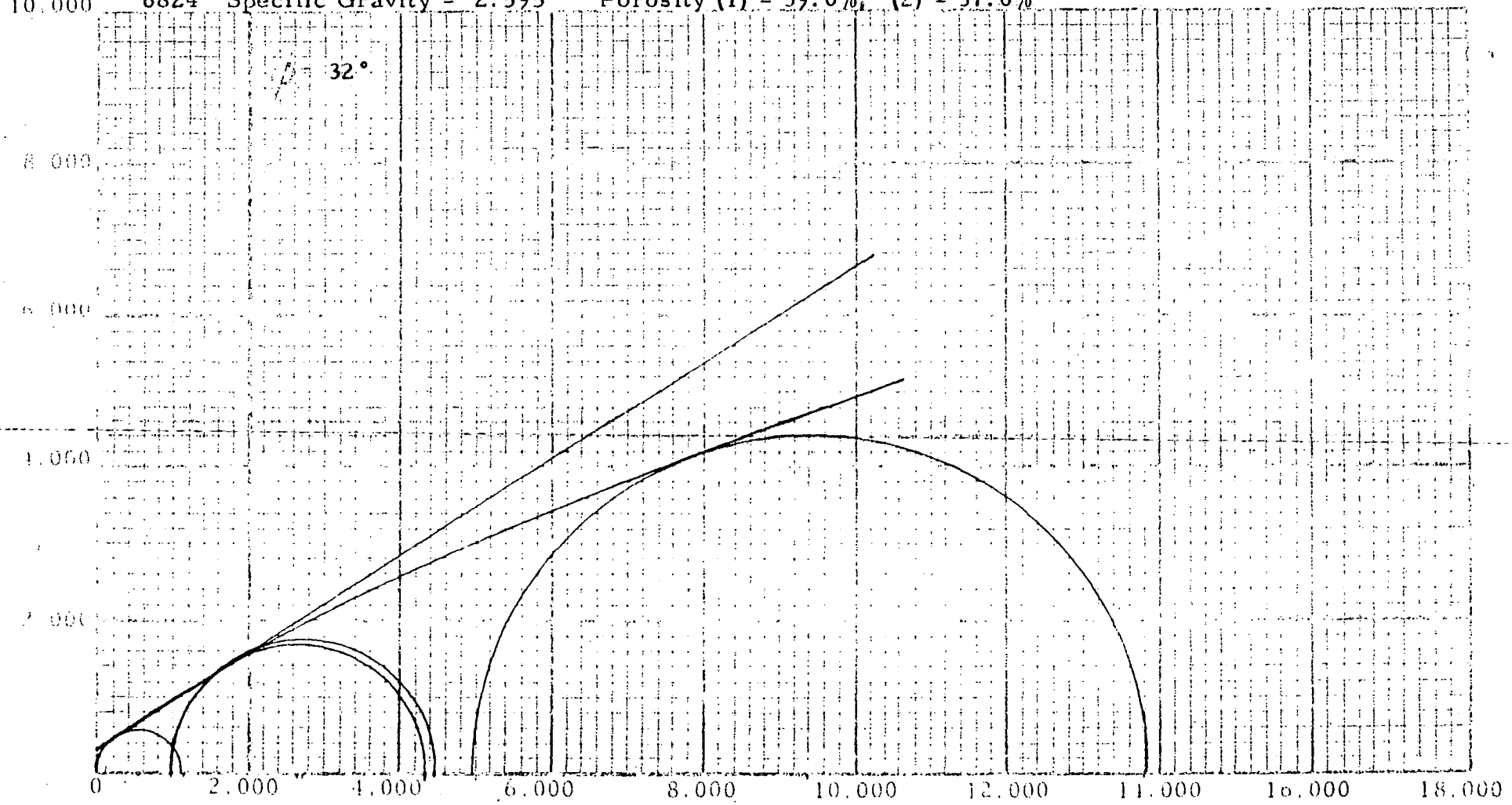
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 K Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$, psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6827	0	1167		1.2	97.7	5.0	1.781	4.03
6824 (1)	1.000	3350	98.9	1.3	97.5	5.0	1.781	4.03
6824 (2)	1.000	3490	102.0	1.3	100.7	5.0	1.750	4.03
6821	5.000	8800		1.7	90.0	5.0	1.781	4.06

6824 Specific Gravity = 2.595 Porosity (1) = 39.0%, (2) = 37.0%

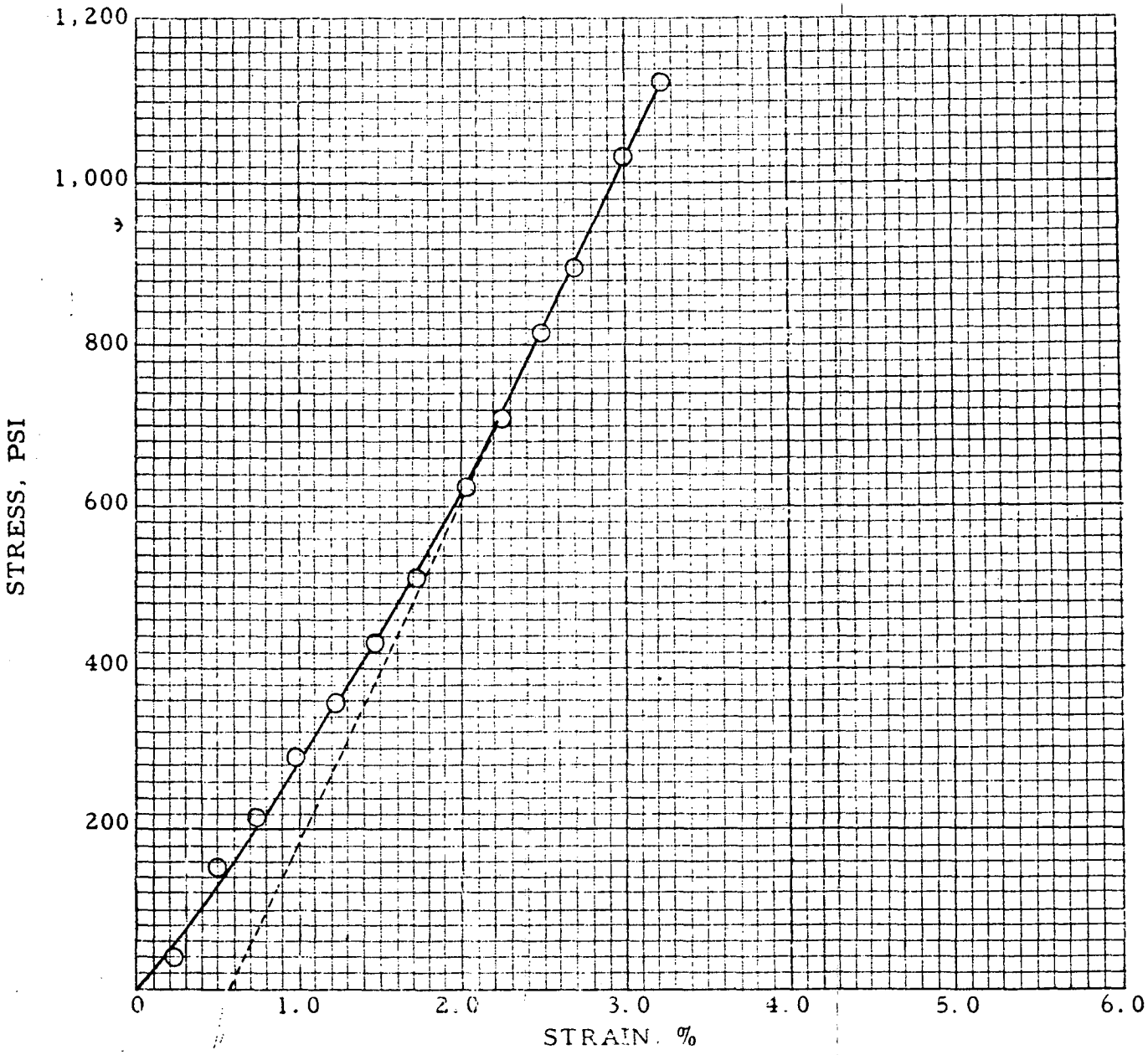


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6828 Boring 2 - K Depth, ft. 66" W



MODULUS OF ELASTICITY, PSI

Elastic Range 42,566

At Failure 42,566

POISSON'S RATIO

Elastic Range .082

At Failure .082

BULK MODULUS, PSI

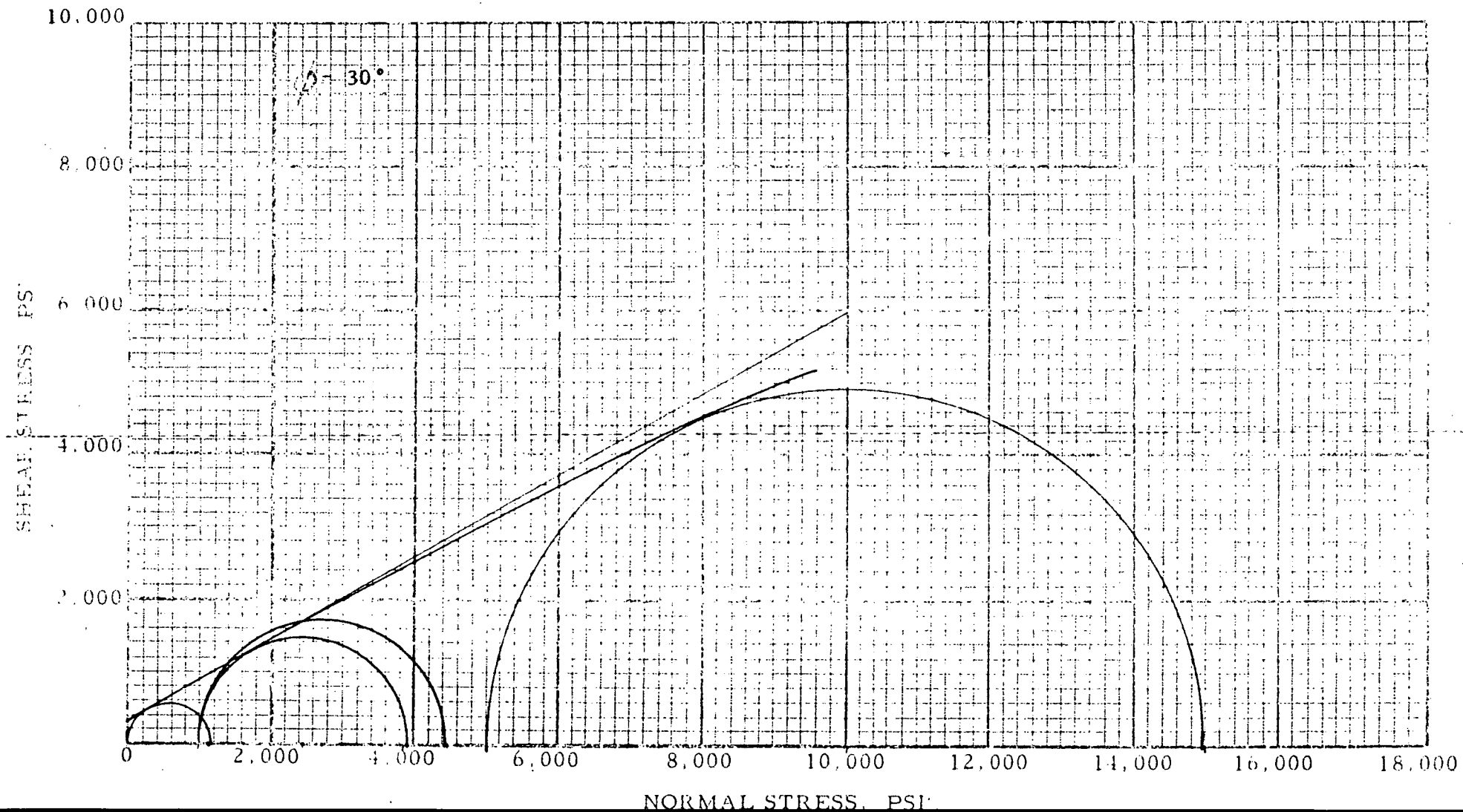
At Failure 46,058

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 K Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6828	0	1128		1.4	100.0	Dry	1.781	4.03
6825 (1)	1,000	3435		1.8	98.0	"	1.75	4.00
6825 (2)	1,000	2930		1.8	98.3	"	1.781	4.03
6822	5 000	10000		2.4	97.4	"	1.781	4.03

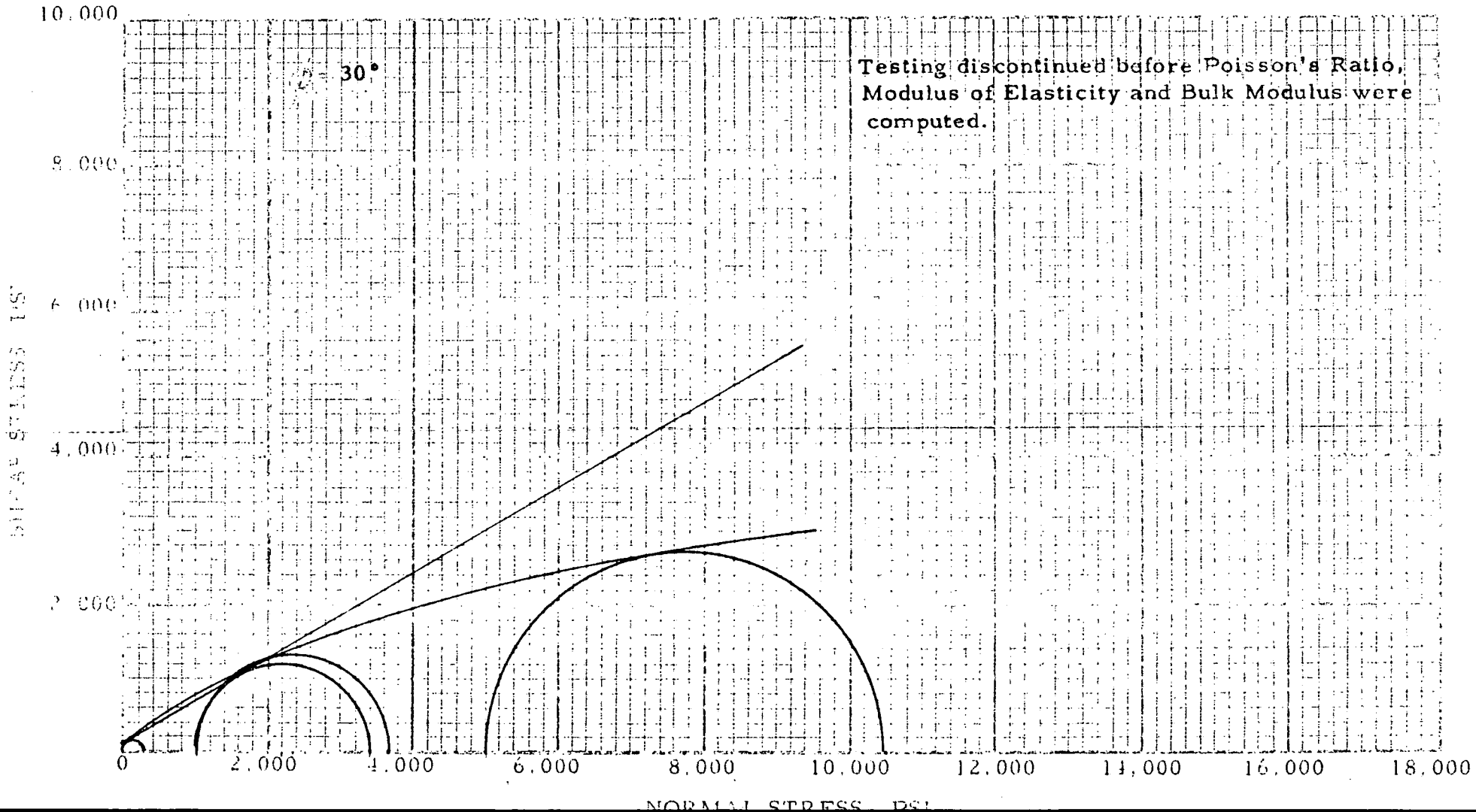


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2-O Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6927	0	256		0.4		Dry	1.72	4.00
6925 (1)	1.000	2650		1.9		"	1.72	4.05
6925 (2)	1.000	2400		1.9		"	1.72	4.03
6923	5.000	5530		1.7		"	1.72	4.05

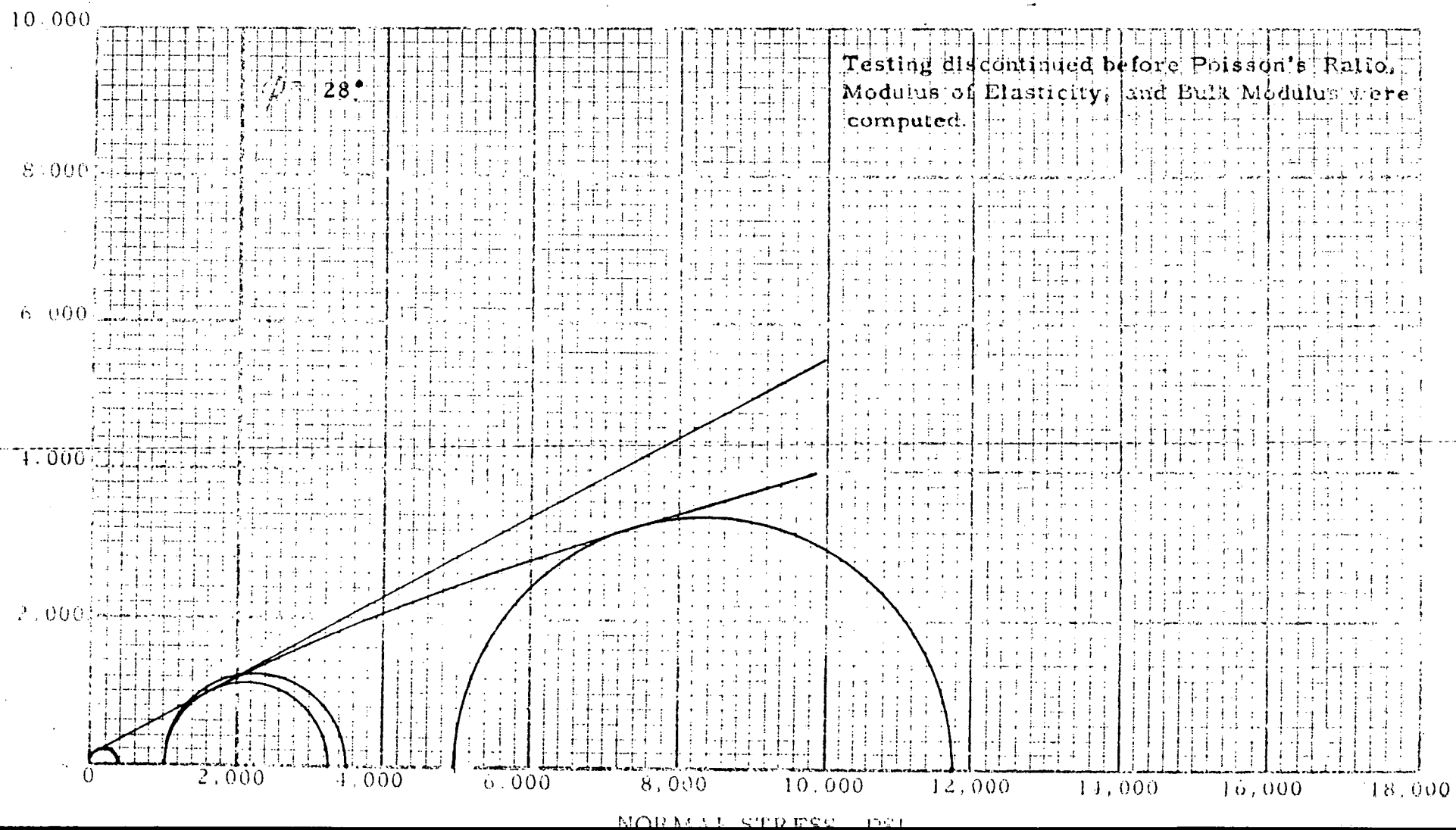


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 - 0 Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6928	0	346		2.3		5.0	1.72	3.95
6926 (1)	1.000	2225		1.2		5.0	1.75	4.08
6926 (2)	1.000	2530		1.2		5.0	1.73	4.03
6924	5.000	6740		1.3		5.0	1.72	4.03

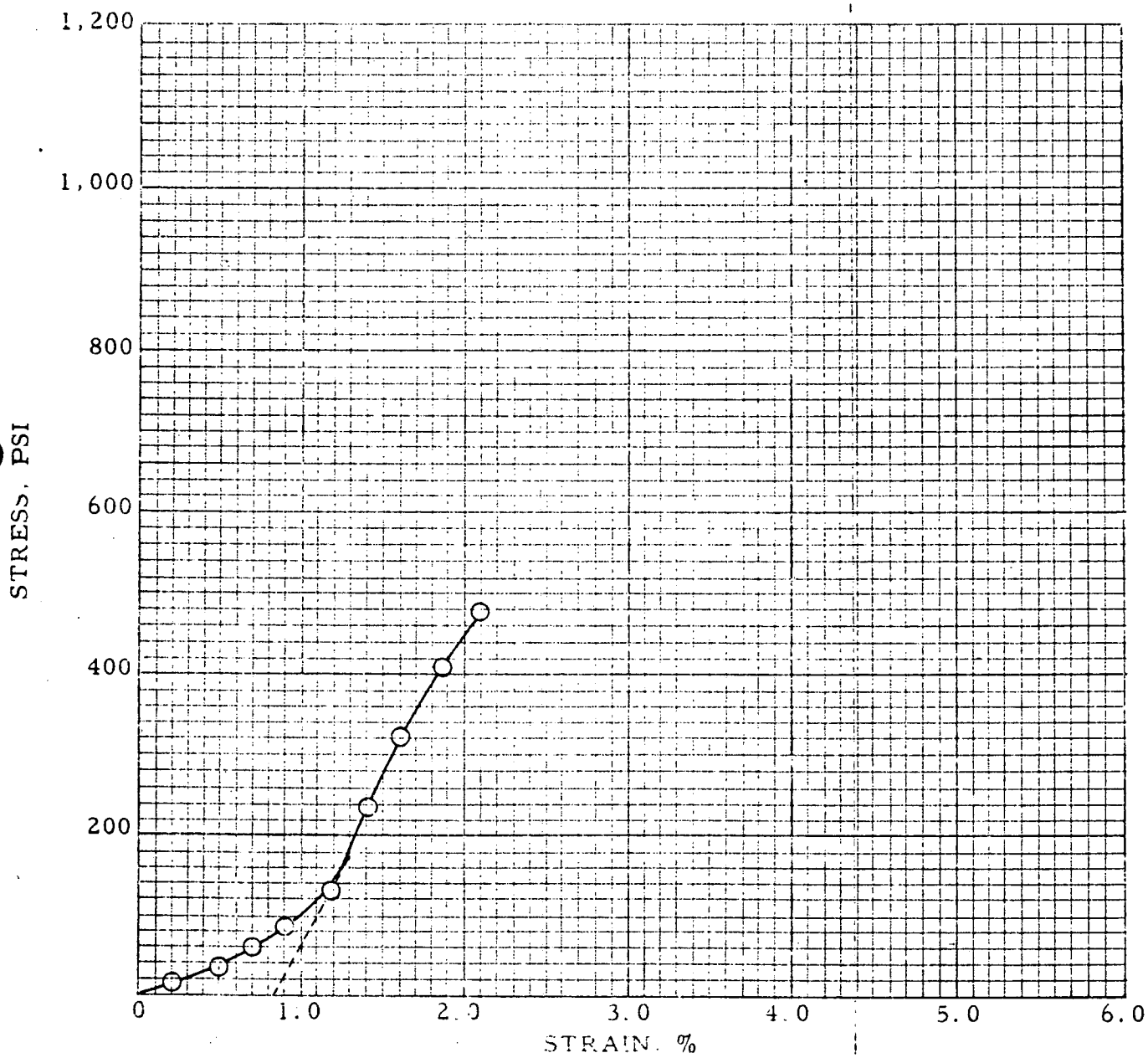


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY Los Alamos, N M. Job No. 59-154

Lab No. 6779 Boring 2 - U Depth, ft. 48' E



MODULUS OF ELASTICITY, PSI

Elastic Range 42,289

At Failure 31,746

POISSON'S RATIO

Elastic Range .212

At Failure .170

BULK MODULUS, PSI

At Failure 43,694

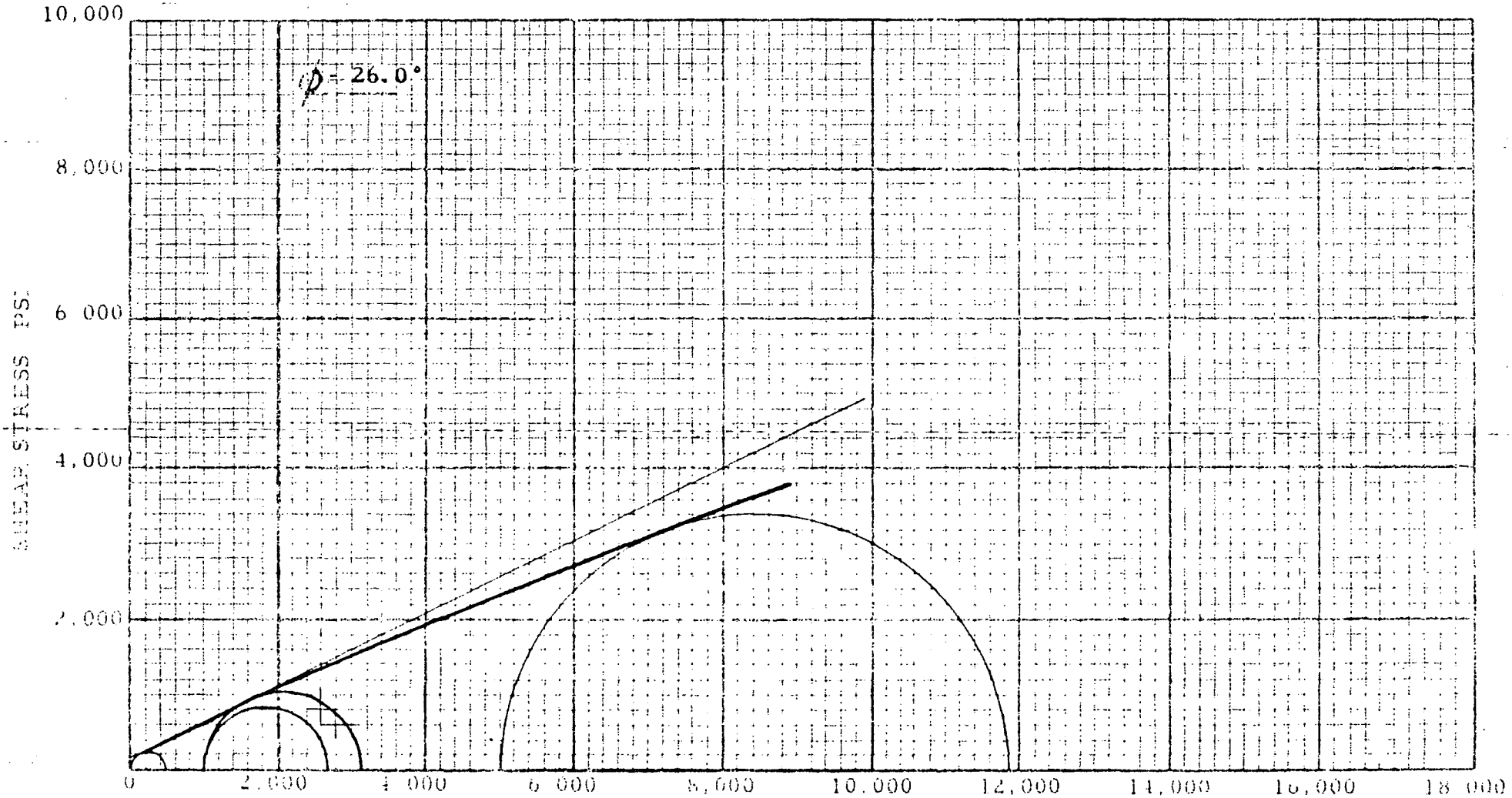
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N. M. Boring 2 u Job No. 59-154

Lab. No.	Confinement σ_3 psi	Max Stress $\sigma_1 - \sigma_3$ psi	Natural Density pcf	Nat Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6779	0	480	86.4	1.90	84.8	5.0	1.720	4.031
6777 (1)	1.000	1,760		1.51	83.9	5.0	1.688	4.031
6777 (2)	1.000	2,130		1.51	84.4	5.0	1.688	4.031
6775	5.000	6,850	88.0	2.14	86.1	5.0	1.750	4.250

6777 - Porosity = 48.0%; Specific Gravity = 2.570

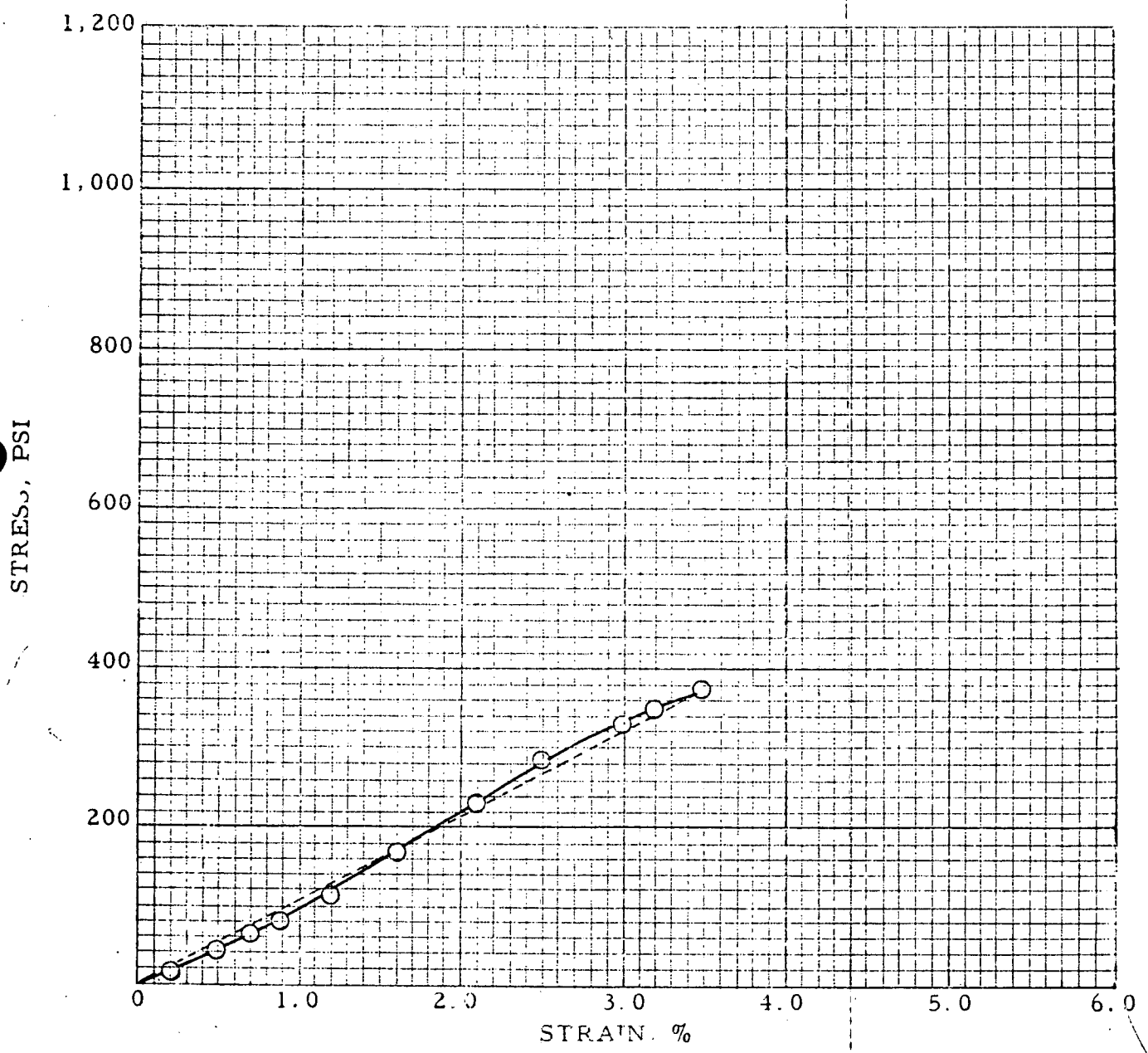


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6780 Boring 2 - U Depth, ft. 49' E



MODULUS OF ELASTICITY, PSI

Elastic Range 11,308

At Failure 10,677

POISSON'S RATIO

Elastic Range .038

At Failure .030

BULK MODULUS, PSI

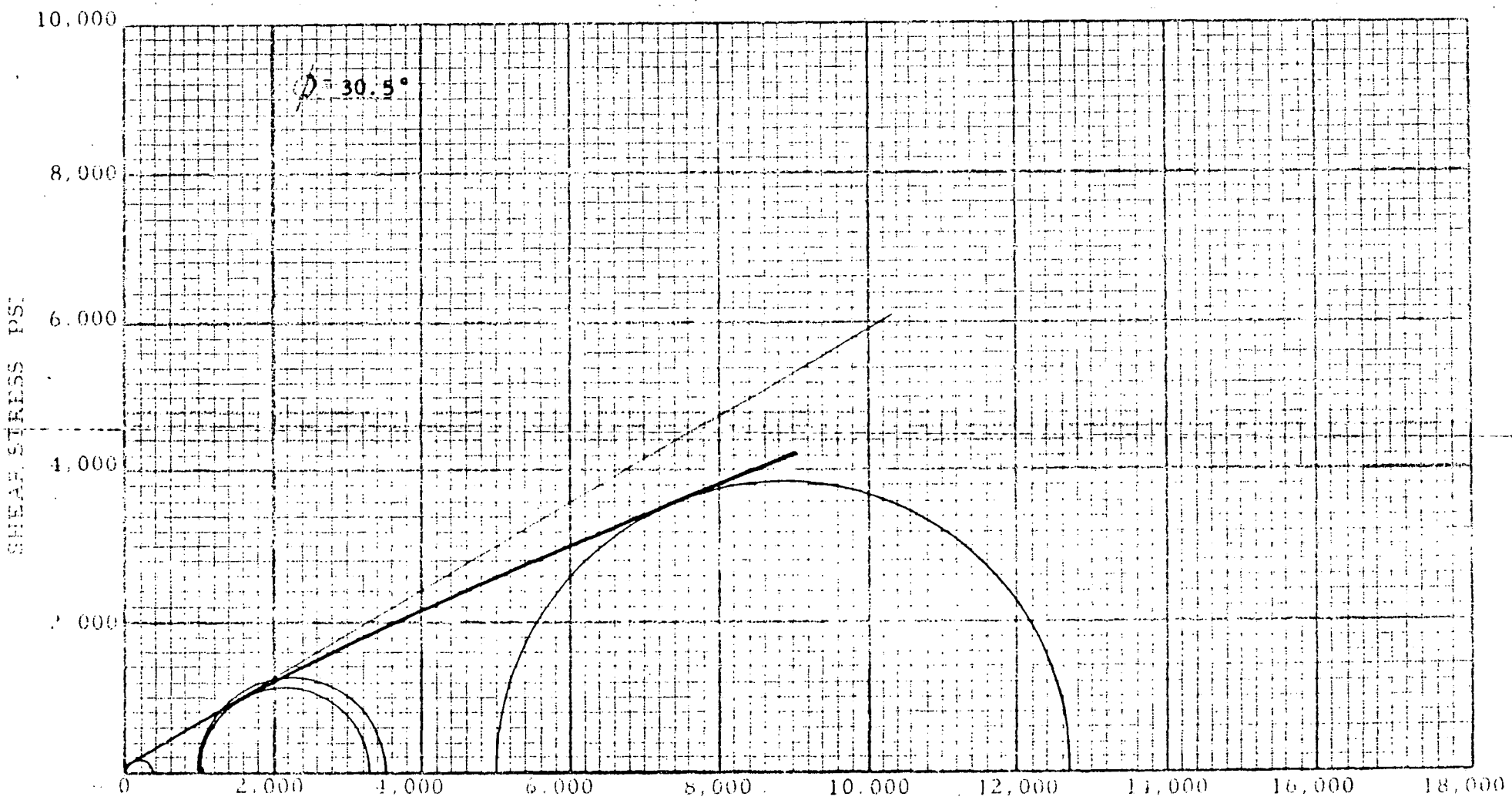
At Failure 10,724

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 u Job No. 59-154

Lab. No	Confinement σ_3, psi	Max Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam in.	Height, in.
6780	0	373	85.9	1.86	84.4	5.0	1.718	4.031
6778 (1)	1,000	2,490	86.5	2.13	84.8	5.0	1.718	4.031
6778 (2)	1,000	2,300	86.2	2.13	84.4	5.0	1.718	4.031
6776	5,000	7,700	87.5	1.74	86.0	5.0	1.718	4,031

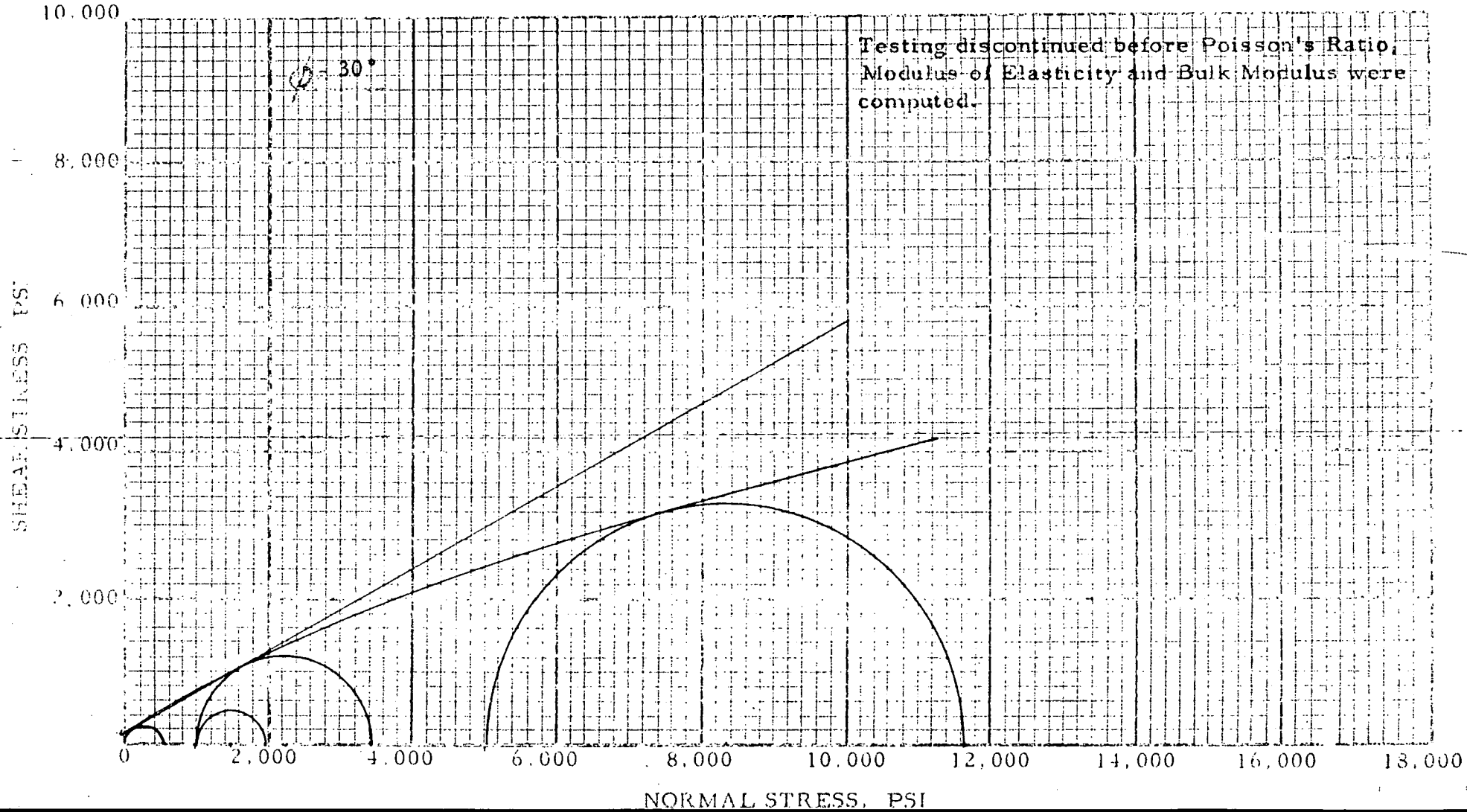


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 - V Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6882	0	516		1.6		5.0	1.72	4.03
6884 (1)	1.000	962		1.1		5.0	1.70	4.09
6884 (2)	1.000	2410		1.1		5.0	1.72	4.13
6886	5.000	6690		2.1		5.0	1.75	4.03

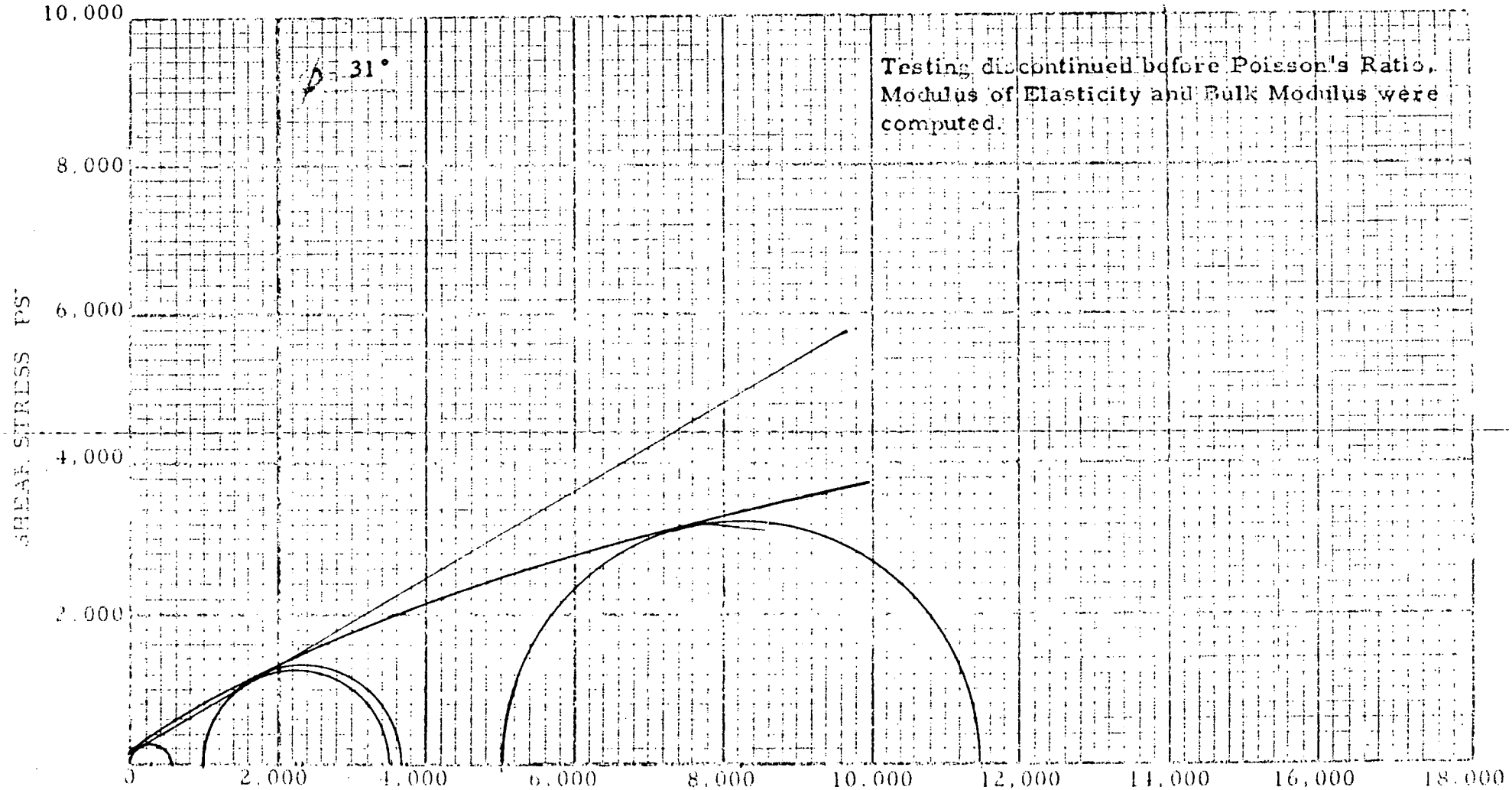


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project. THE ZIA COMPANY, Los Alamos, N.M. Boring 2 - V Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6883	0	570		2.1		Dry	1.72	4.03
6885 (1)	1,000	2735		1.4		"	1.73	4.08
6885 (2)	1,000	2540		1.4		"	1.75	4.05
6887	5,000	6500		2.0		"	1.75	4.23

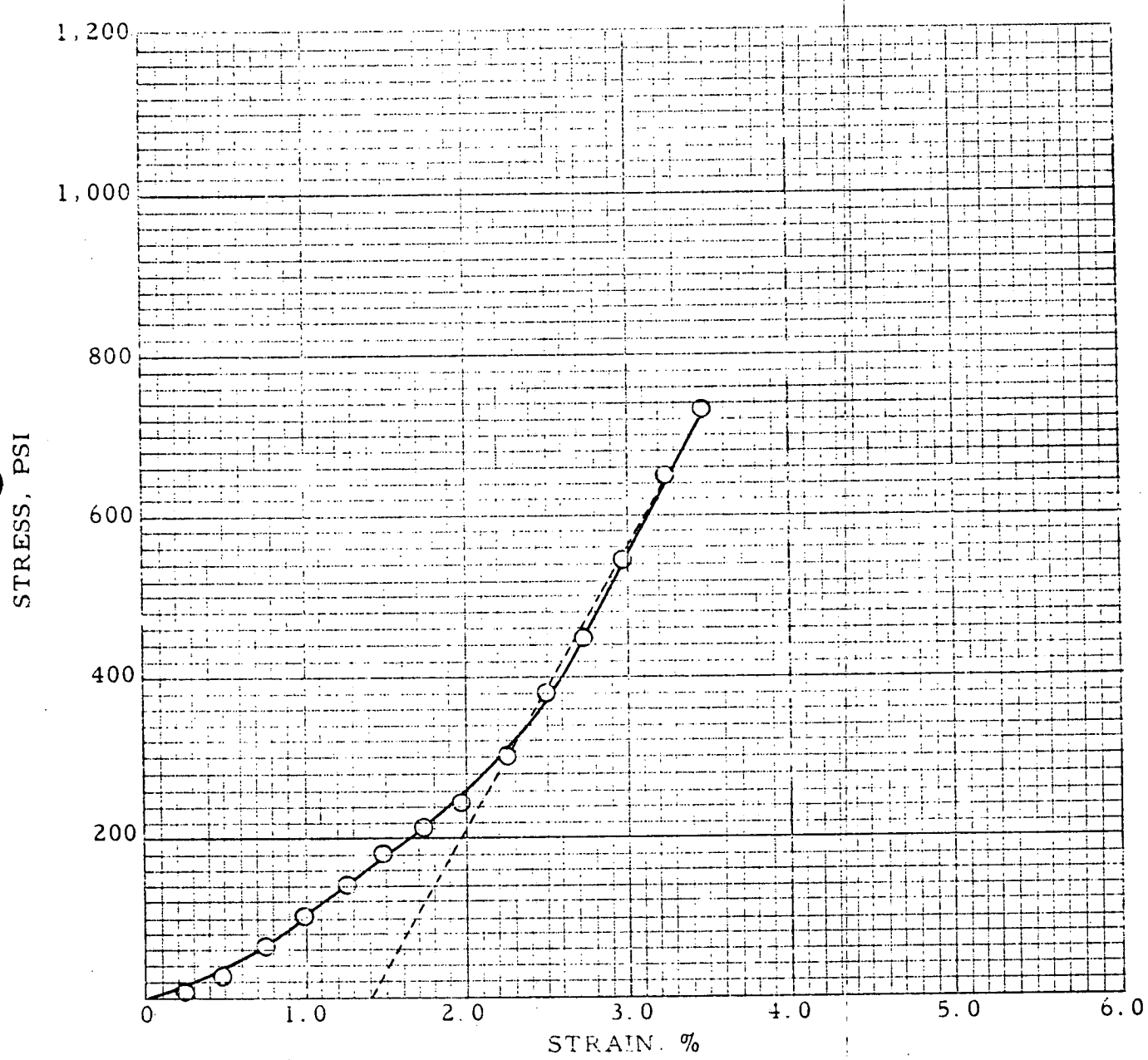


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6852 Boring 2 - W Depth, ft. 57' W



MODULUS OF ELASTICITY, PSI

Elastic Range 44,909

At Failure 39,245

POISSON'S RATIO

Elastic Range .054

At Failure .050

BULK MODULUS, PSI

At Failure 42,699

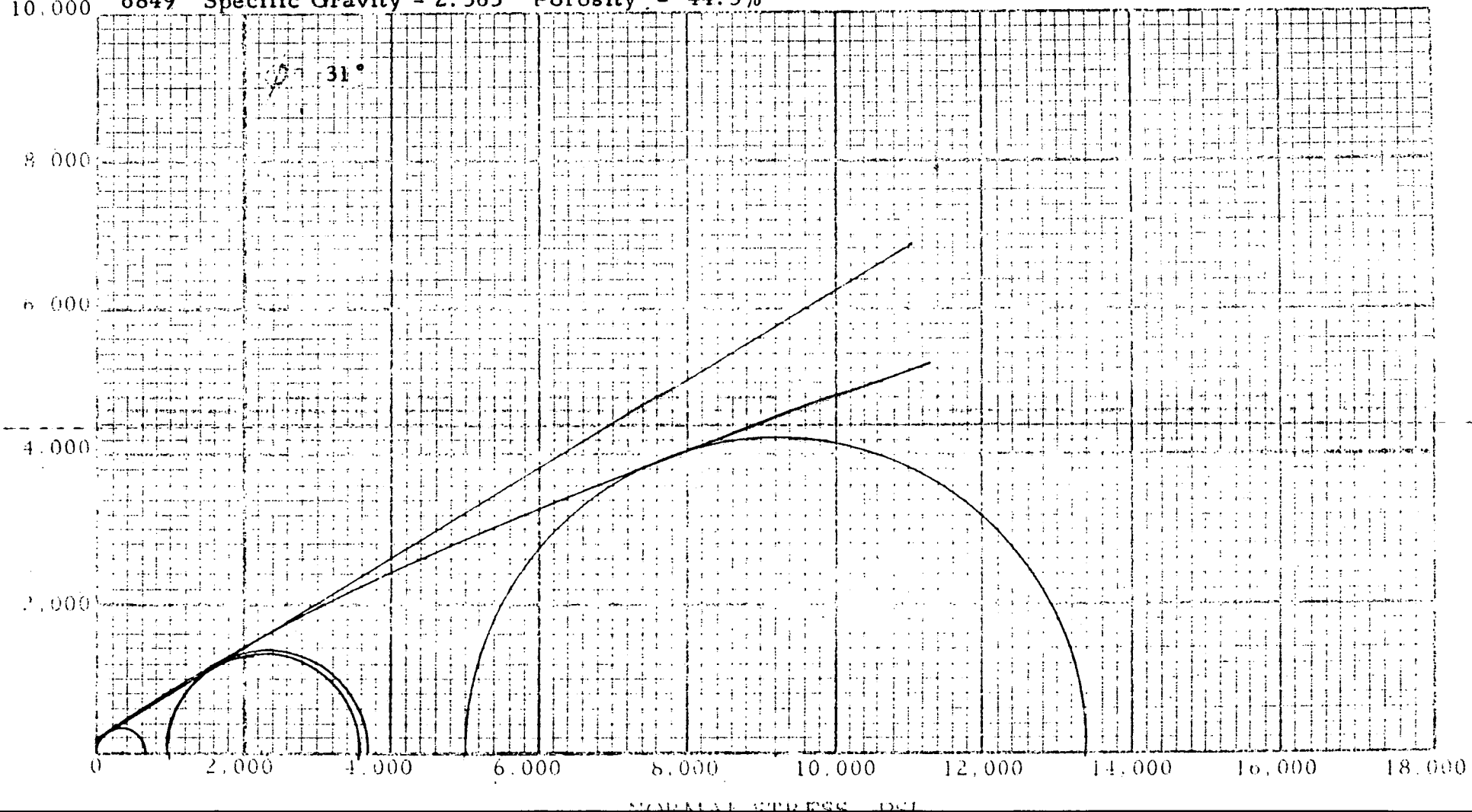
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 W Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6852	0	624		2.00	89.5	5.0	1.766	4.031
6849 (1)	1.000	2670	90.5	1.80	88.9	5.0	1.750	4.063
6849 (2)	1.000	2570	90.5	1.80	89.3	5.0	1.750	4.063
6846	5.000	8400		0.90	86.6	5.0	1.719	4.031

6849 Specific Gravity = 2.565 Porosity = 44.5%

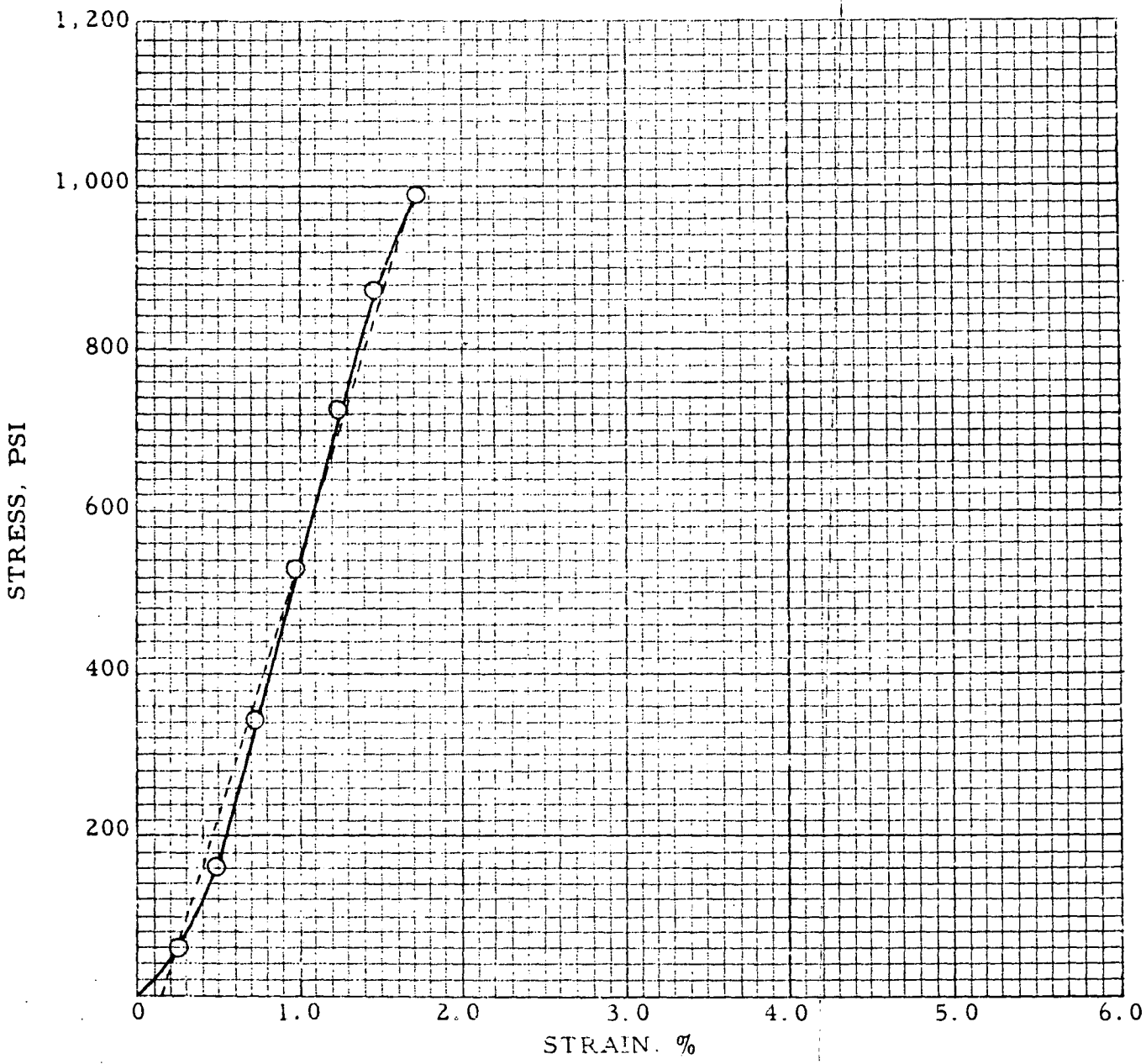


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6853 Boring 2 - W Depth, ft. 57 E



MODULUS OF ELASTICITY, PSI

Elastic Range 68,851

At Failure 62,722

POISSON'S RATIO

Elastic Range .076

At Failure .074

BULK MODULUS, PSI

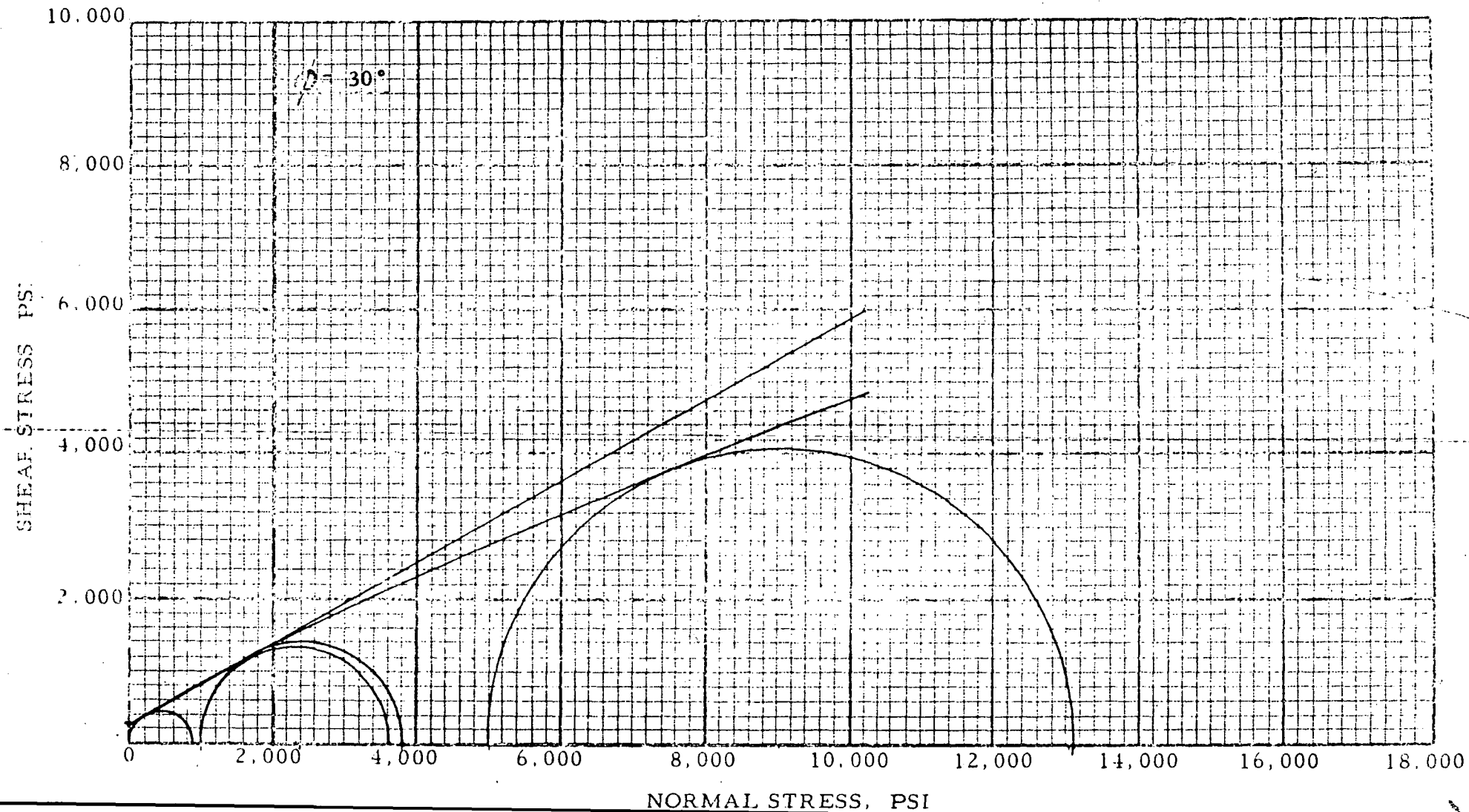
At Failure 48,953

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 W Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam., in.	Height, in.
6853	0	991		2.0	90.8	Dry	1.75	4.03
6850 (1)	1,000	2800		1.1	88.7	"	1.75	4.00
6850 (2)	1,000	2610		1.1	83.0	"	1.75	3.28
6848	5,000	8050		1.1	94.2	"	1.59	4.09

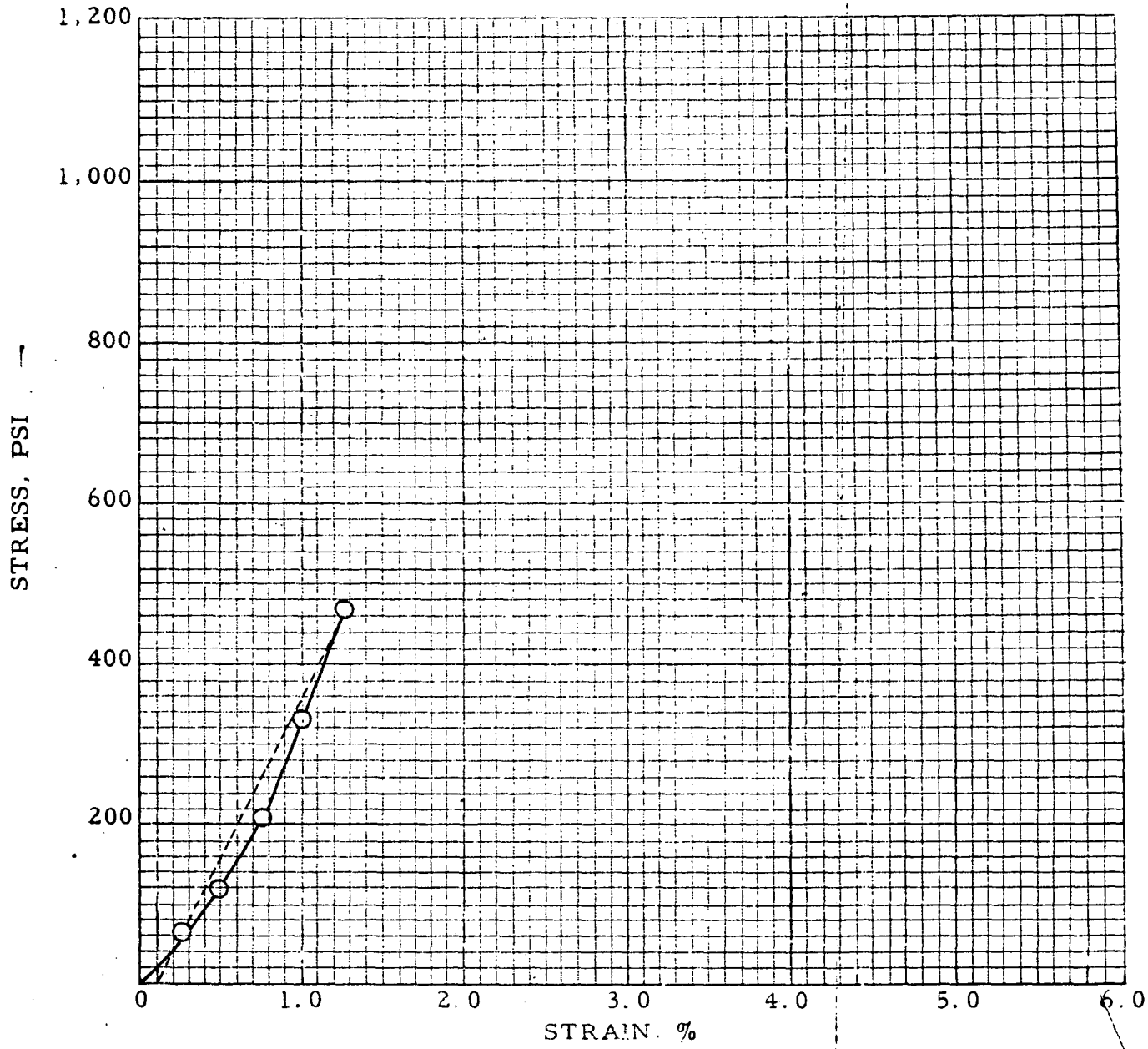


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6894 Boring 2 X Depth, ft. 56" W



MODULUS OF ELASTICITY, PSI

Elastic Range 52,888

At Failure 52,888

POISSON'S RATIO

Elastic Range .170

At Failure .170

BULK MODULUS, PSI

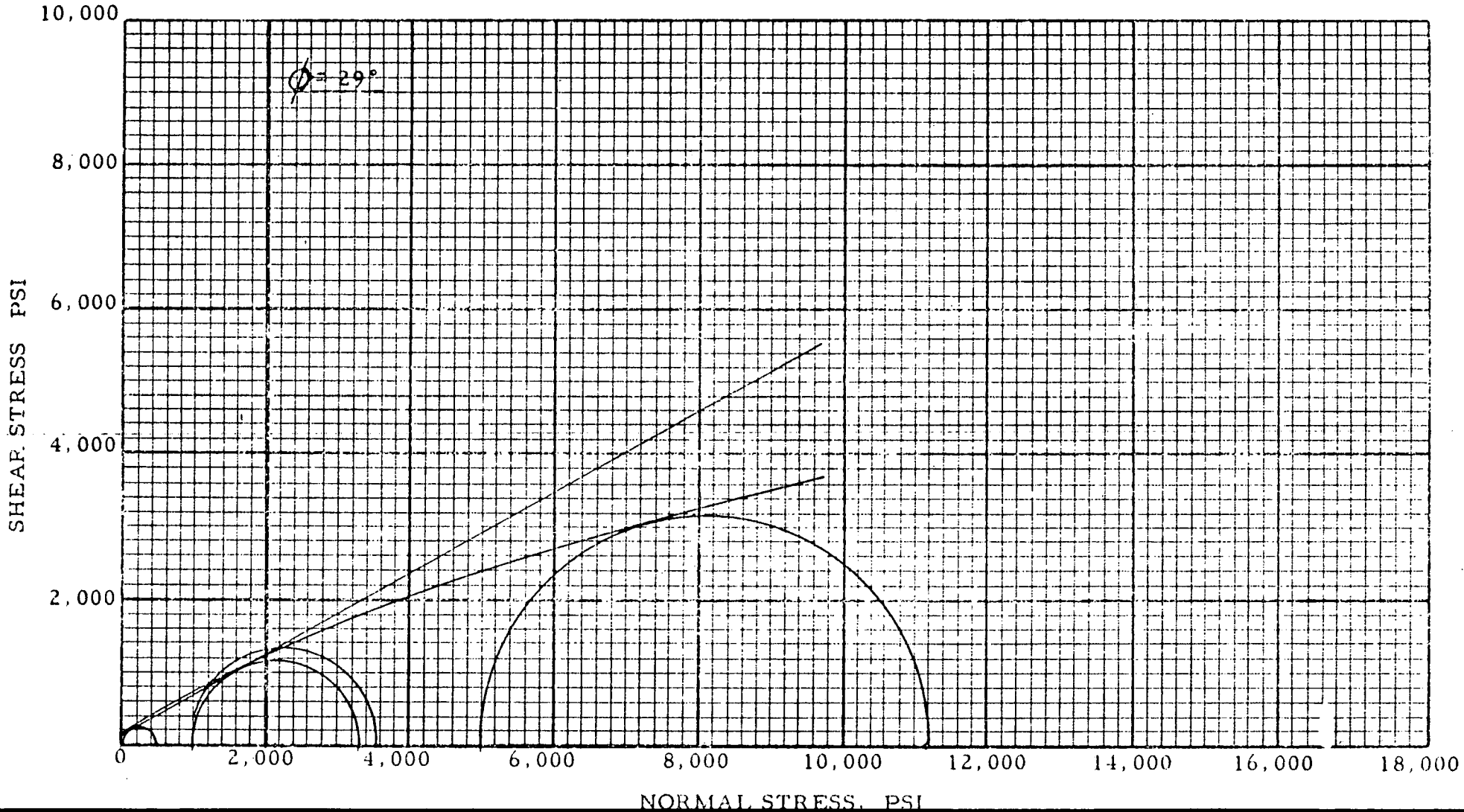
At Failure 45,837

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 - X Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6894	0	476		1.0		5.0	1.75	4.02
6892-1	1,000	2320		1.9		5.0	1.75	4.03
6892-2	1,000	2520		1.9		5.0	1.75	4.03
6890	5,000	6190		1.9		5.0	1.72	4.03

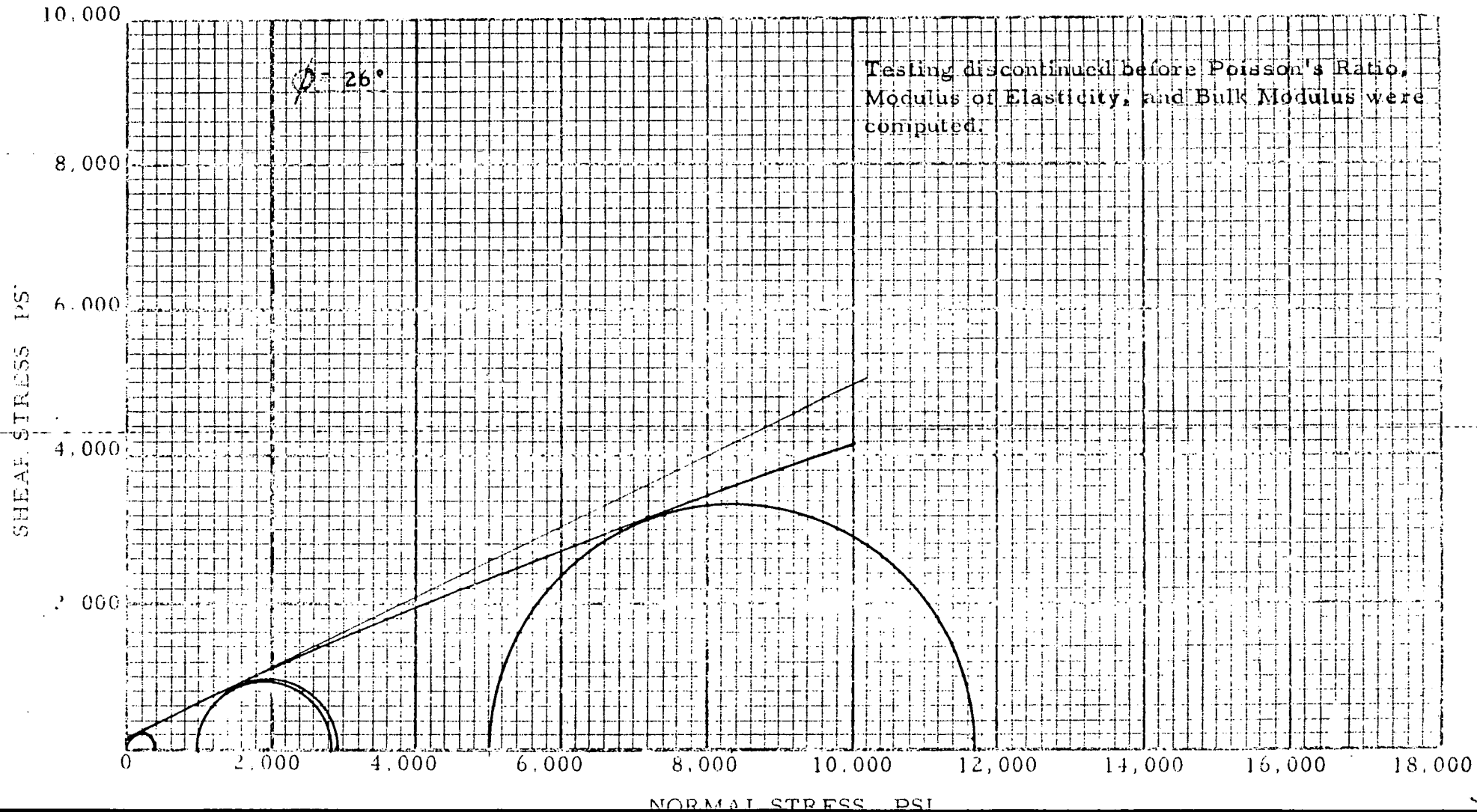


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 2 - X Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6895	0	368		1.4		5.0	1.75	3.13
6893 (1)	1,000	1815		1.1		5.0	1.75	4.09
6893 (2)	1,000	1870		1.1		5.0	1.72	4.00
6891	5,000	6760		1.1		5.0	1.75	4.03

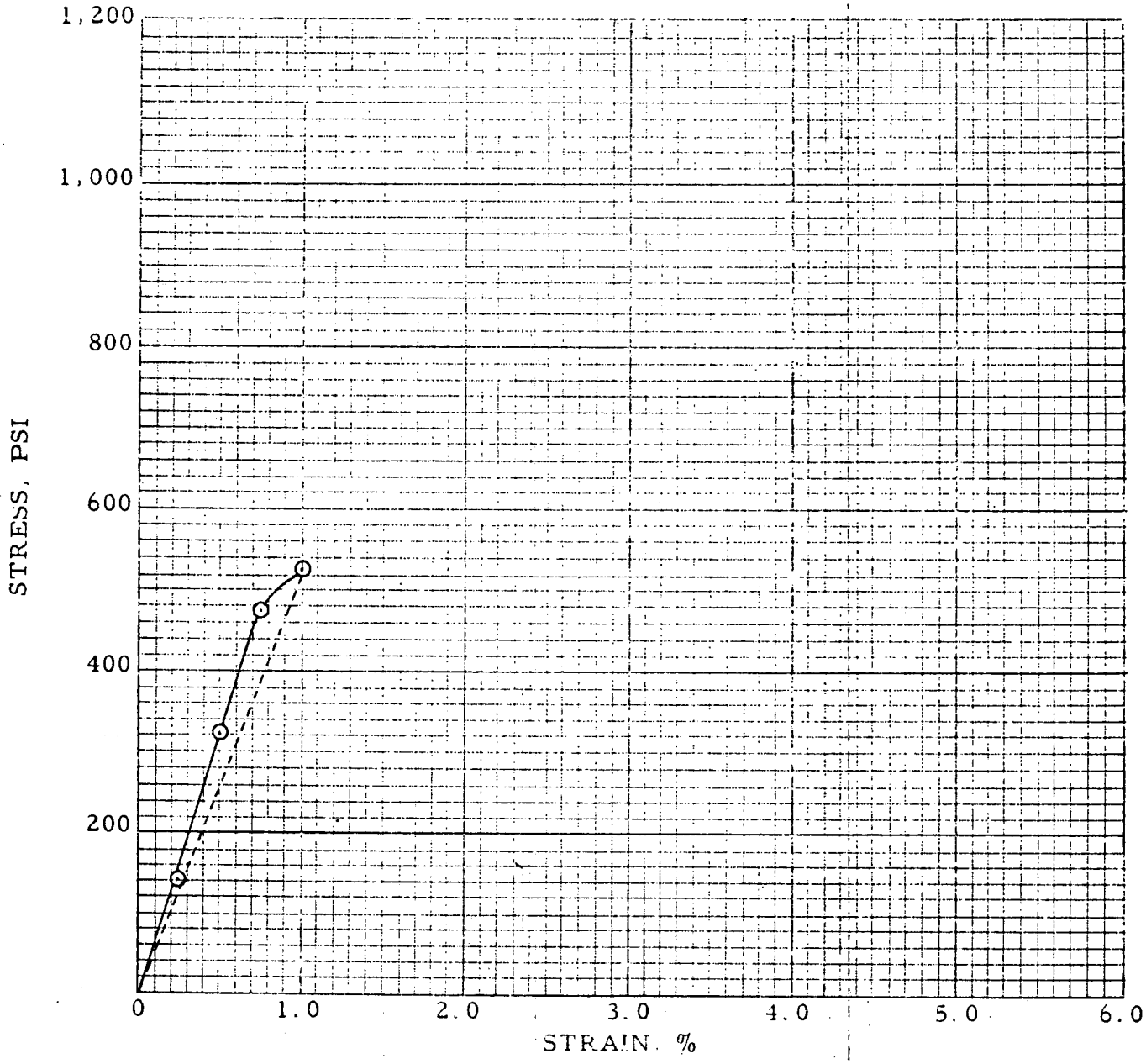


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No 59-154

Lab No. 7028 Boring 2- Y Depth, ft. 58



MODULUS OF ELASTICITY, PSI

Elastic Range 64,400

At Failure 52,600

POISSON'S RATIO

Elastic Range .042

At Failure .063

BULK MODULUS, PSI

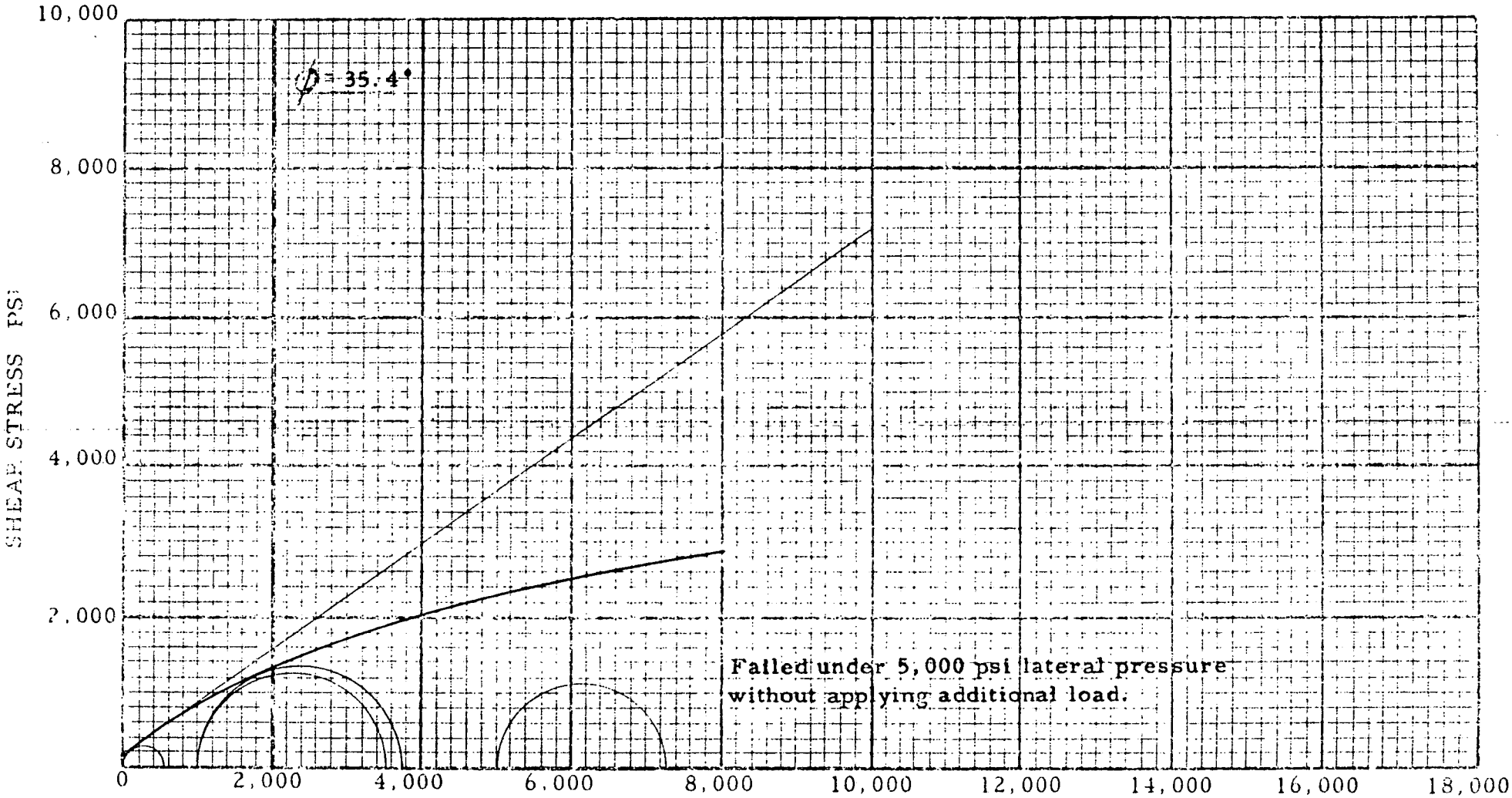
At Failure 56,681

SOIL MECHANICS, INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 - Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
7028	0	526			88.9	0	1.71	4.00
7029 (1)	1,000	2586			91.2	0	1.84	4.03
7029 (2)	1,000	2695			88.5	0	1.78	4.02
7031	5,000	2375			83.1	0	1.76	4.00



NO. 340R-10 DIETZGEN GRAPH PAPER
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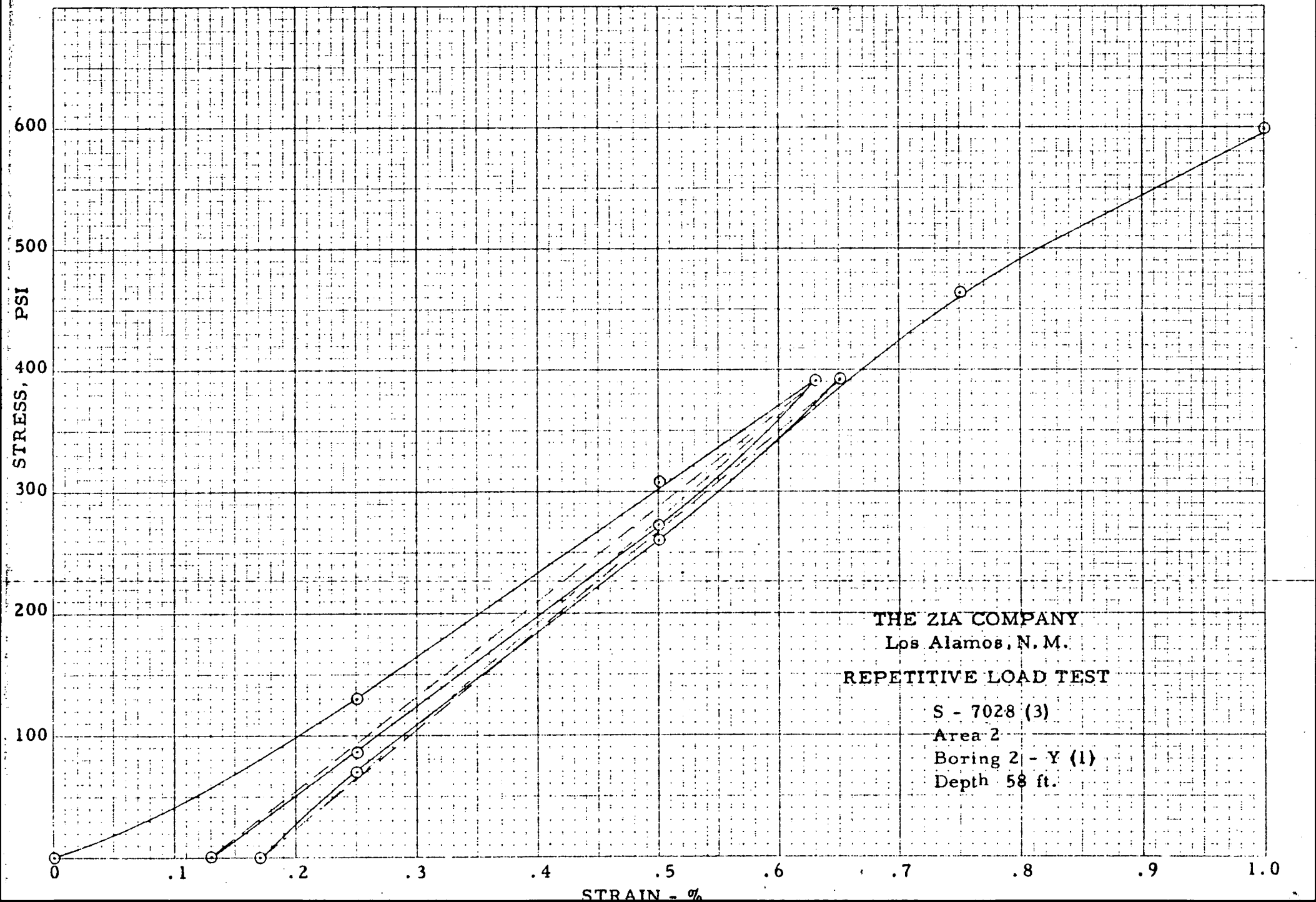
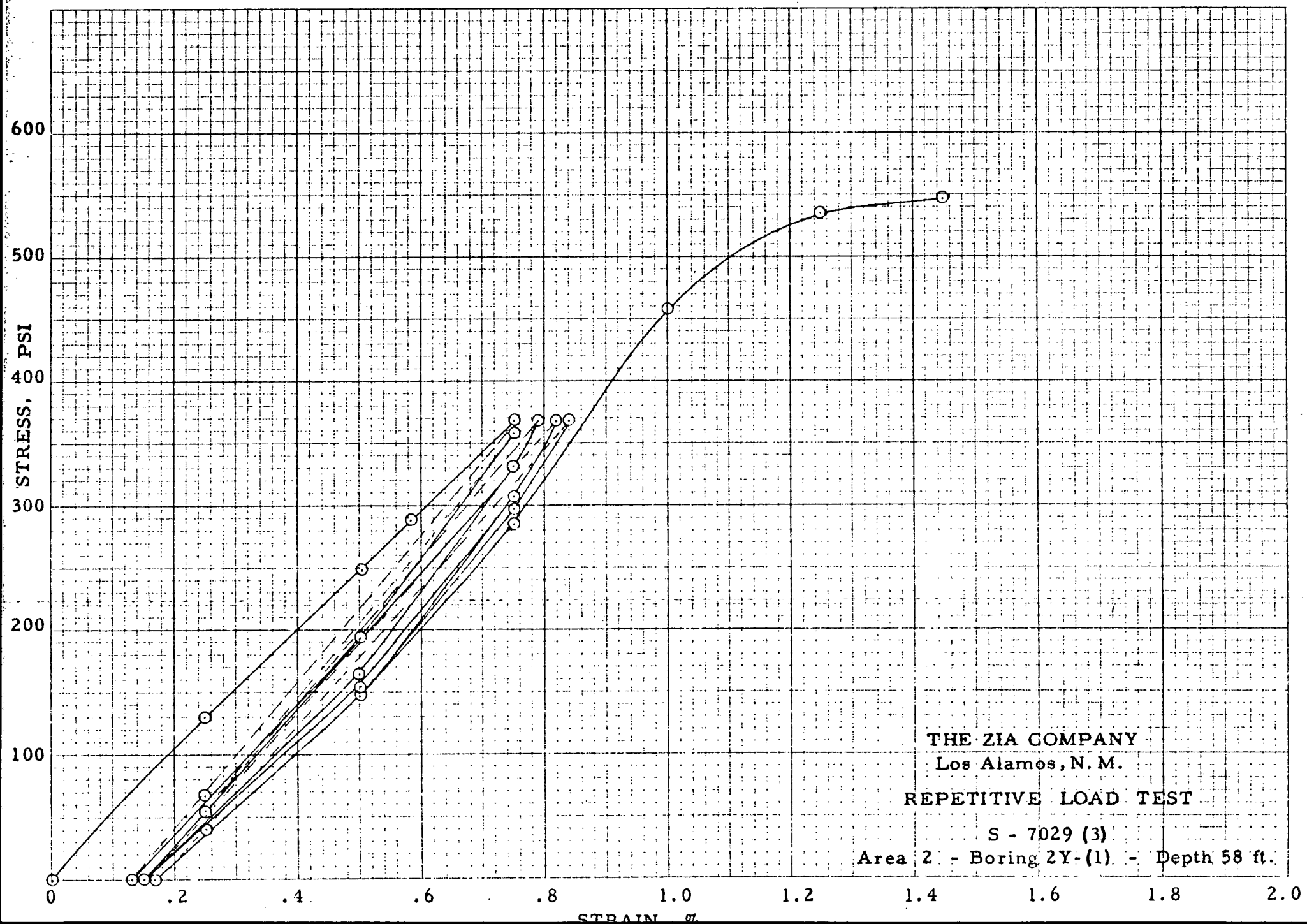
EUGENE DIETZGEN CO.
MADE IN U.S.A.



NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

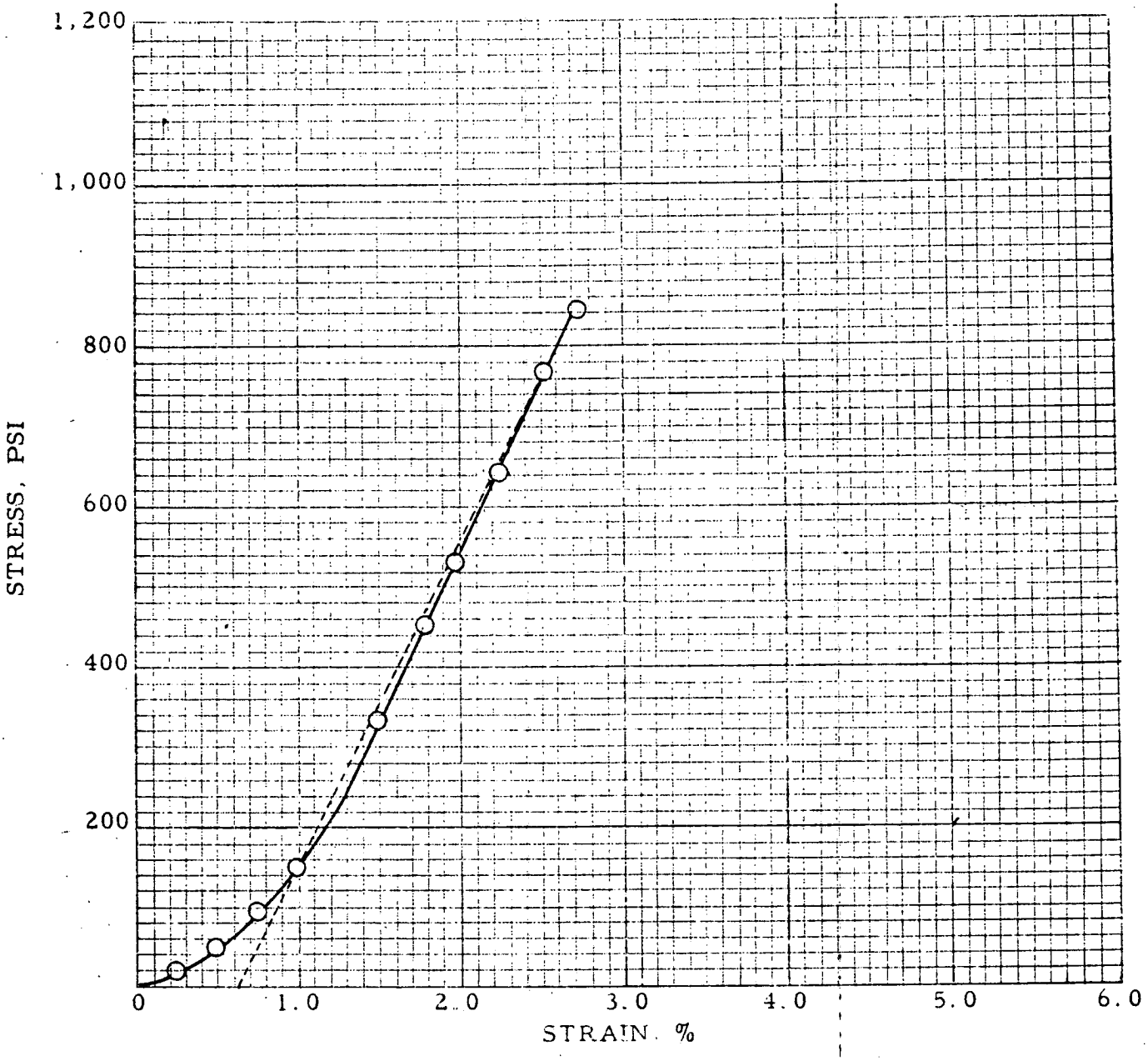


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6812 Boring 2 - Y Depth, ft. 72' E



MODULUS OF ELASTICITY, PSI

Elastic Range 40,047

At Failure 40,047

POISSON'S RATIO

Elastic Range .072

At Failure .072

BULK MODULUS, PSI

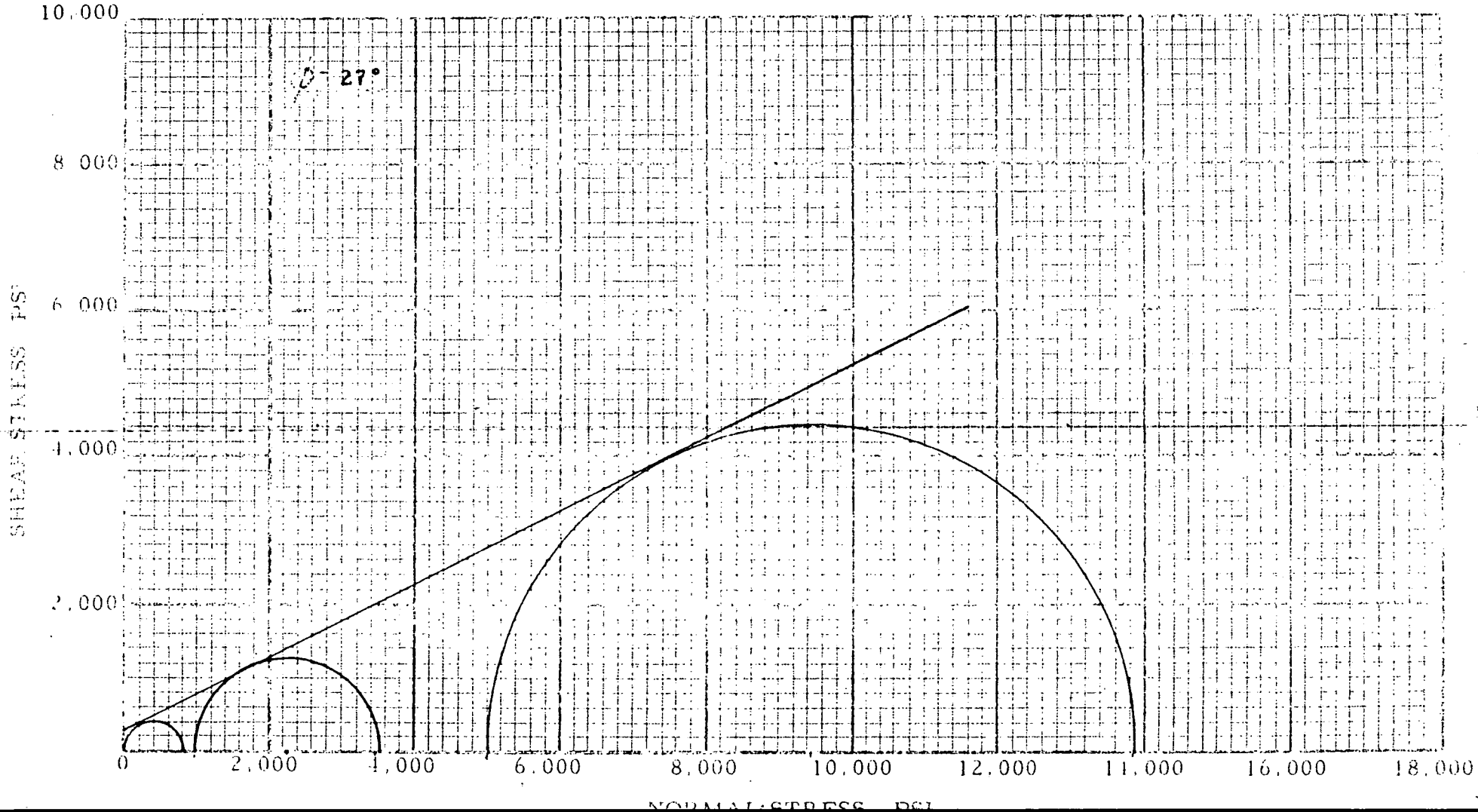
At Failure 73,678

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 - Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6812	0	845		2.70	93.7	Dry	1.75	4.03
6814 (1)	1.000	2458		2.65	91.0	"	1.7812	4.06
6814 (2)	1.000	2525		2.65	91.4	"	1.7812	4.03
6816	5.000	8820		2.40	85.2	"	1.719	3.91

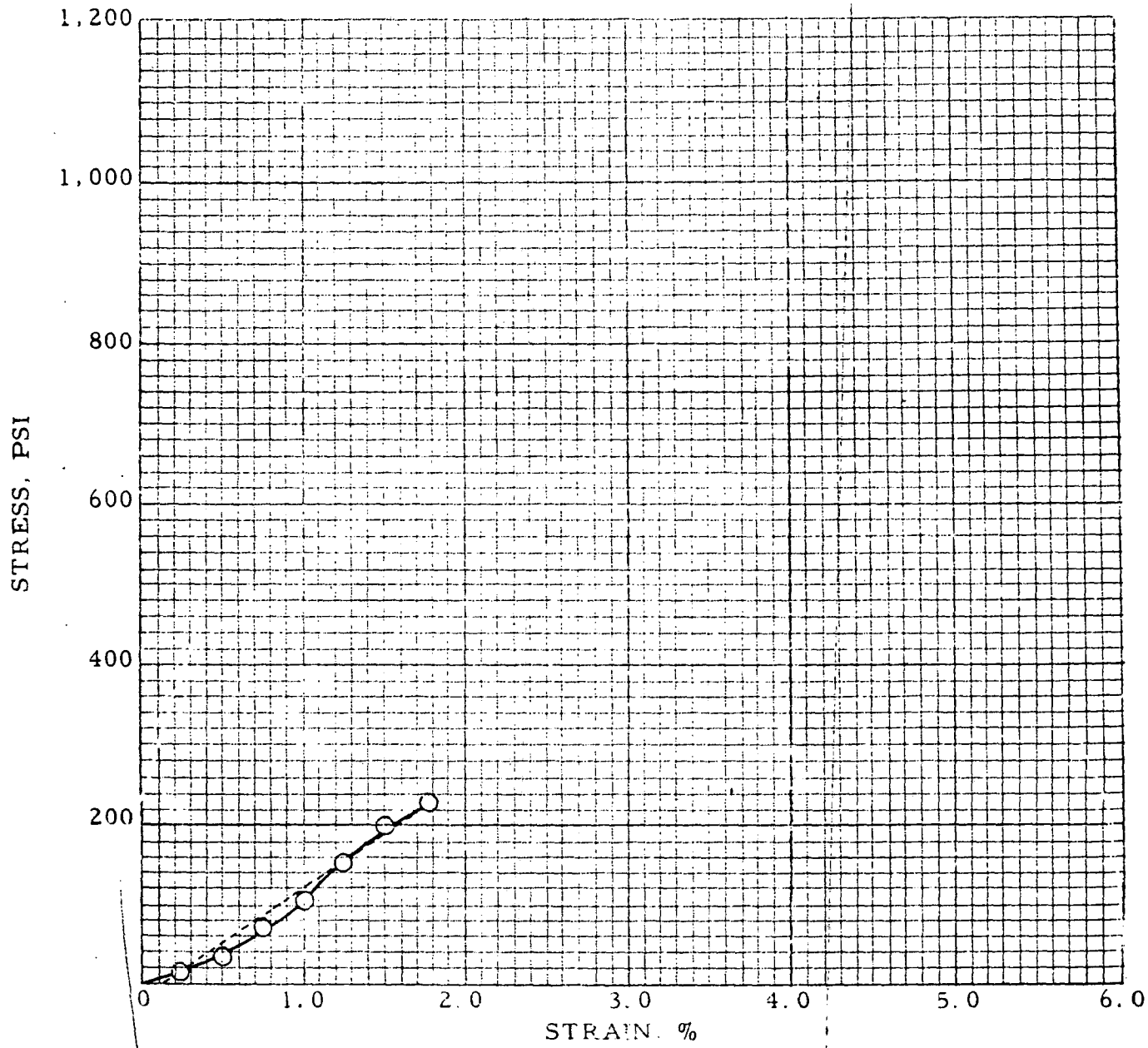


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6813 Boring 2 - Y Depth, ft. 72' W



MODULUS OF ELASTICITY, PSI

Elastic Range 14,818

At Failure 14,321

POISSON'S RATIO

Elastic Range .110

At Failure .090

BULK MODULUS, PSI

At Failure 15,185

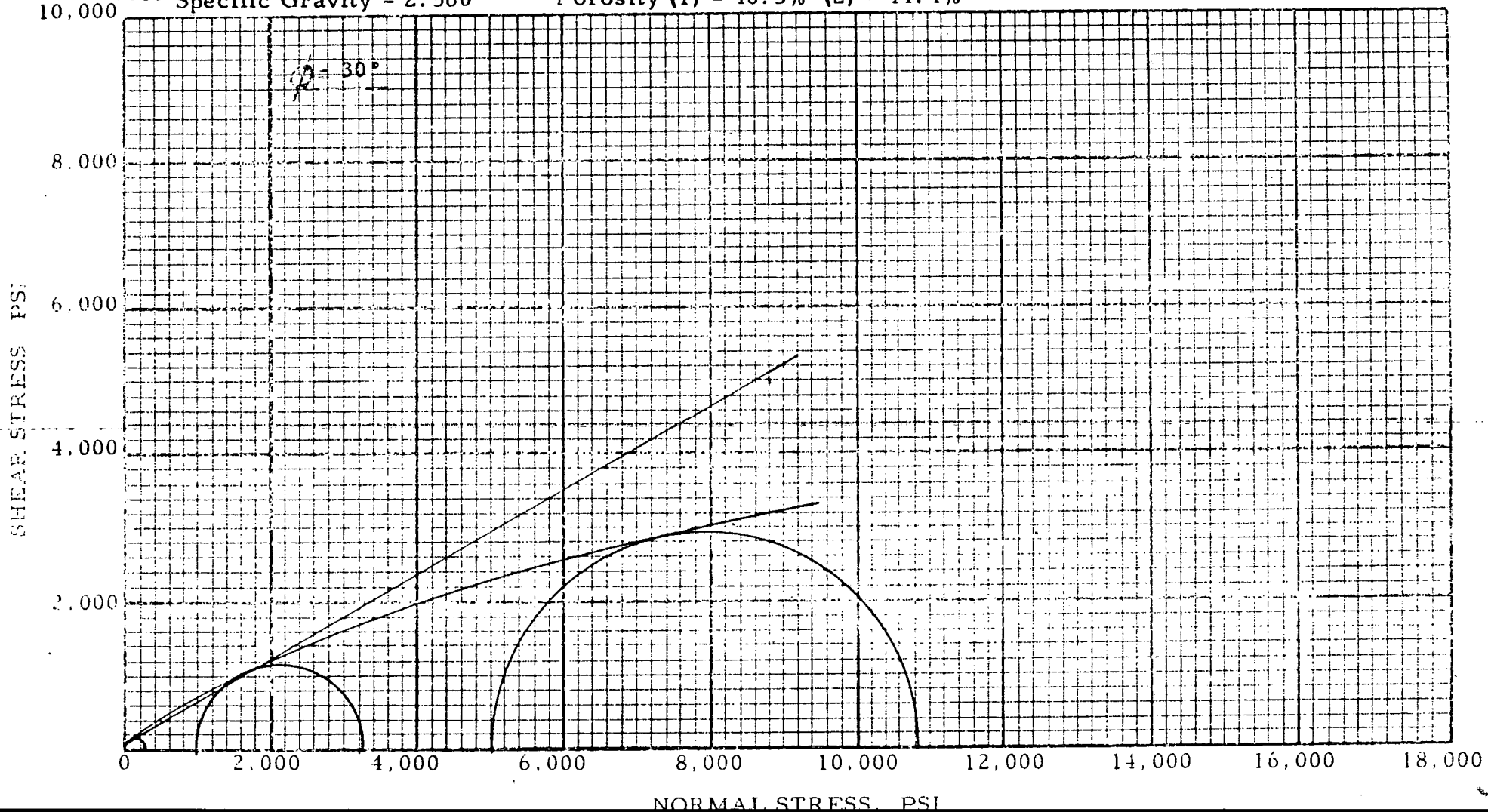
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6813	0	232		1.8	82.7	5.0	1.688	4.00
6815-1	1,000	2200	85.4	3.6	82.6	5.0	1.625	4.03
5815-2	1,000	2245	88.9	3.16	86.1	5.0	1.719	3.84
6817	5,000	5810		2.13	83.4	5.0	1.750	4.03

6815 Specific Gravity = 2.560 Porosity (1) = 46.5% (2) = 44.4%

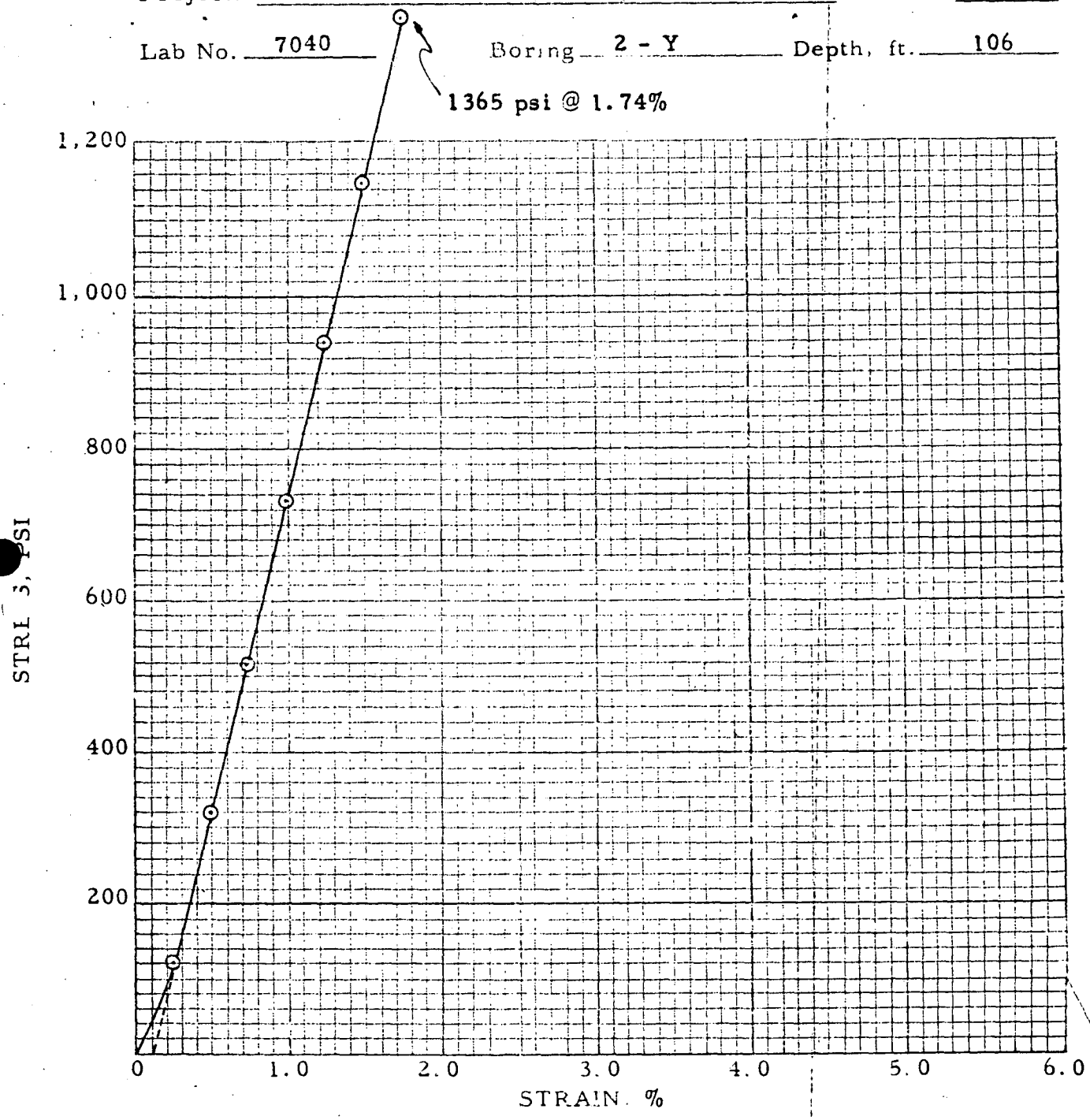


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 7040 Boring 2 - Y Depth, ft. 106



MODULUS OF ELASTICITY, PSI

Elastic Range 83,435

At Failure 83,435

POISSON'S RATIO

Elastic Range .0204

At Failure .0444

BULK MODULUS, PSI

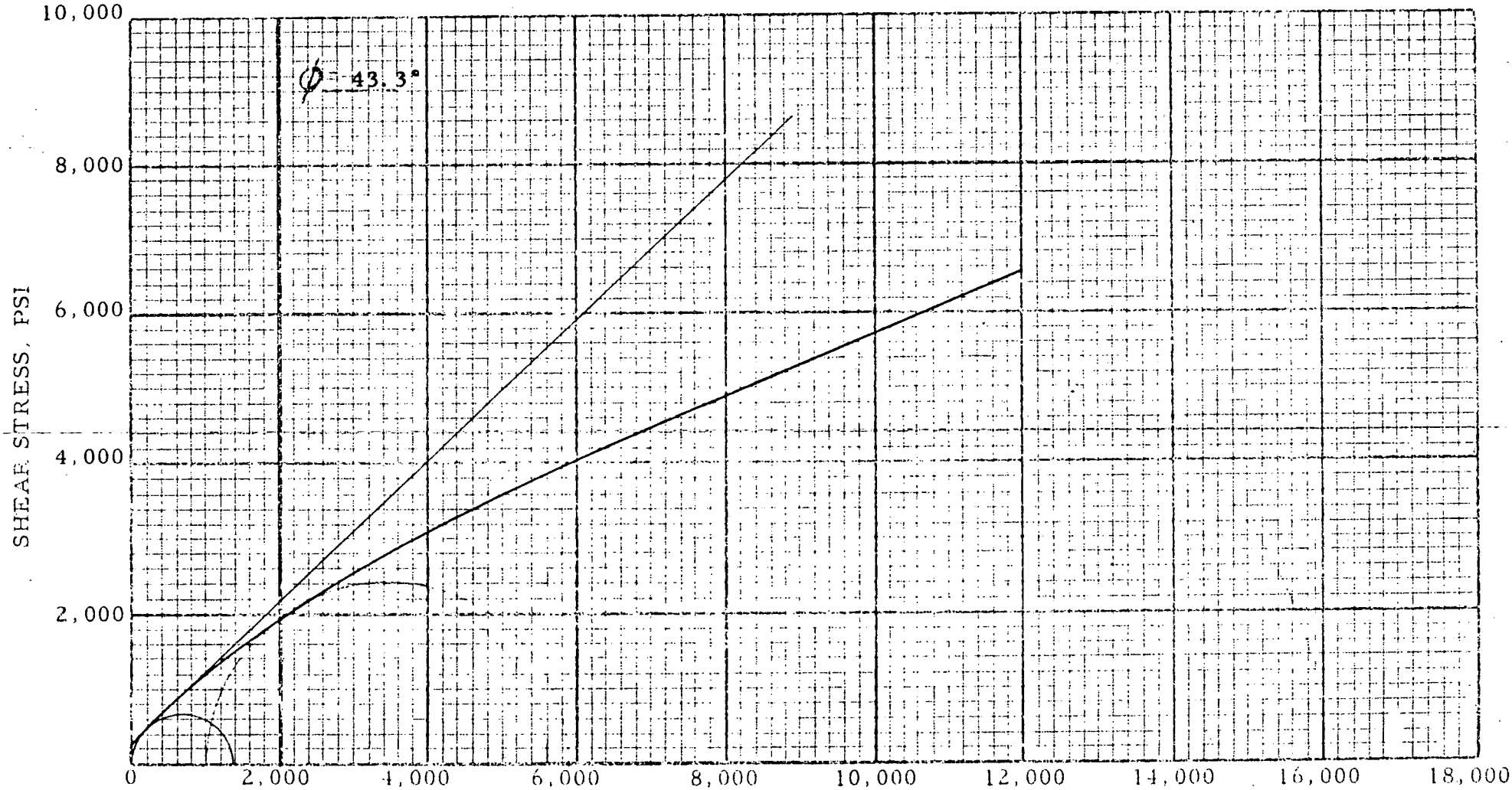
At Failure 88,439

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

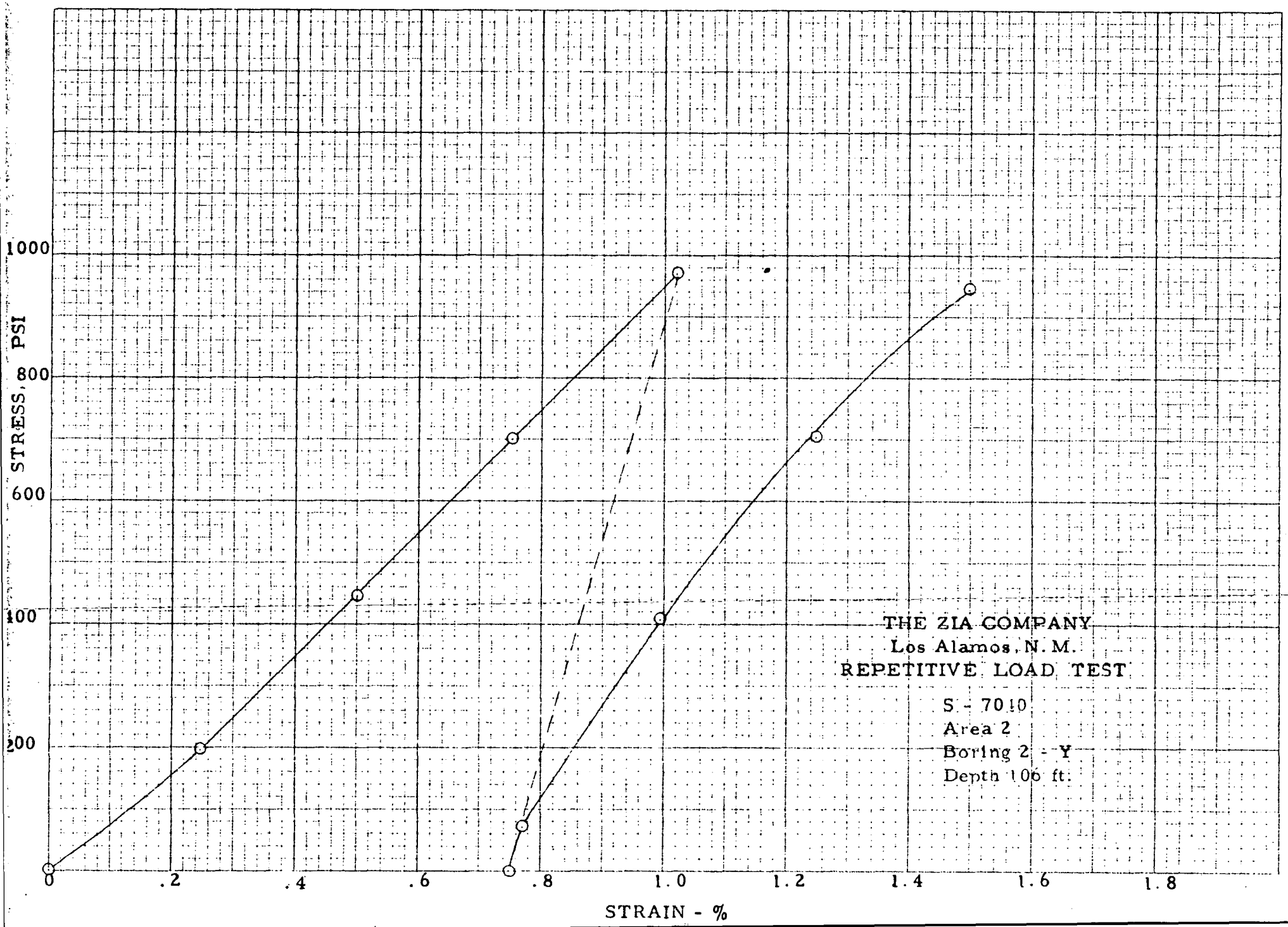
Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 2 - Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
7040	0	1365			114.1	0	1.75	4.03
7039(1)	1,000	4860			117.9	0	1.73	4.03
7039(2)	1,000	4560			118.7	0	1.73	4.00
7038	5,000	11,010			105.1	0	1.88	4.03



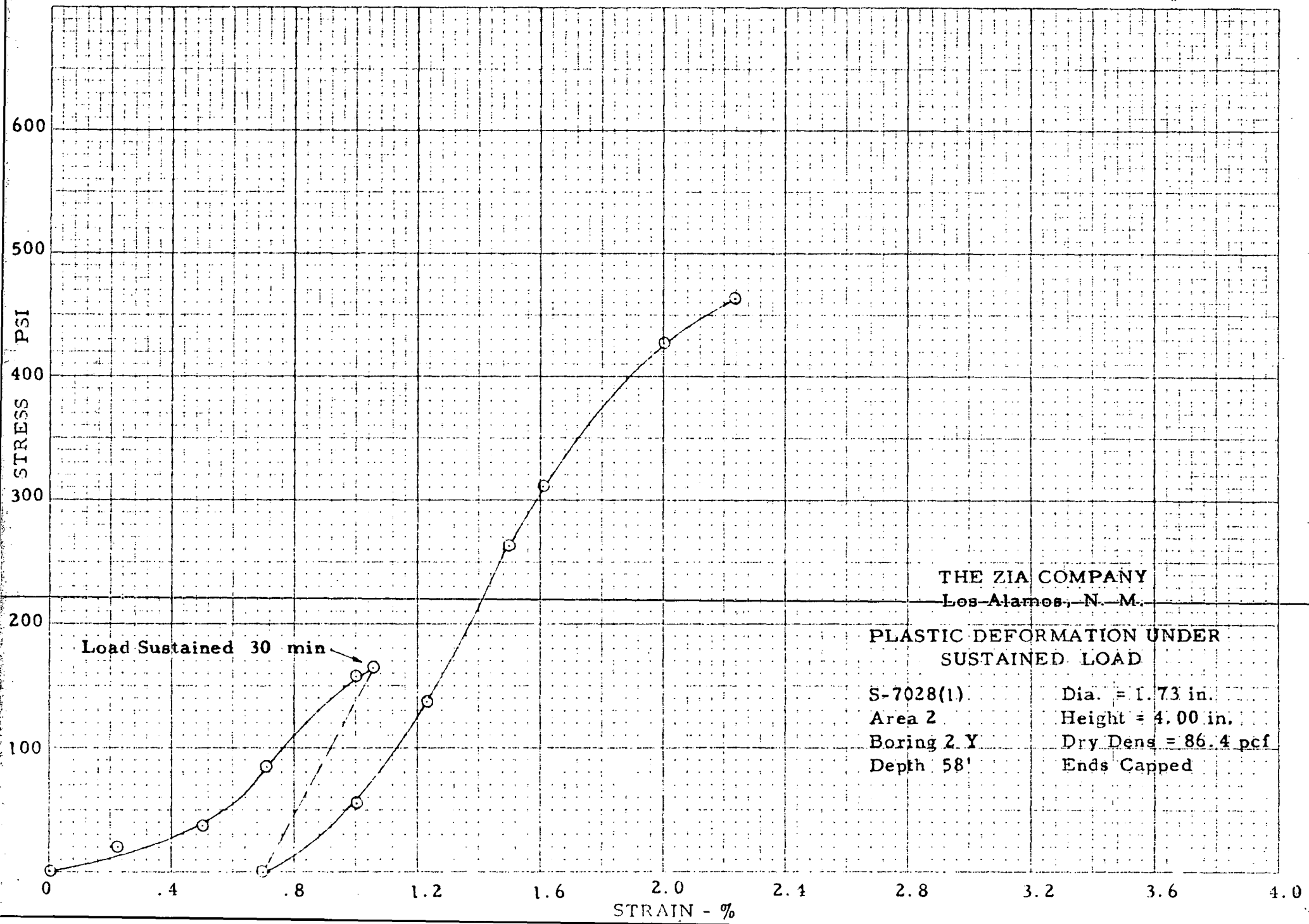
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U.S.A.



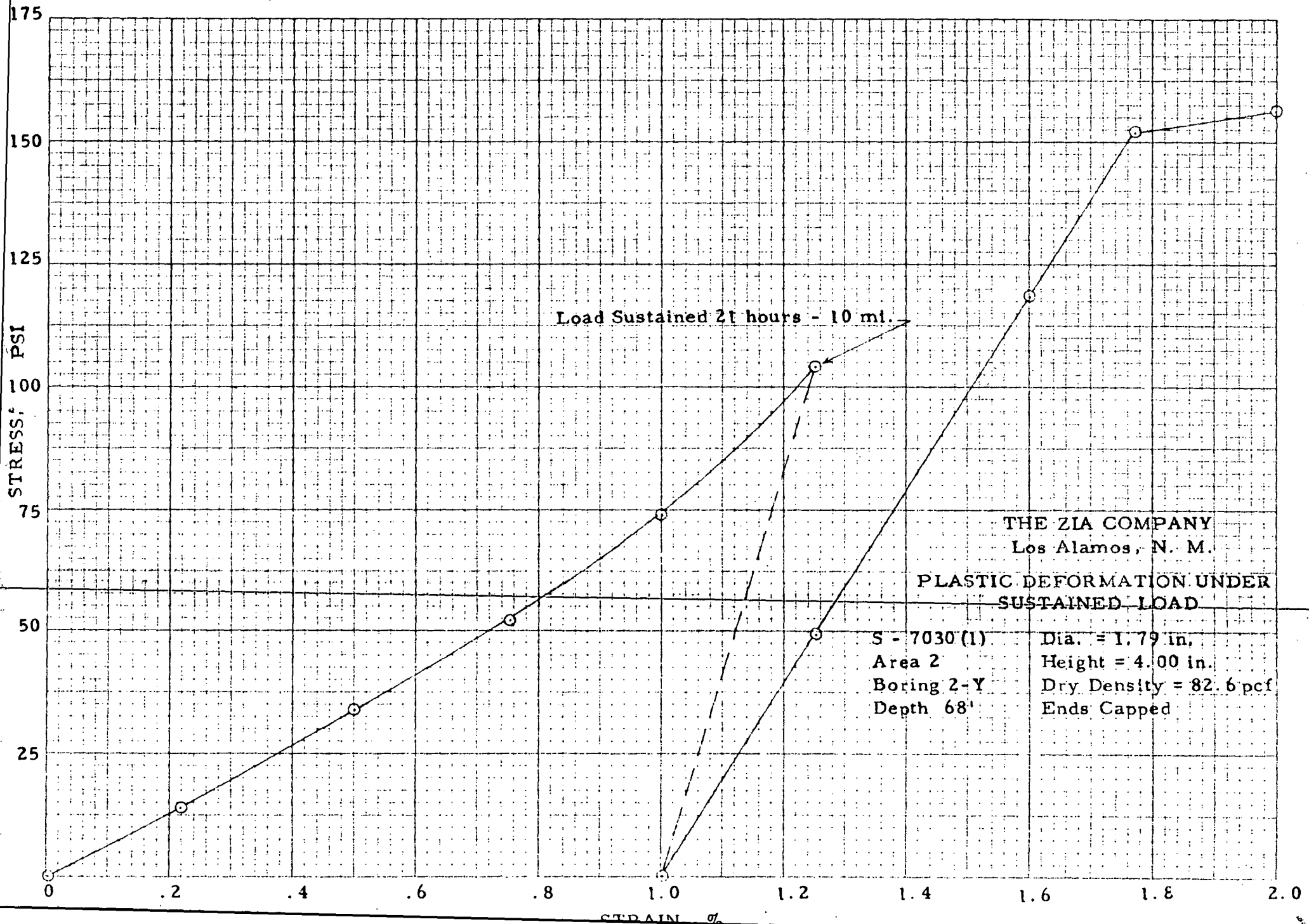
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U.S.A.



NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U.S.A.



NO. 340R-10 DIETZGEN GRAPH PAPER
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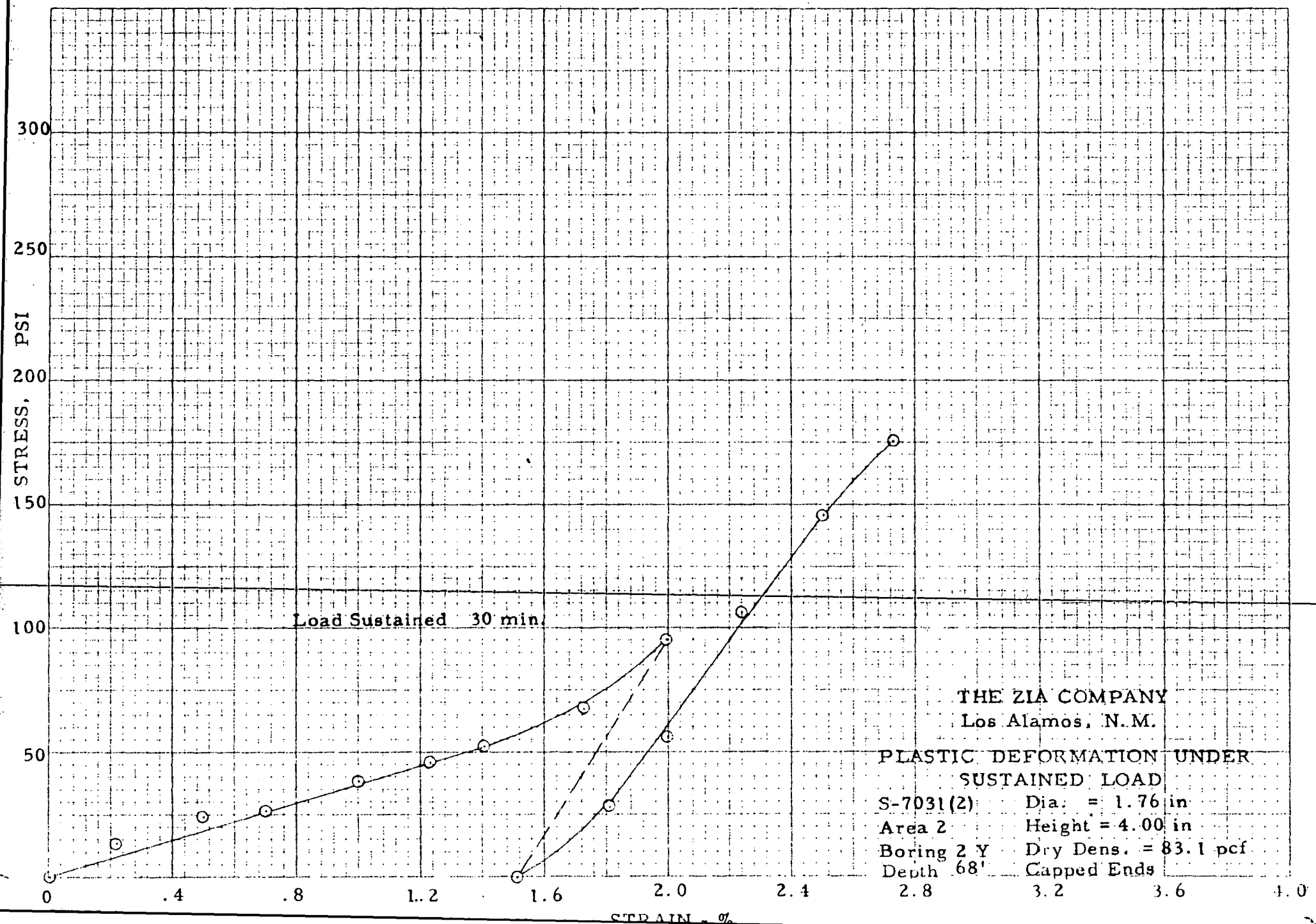
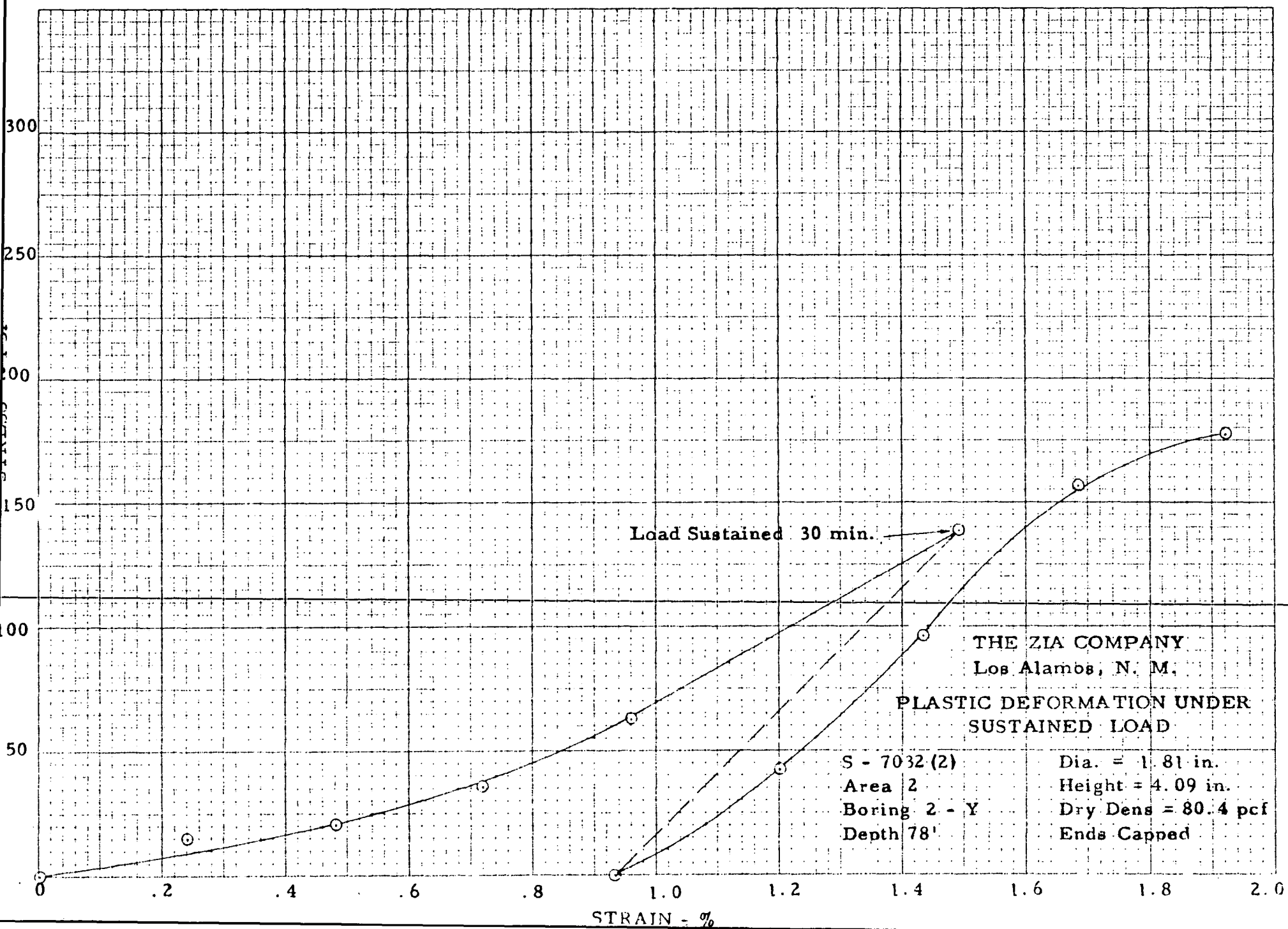
EUGENE DIETZGEN CO.
MADE IN U. S. A.



NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

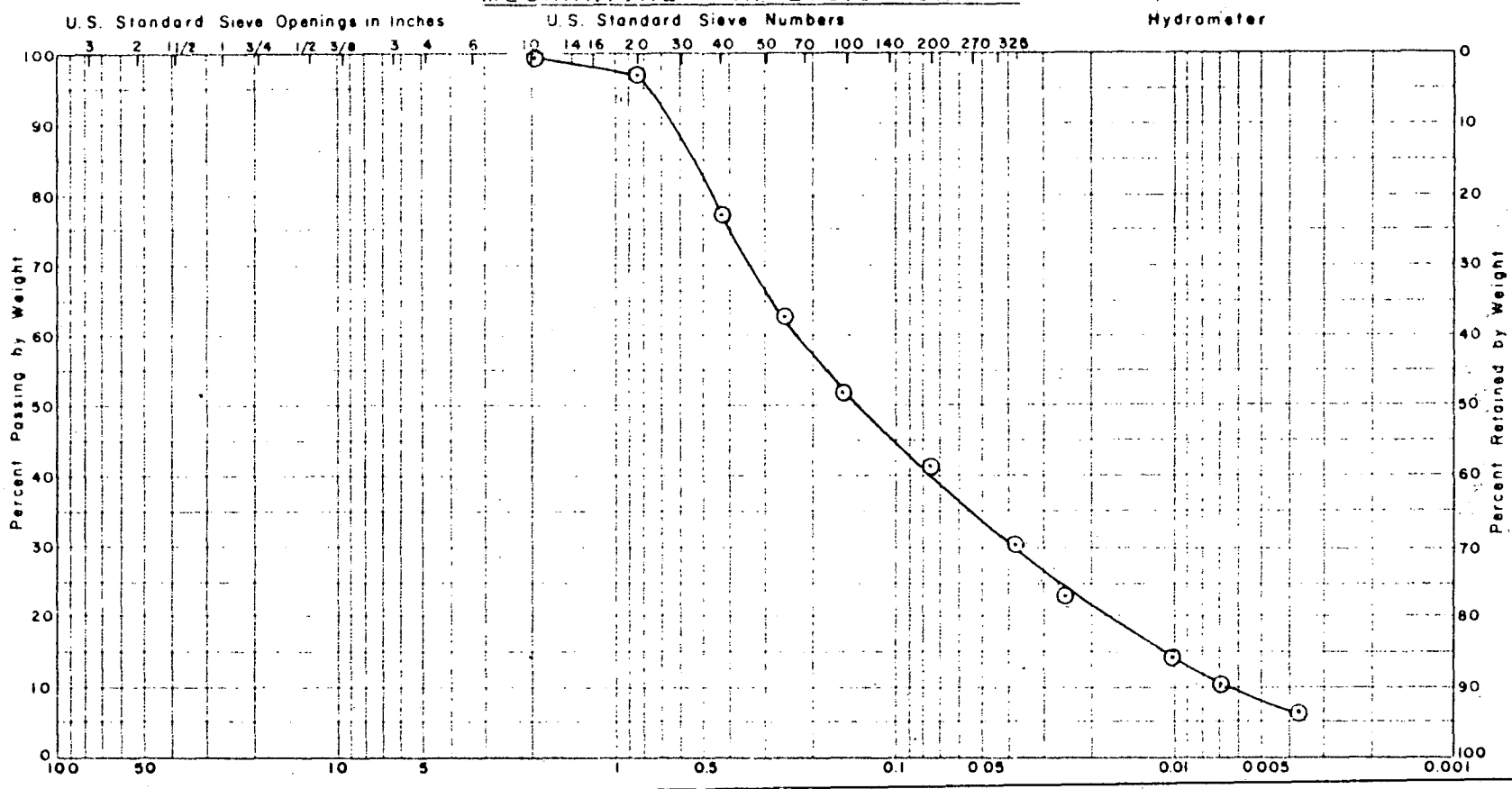


SEMI-QUANTITATIVE SPECTOGRAPHIC ANALYSIS

AREA TWO

Sample No.	6789	6792
Depth	44.5 - 46.0	105 - 110
Element	Approx. %	
Copper	0.0004	0.04
Iron	0.5	0.5
Silicon	36.	37.
Manganese	0.06	0.06
Chromium	Trace	0.002
Aluminum	6.	5.
Magnesium	0.1	0.05
Titanium	0.2	0.09
Calcium	2.	1.
Potassium	0.2	2.
Zirconium	0.01	0.02
Sodium	1.	2.
Barium	Trace	Trace
Strontium	Trace	Trace

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

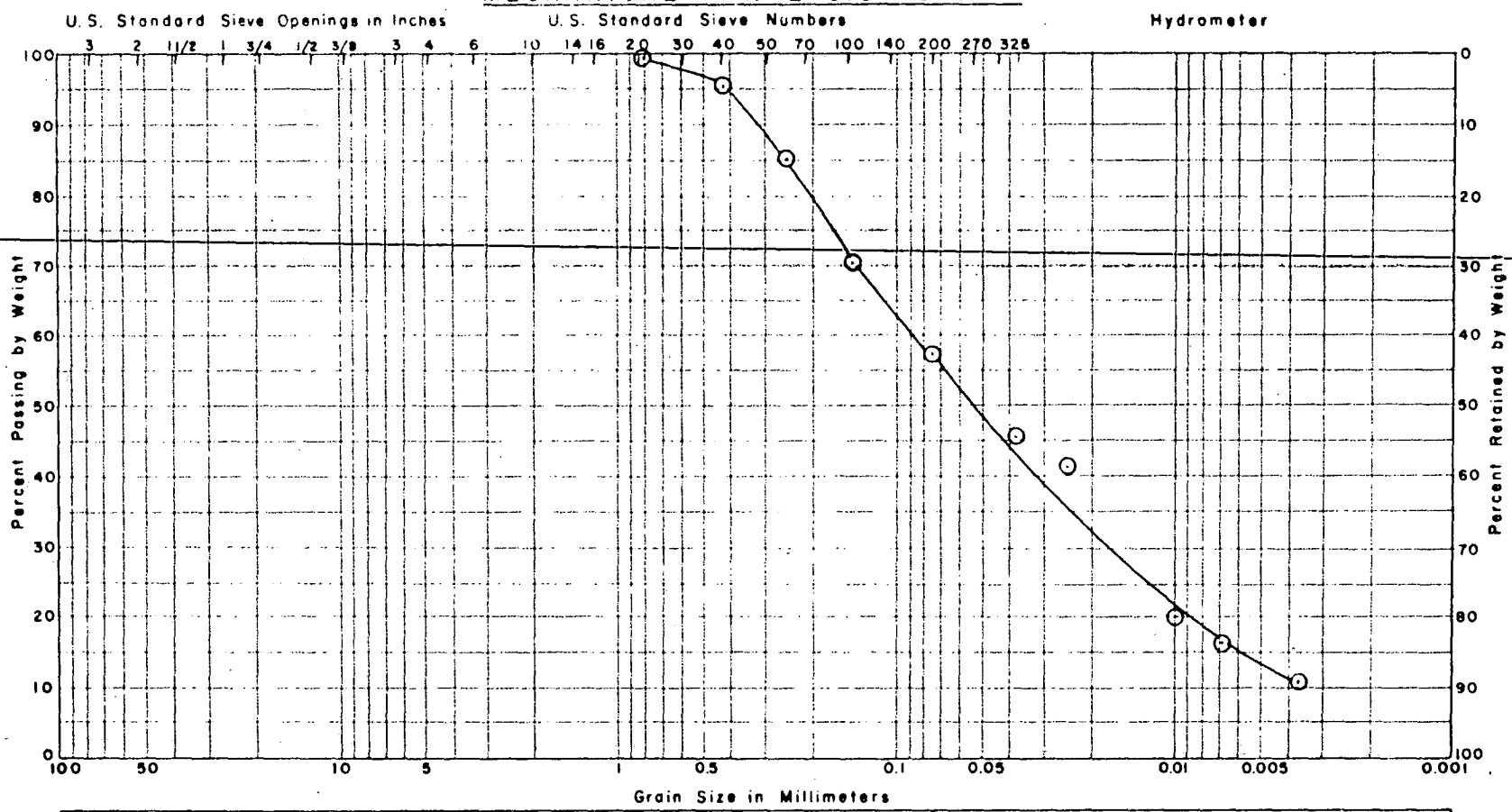
Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Job No. 59-154
Lab No. 6792

Tuff Area E

SOIL MECHANICS INCORPORATED

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Job No. 59-154
Lab No. 6789

Tuff Area 2

SAMPLE NO. 6789 - Area 2

This rock, like Samples Nos. 6786, 6787, and 6788, is a rhyolitic tuff consisting of mineral fragments and a very few rock fragments in a matrix of volcanic glass shards, very fine-grained crystalline material, and structureless volcanic glass. It is very similar to No. 6787.

Its approximate composition is as follows (estimate only, from microscopic examination of thin section):

	%	%	%
Fragments			10
Mineral fragments		10	
Orthoclase	4		
Quartz	4		
Albite	1		
Augite (green, probably sodic)	0.5		
Magnetite	0.5		
Rock fragments (brown, fine grained to glassy lava)	Less than 0.5		
Matrix			90
Fine granular tridymite, feldspar, and glass		70	
Volcanic glass shards, partly devitrified		20	
Alteration		Very slight	

As compared with the other samples above mentioned, this sample contains fewer rock fragments and less augite. The mineral fragments also include a few conspicuous grains of albite. The matrix contains fewer shards and more tridymite and structureless glass. As in Sample 6787, this glass is crowded with microlites, which in this case are very tiny equant grains and resemble dust.

As in the other samples, the properties of the augite and the feldspar suggest a high sodium content for the rock.

Alteration of the rock is practically negligible and has formed only traces of clay minerals and limonite.

SAMPLE NO. 6792 - Area 2

This rock, like Samples Nos. 6786, 6787, 6788, and 6789, is a rhyolitic tuff consisting of mineral and rock fragments in a matrix of volcanic glass shards, very fine-grained crystalline material, and structureless volcanic glass.

Its approximate composition is as follows (estimate only, from) microscopic examination of thin section):

		%	%	%
Fragments				20
Mineral fragments			16	
Orthoclase		10		
Quartz		5		
Albite	Less than	0.5		
Augite (green, probably sodic)	Less than	0.5		
Magnetite	Less than	0.5		
Rock fragments (fine-grained lava and brown glass)			4	
Matrix				80
Fine granular tridymite and feldspar, and glass			65	
Volcanic glass shards, partly devitrified			15	
Alteration			None	

Most of the mineral fragments are orthoclase and quartz, but a little augite, magnetite, and zoned albite are present. The rock fragments consist of fine-grained to vitrophyric lava, apparently of composition similar to that of the rock as a whole. The volcanic glass shards form a somewhat smaller proportion of the matrix than in most of the other samples so far examined. The space between them is filled with a tangled mass of feldspar fragments, tridymite grains, and glass containing myriads of tiny equant microlites or "dust".

The rock shows no appreciable alteration.

AREA THREE

SOIL MECHANICS INCORPORATED

SUMMARY OF LABORATORY TESTS

Lab. No.	Boring	Depth, ft	Confinement psi	Max. Stress psi	Nat. Moist. Content, %	Nat. Density pcf	Dry Density pcf	Testing Moist, %	Wet Density pcf
* 7001	Area 3	60-62	1,000	3,540	1.3	97.4	96.1	5.0	110.2
7002	Area 3	72±	1,000	1,286	2.6		80.1	5.0	
* 7003	Area 3	108±	1,000	3,970	0.2	111.8	111.4	5.0	135.6

* Chemical Analysis, Air Permeability and Mechanical Analysis Data Attached

7001 Specific Gravity - 2.520

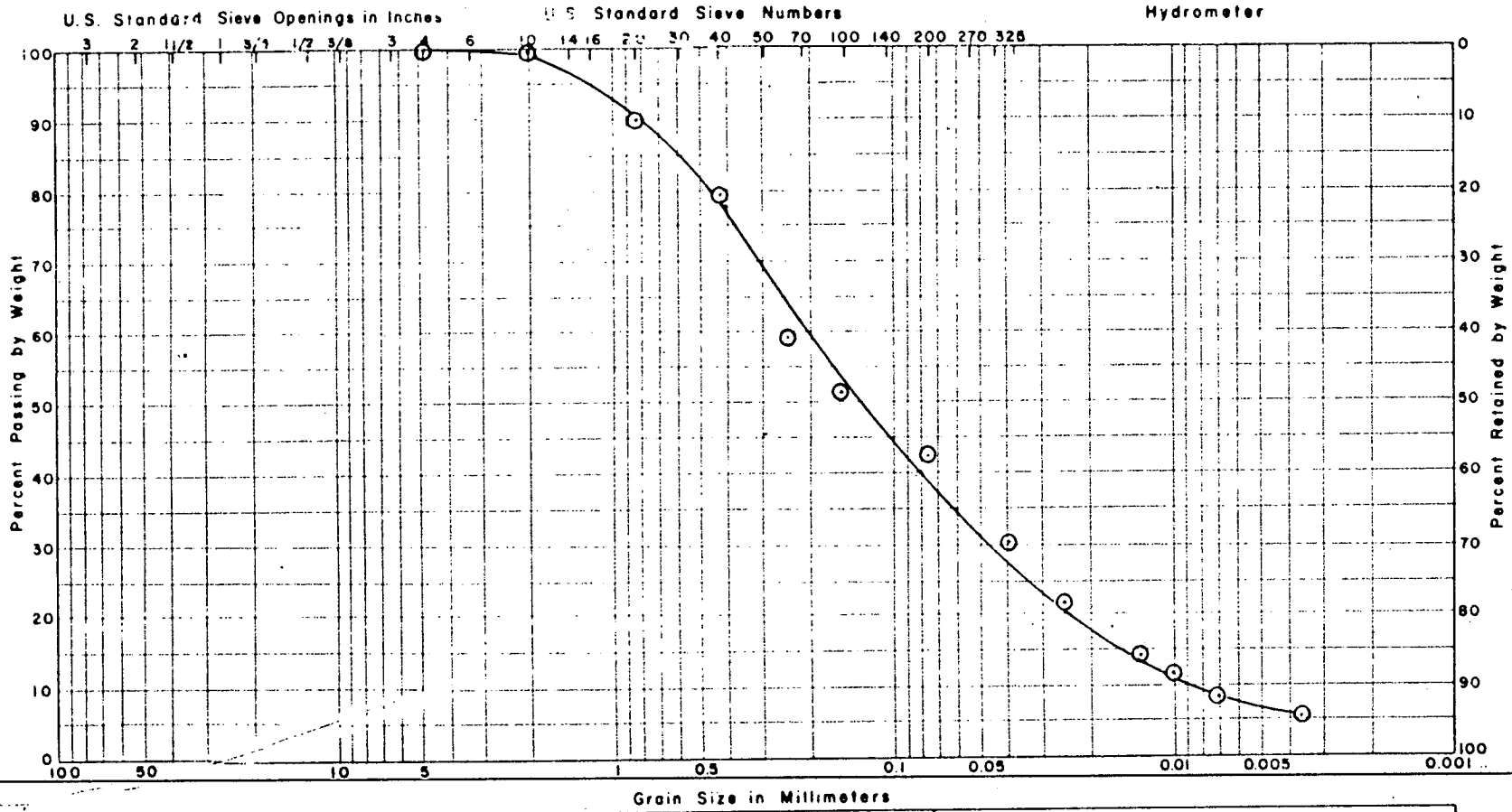
7003 Specific Gravity - 2.550

SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSIS

AREA THREE

Sample No.	7001	7003
Depth	60 - 62	108±
Element	Approx. %	
Copper	0.003	0.003
Iron	1.	0.6
Manganese	0.08	0.05
Nickel	Trace	Trace
Chromium	0.002	0.001
Aluminum	7.	5.
Magnesium	0.1	0.06
Calcium	3.	1.
Titanium	0.1	0.07
Sodium	2.	1.
Barium	Trace	Trace
Potassium	2.	2.
Strontium	Trace	Trace
Zirconium	0.01	0.01
Silicon	33.	37.

MECHANICAL ANALYSIS CHART



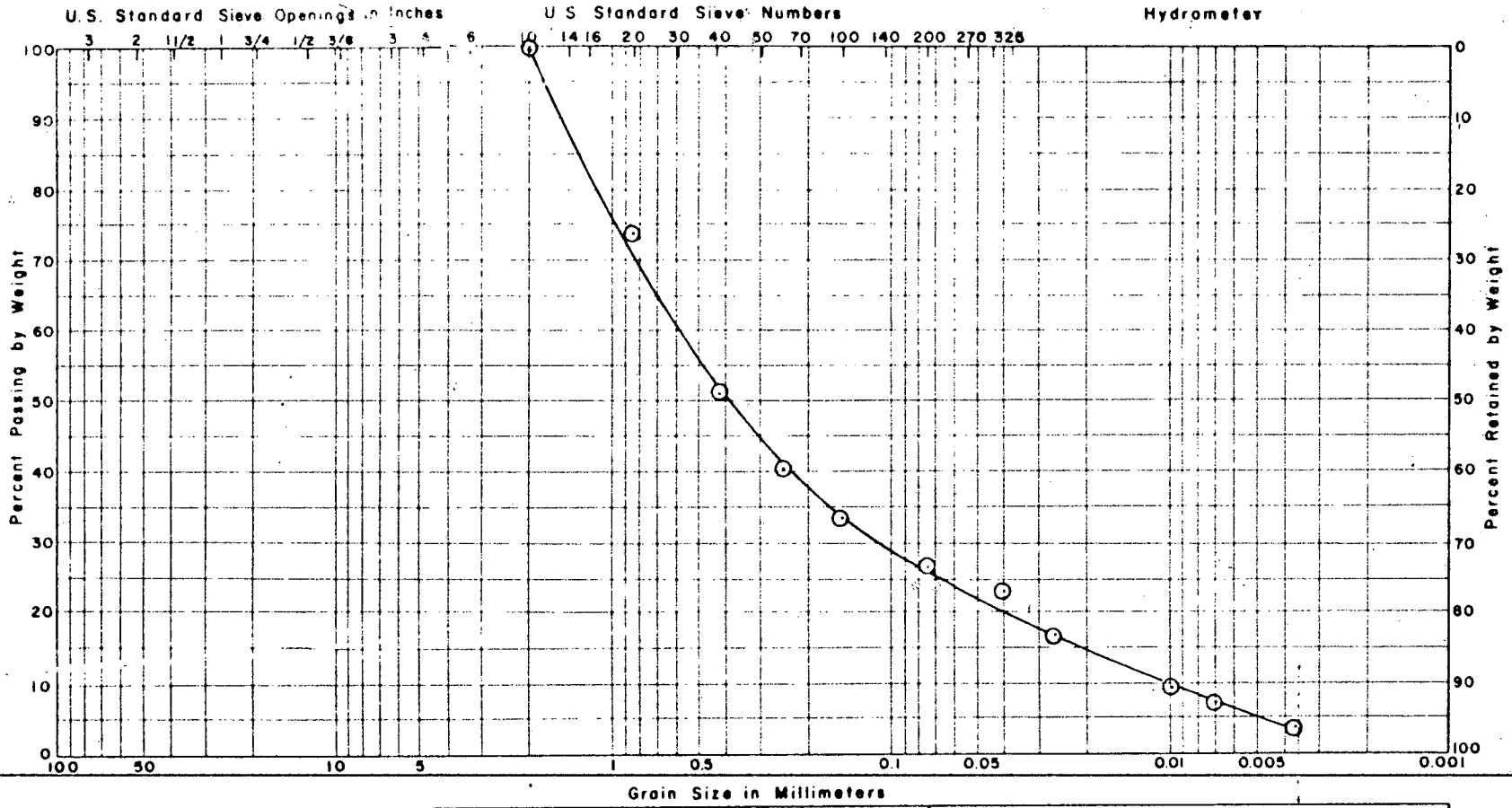
GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, New Mexico

Sample No. 7001
Area 3 60 - 62'

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, New Mexico

Sample No. 7003
Area 3 108±

SAMPLE NO. 7001 - AREA 3 - DEPTH 60' - 62'

This rock, like the other cores previously examined, is a rhyolitic tuff. It consists of mineral and rock fragments in a matrix of volcanic glass shards, very fine-grained crystalline material, glass, and dust.

Its approximate composition is as follows (estimate only, from microscopic examination of thin sections):

	%	%	%
Fragments			10
Mineral fragments		9	
Orthoclase	3		
Quartz	4.5		
Albite	0.5		
Augite	0.5		
Magnetite	0.5		
Rock fragments (fine-grained crystalline lava and glass)		1	
Matrix			90
Fine granular tridymite and feldspar		20	
Glass and dust		40	
Volcanic glass shards, largely devitrified		30	

Alteration products: Traces of clay minerals and of limonite. Small amounts of amphibole and chlorite from alteration of the augite.

The augite in this core is not so green as in the samples previously examined, and many of the augite grains are partly altered, some to what appears to be an aggregate of amphibole rods and others to chlorite. Some of the magnetite is clustered around the augite grains and may also be a product of their alteration.

Most of the shards are partly to completely collapsed bubbled, which show a rough alignment perpendicular to the axis of the core (therefore presumably in horizontal laminae). All are somewhat devitrified, and are lined with an aggregate of tiny needle-like grains of very low birefringence, which may possibly be zeolites.

Tridymite occurs in the matrix as tiny hexagonal plates and irregular grains, together with a few small fragments of felspar. The remainder of the matrix consists of a "dust" of myriads of tiny grains of barely detectable birefringence, which are probably partly devitrified glass.

SAMPLE NO. 7003 - AREA 3 - DEPTH 108

This rock is a rhyolitic tuff similar to Sample No. 7001. It consists of mineral and rock fragments in a matrix of volcanic glass shards, very fine-grained crystalline material, and minute grains of glass which may be called "dust".

Its approximate composition is as follows (estimate only, from microscopic examination of thin sections):

	%	%	%
Fragments			20
Mineral fragments		12	
Orthoclase	7		
Quartz	4		
Albite	Less than 0.5		
Augite	Less than 0.5		
Magnetite	Less than 0.5		
Rock fragments (fine-grained lava)		8	
Matrix			80
Fine granular tridymite, and some feldspar		30	
Glass and just		20	
Volcanic glass shards, mostly devitrified		30	

Alteration: Some of the magnetite appears to be derived from the augite; otherwise there is practically no alteration of the rock.

The augite in this core is greener than that in Sample No. 7001, and some of the feldspar fragments have a smaller optic angle than that expected for orthoclase. These facts suggest a somewhat higher sodium content for the rock.

Many of the augite grains are bordered by a thin zone of magnetite, but otherwise they show little alteration.

Most of the shards consist of partly to completely collapsed unbroken bubbles, rather than broken fragments, and lie in rough alignment perpendicular to the axis of the core. Nearly all are devitrified to an aggregate of parallel, needle-like grains of very low birefringence, which may possibly be zeolites.

Tridymite occurs as very small irregular grains within these distorted bubbles, and also in clusters of still smaller grains in the matrix outside of them.

The remainder of the matrix consists of a "dust" of myriads of tiny isotropic grains, apparently of volcanic glass.

SUMMARY OF AIR PERMEABILITY TESTS

AREA THREE

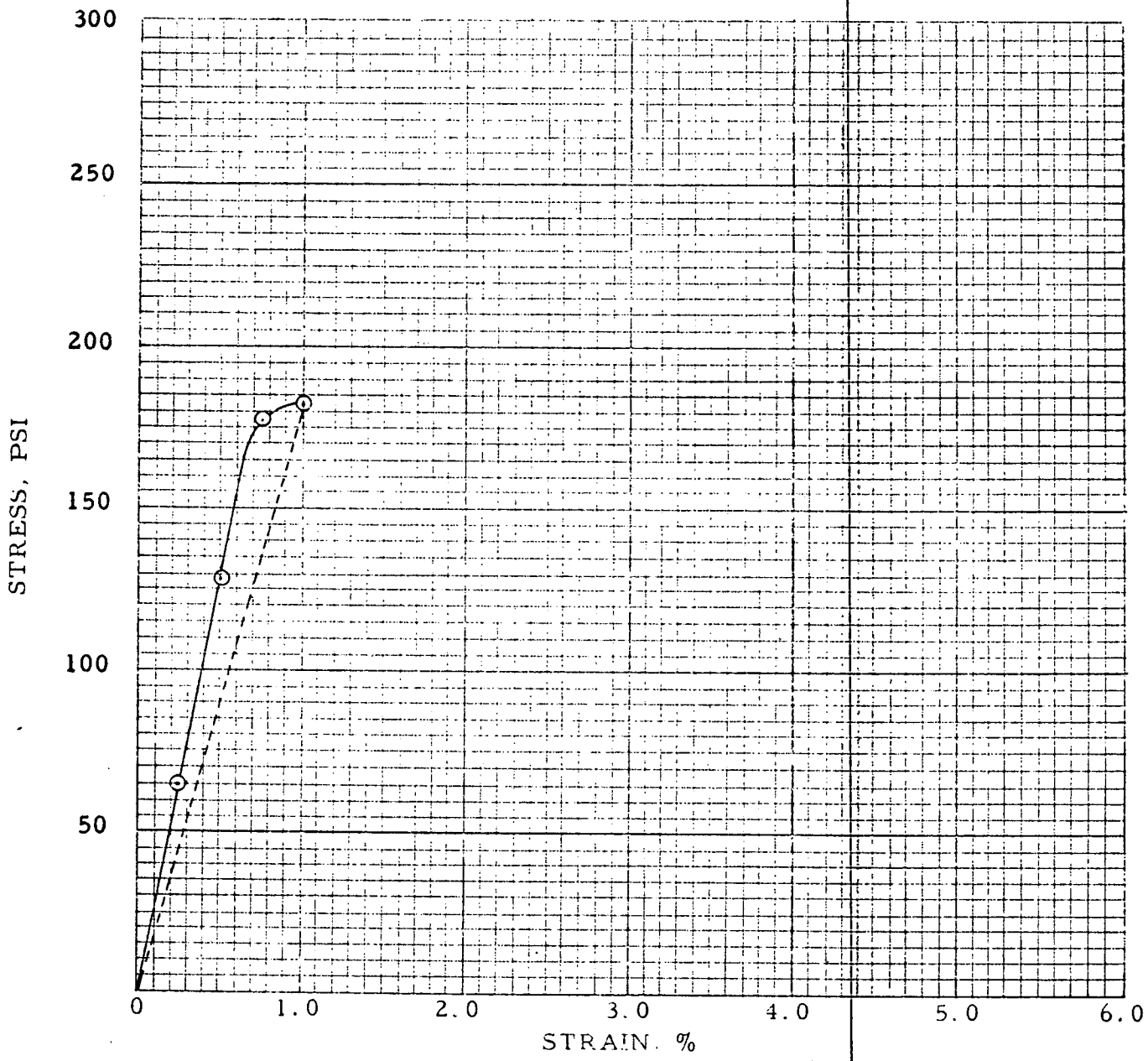
Sample No.	Depth	Vertical Permeability to Air, Millidarcys
7001	60 - 62	79
7003	108±	27

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project. THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 7012 Boring 3 - A Depth, ft. 87



MODULUS OF ELASTICITY, PSI

Elastic Range 25,800

At Failure 18,200

POISSON'S RATIO

Elastic Range .740

At Failure .555

BULK MODULUS, PSI

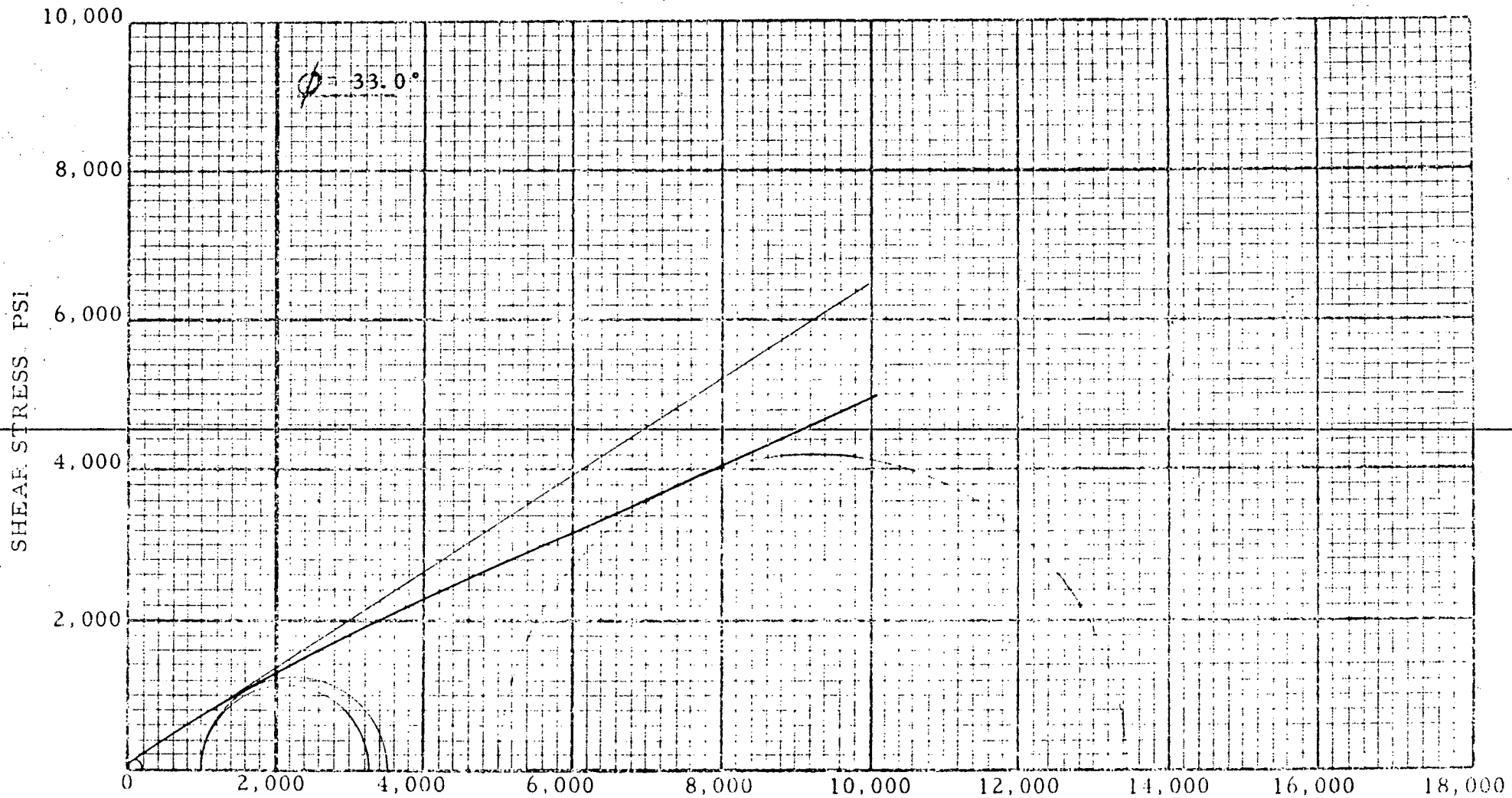
At Failure 67,988

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

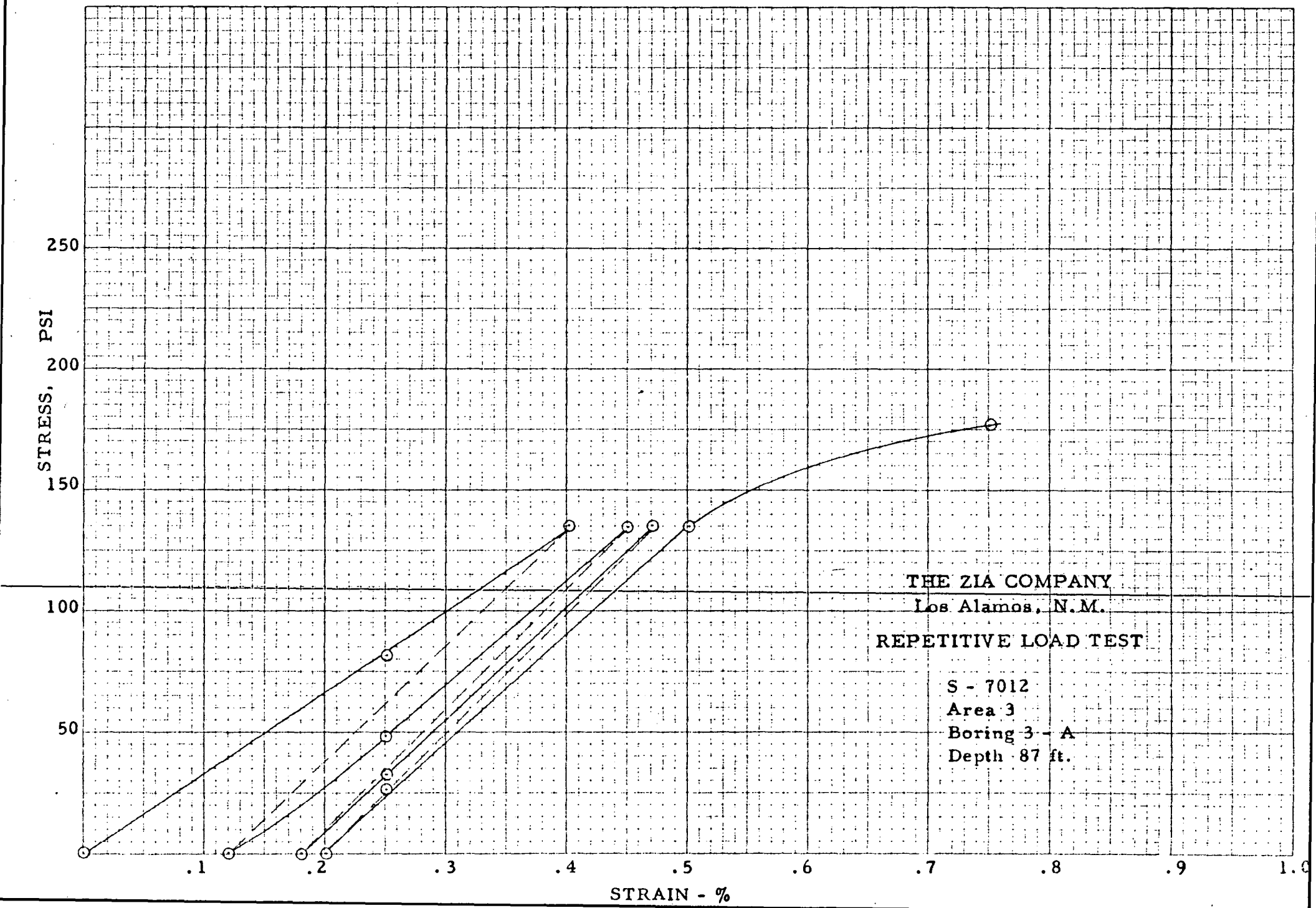
Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 3 - A Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
7012	0	182			85.9	0	1.72	4.00
7007 (1)	1,000	2250			81.8	0	1.81	4.00
7007 (2)	1,000	2540			84.1	0	1.78	4.01
7010	5,000	8420			82.8	0	1.74	4.00



NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U.S.A.



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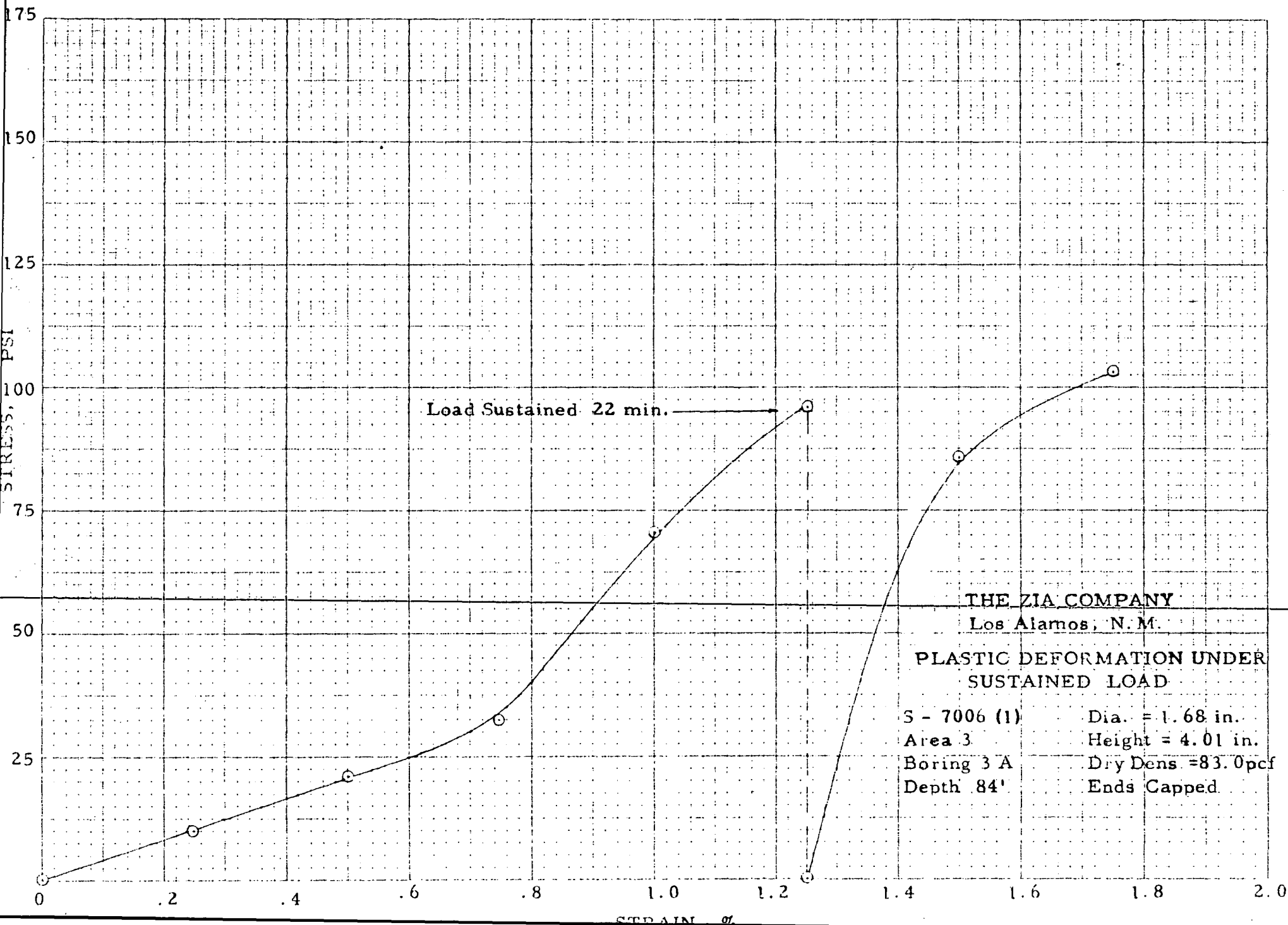
MADE IN U.S.A.



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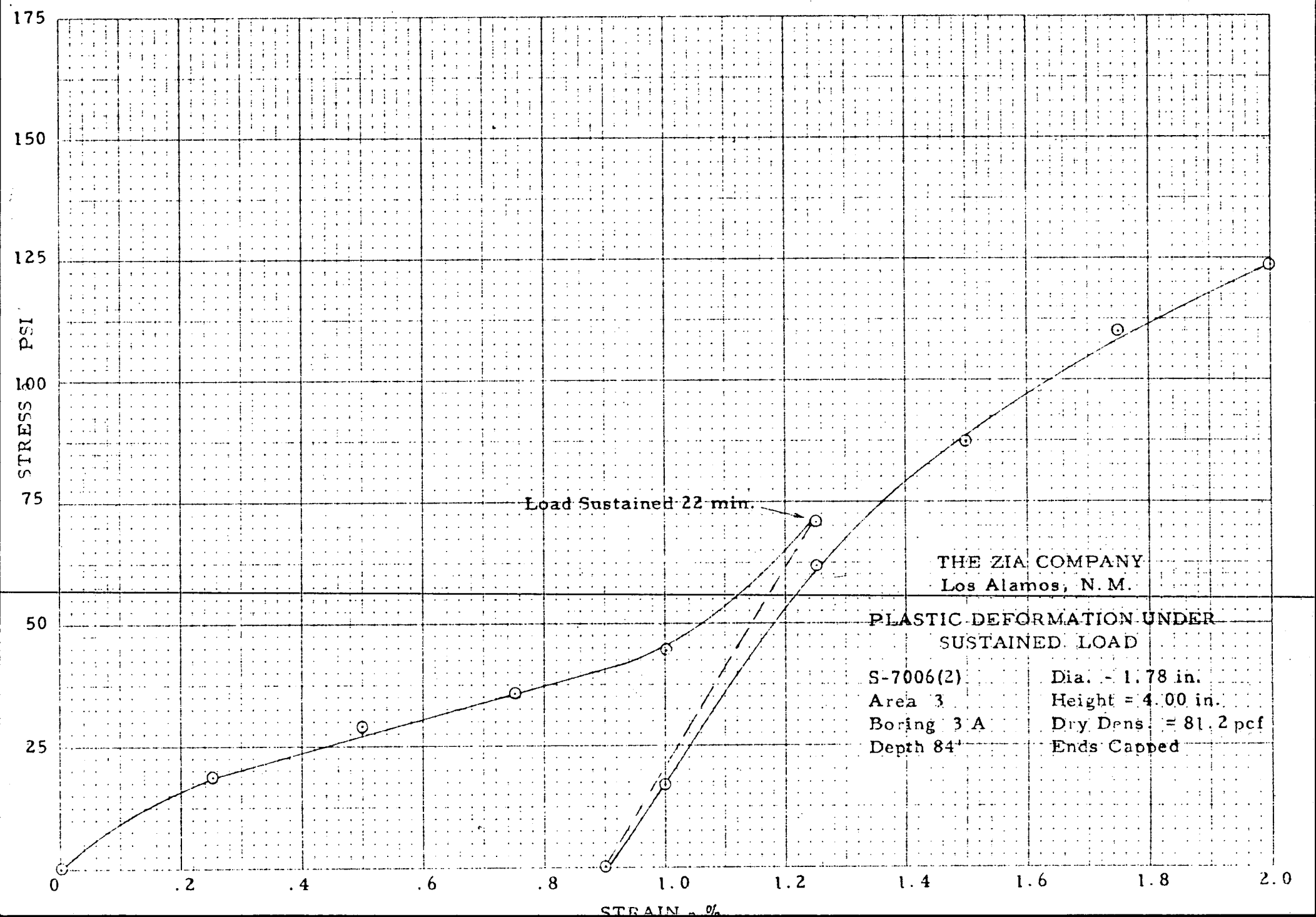
10 x 10 PER INCH
EUGENE DIETZGEN CO.



NO. 340R-10 DIETZGEN GRAPH PAPER
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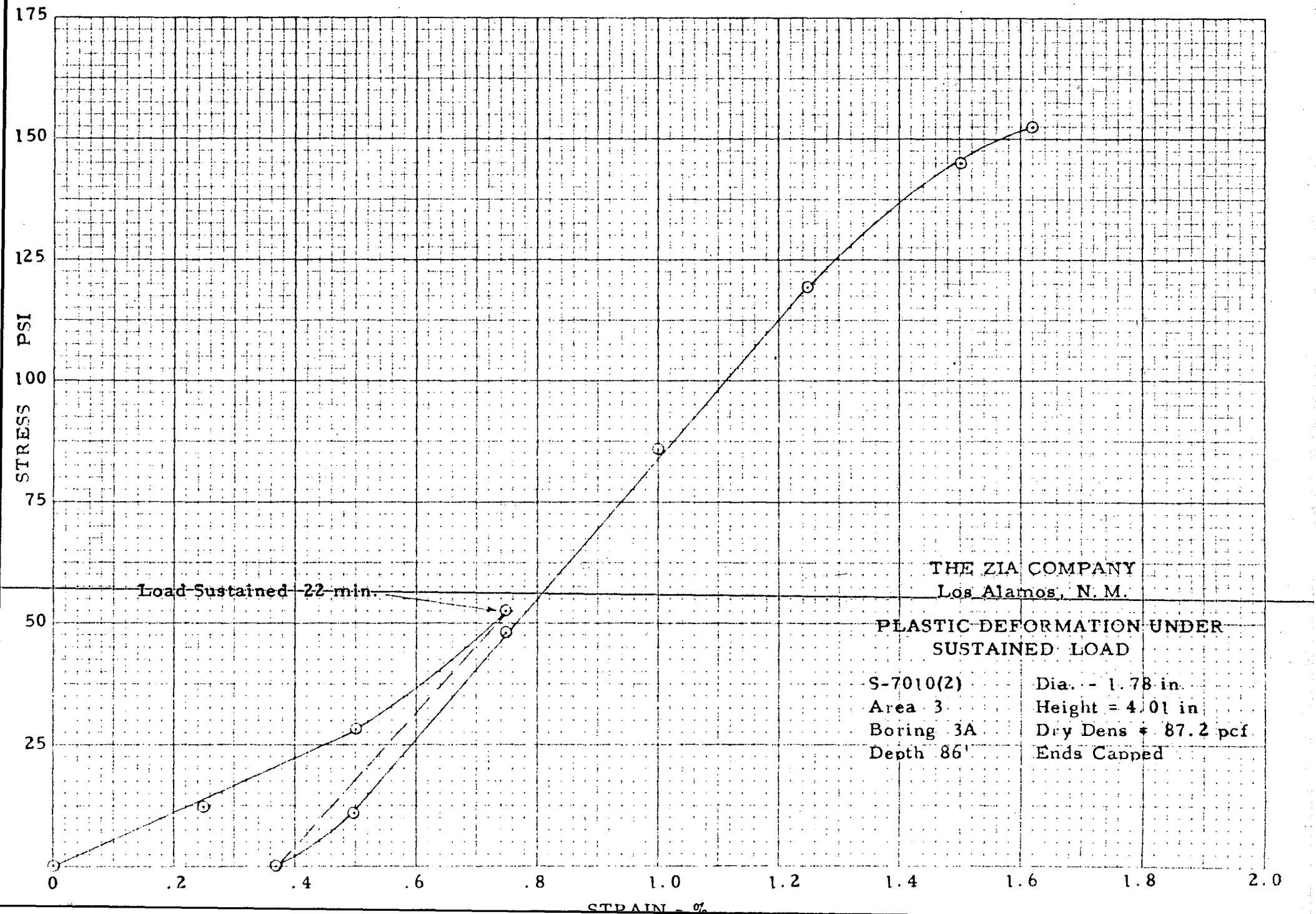
MADE IN U.S.A.

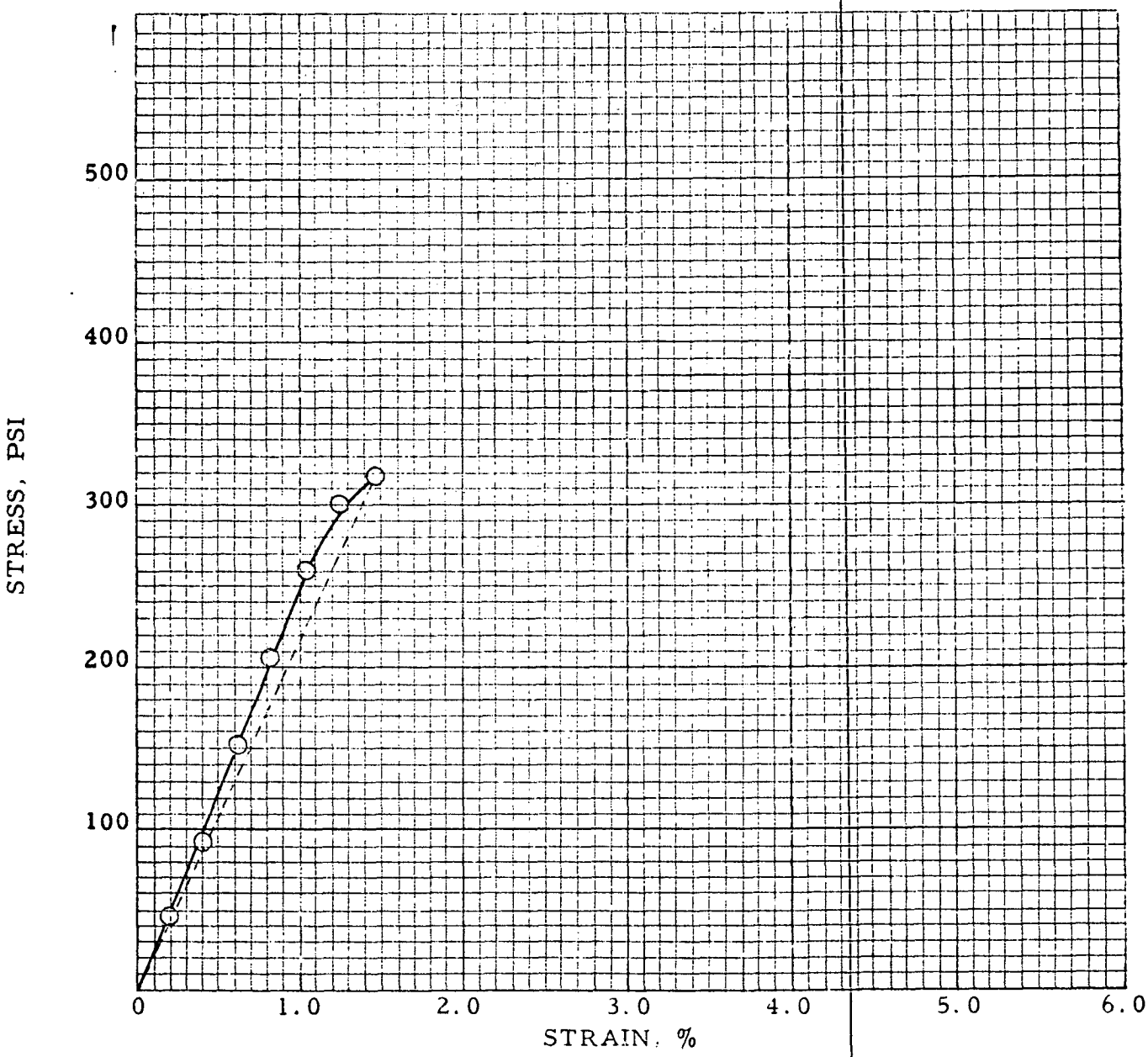


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6995 Boring 3 - C Depth, ft. 87' E



MODULUS OF ELASTICITY, PSI

Elastic Range 25,048

At Failure 21,565

POISSON'S RATIO

Elastic Range .052

At Failure .074

BULK MODULUS, PSI

At Failure 23,092

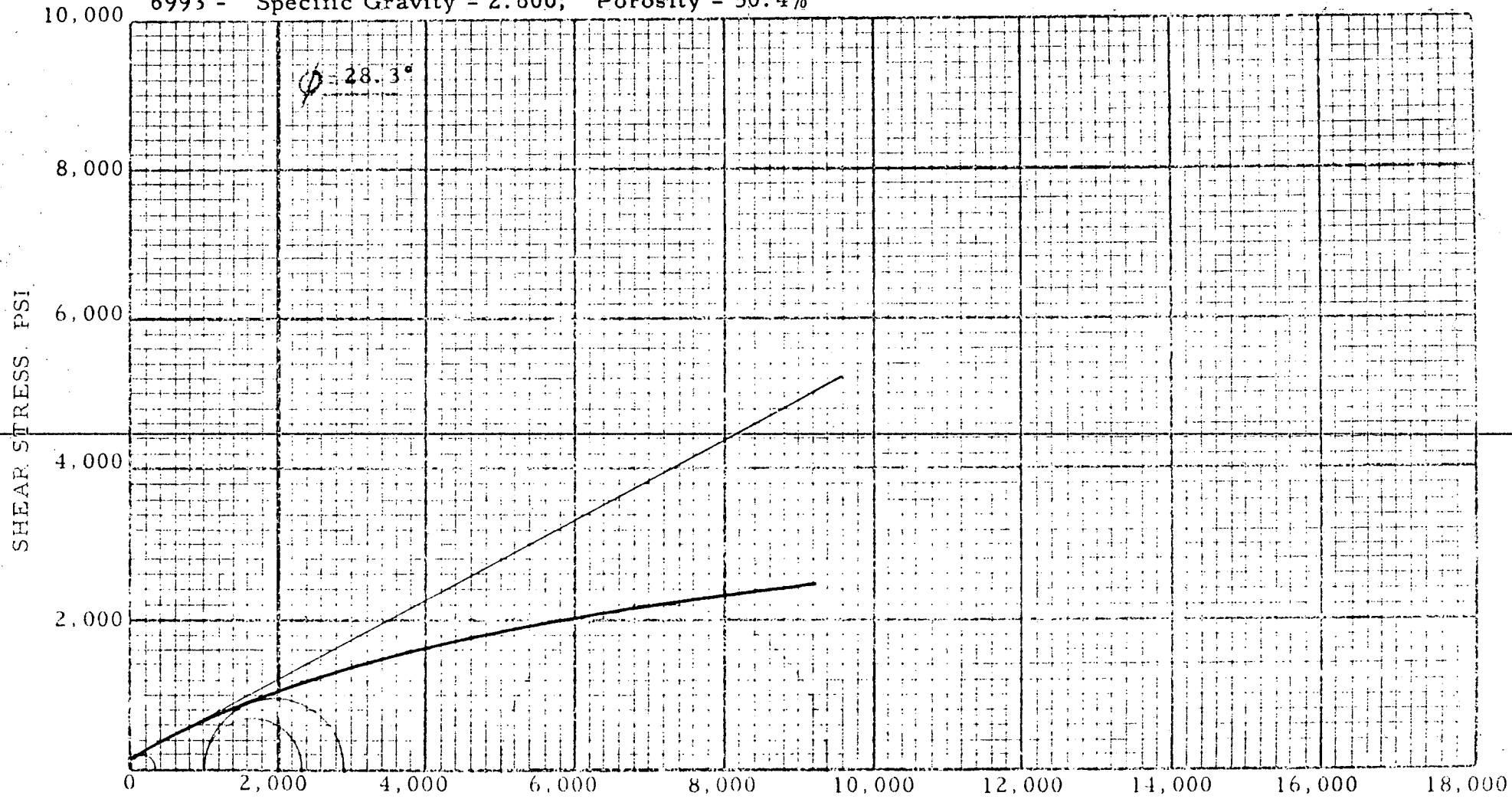
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 3 - C Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6995	0	317				Dry	1.188	4.75
6993 (1)	1,000	1945		0.1	80.5	"	1.75	4.00
6993 (2)	1,000	1350		0.1	80.4	"	1.75	3.375
6991	5,000	4400		0.1	75.5	"	1.69	4.03

6993 - Specific Gravity = 2.600; Porosity = 50.4%

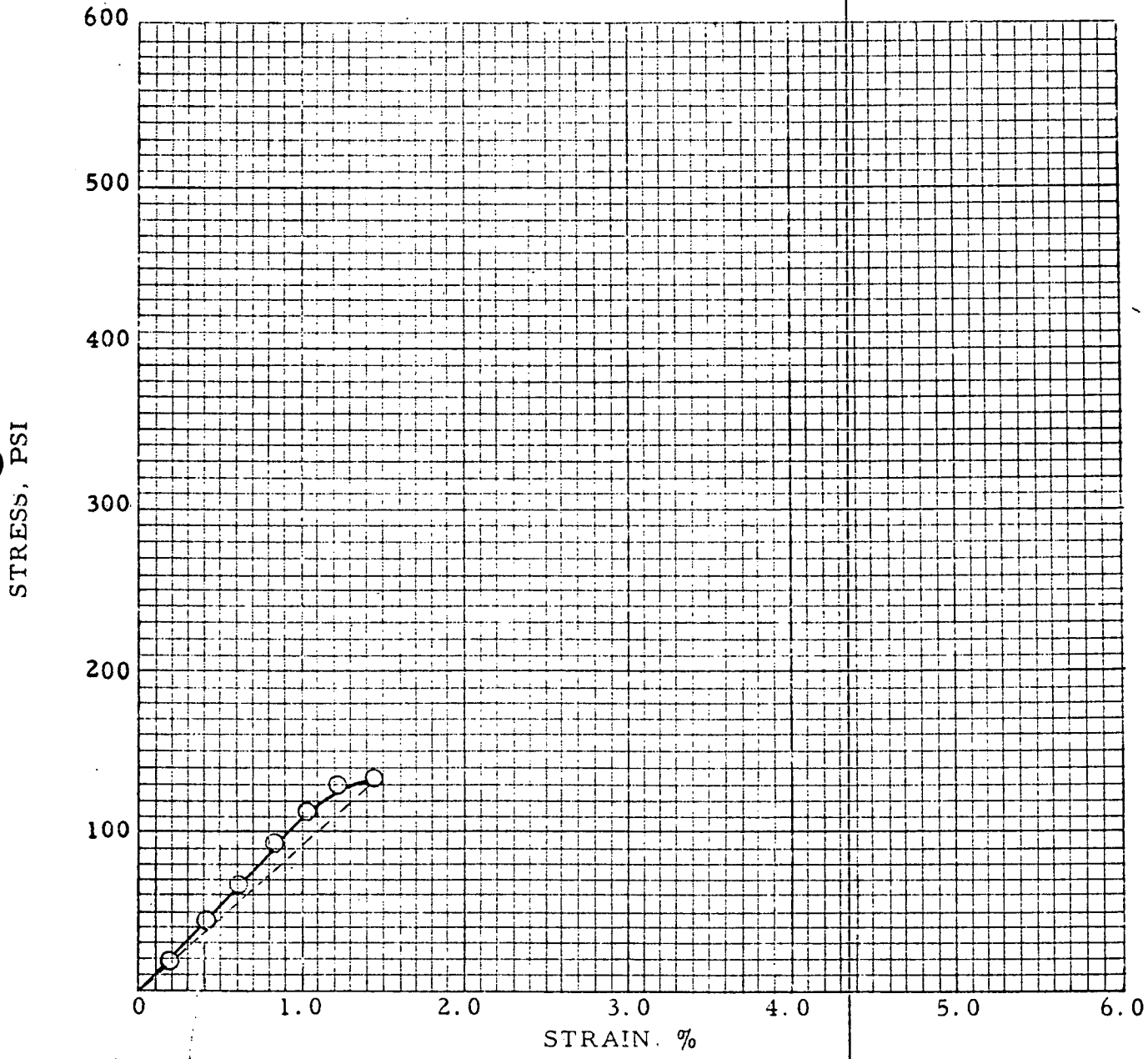


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6996 Boring 3-C Depth, ft. 86' E



MODULUS OF ELASTICITY, PSI

Elastic Range 10,857

At Failure 9,048

POISSON'S RATIO

Elastic Range .034

At Failure .034

BULK MODULUS, PSI

At Failure 9,702

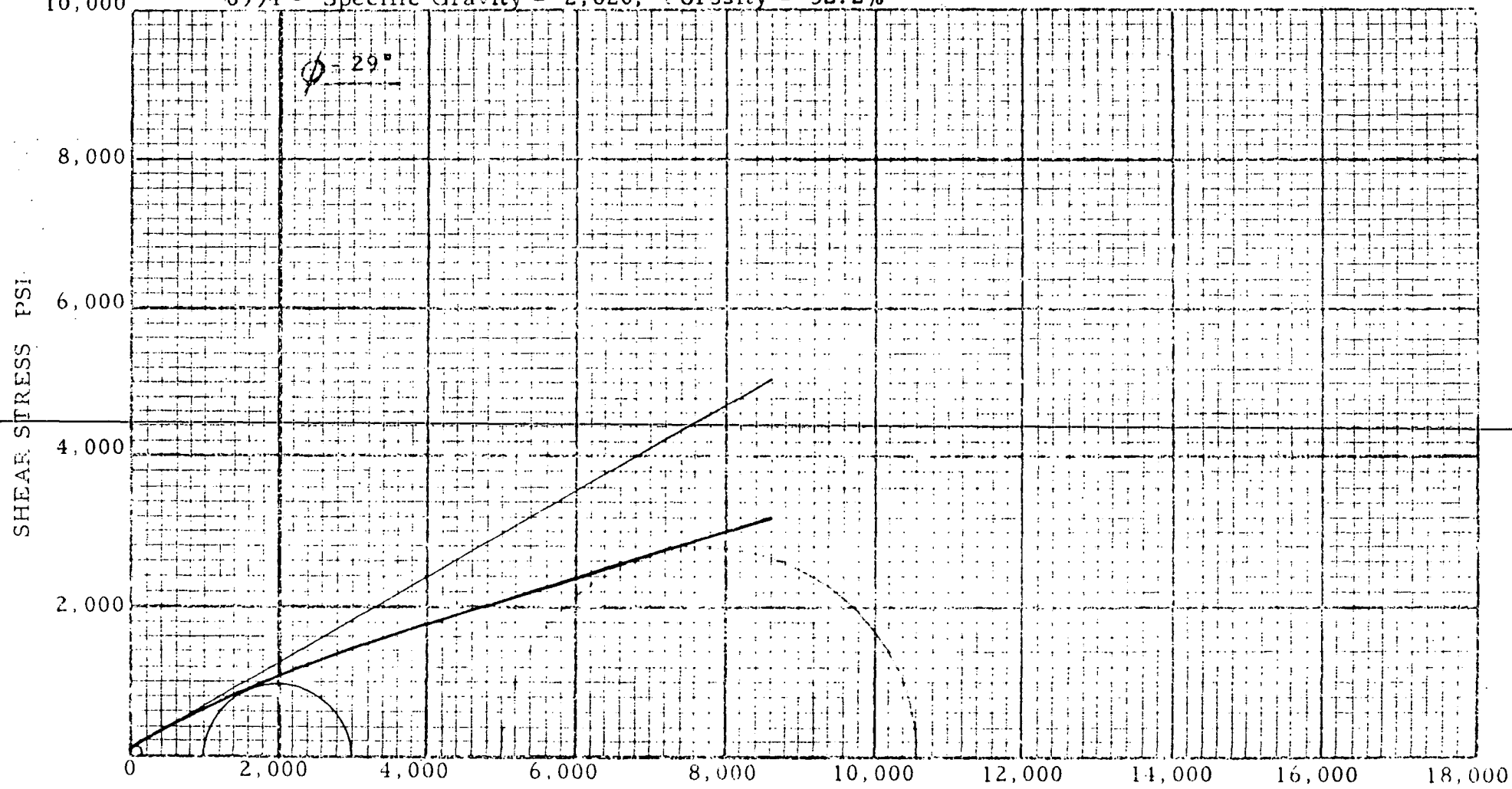
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N. M. Boring: 3 - C Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6996	0	133				5.0	1.81	4.81
6994 (1)	1,000	2040	0.1	78.1		5.0	1.75	4.00
6994 (2)	1,000	2000				5.0	1.75	4.75
6992	5,000	5,670	0.1	78.3		5.0	1.75	2.38

6994 - Specific Gravity = 2,620; Porosity = 52.2%

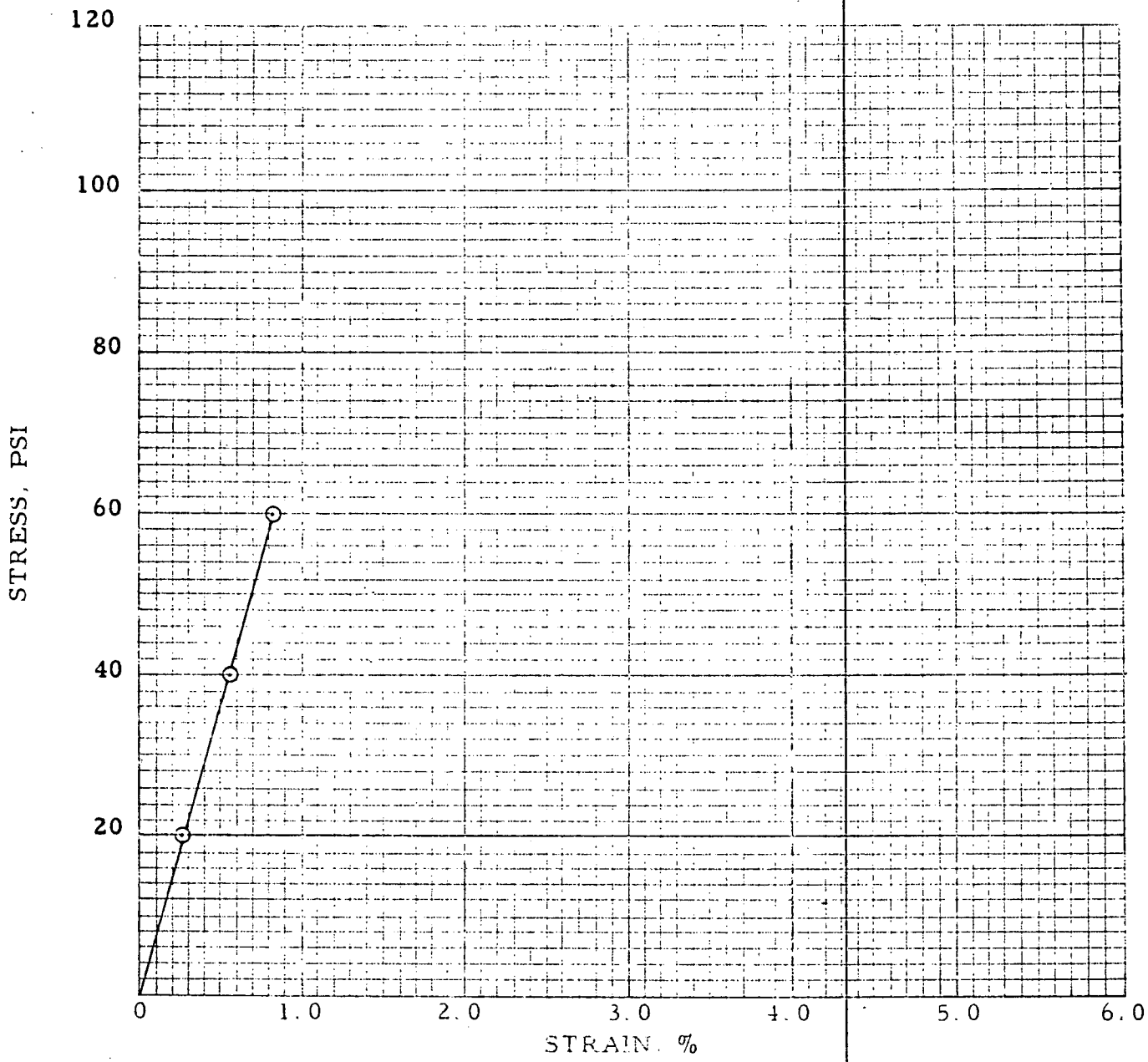


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 7022 Boring 3 - Y Depth, ft. 84



MODULUS OF ELASTICITY, PSI

Elastic Range 7,317

At Failure 7,317

POISSON'S RATIO

Elastic Range .563

At Failure .720

BULK MODULUS, PSI

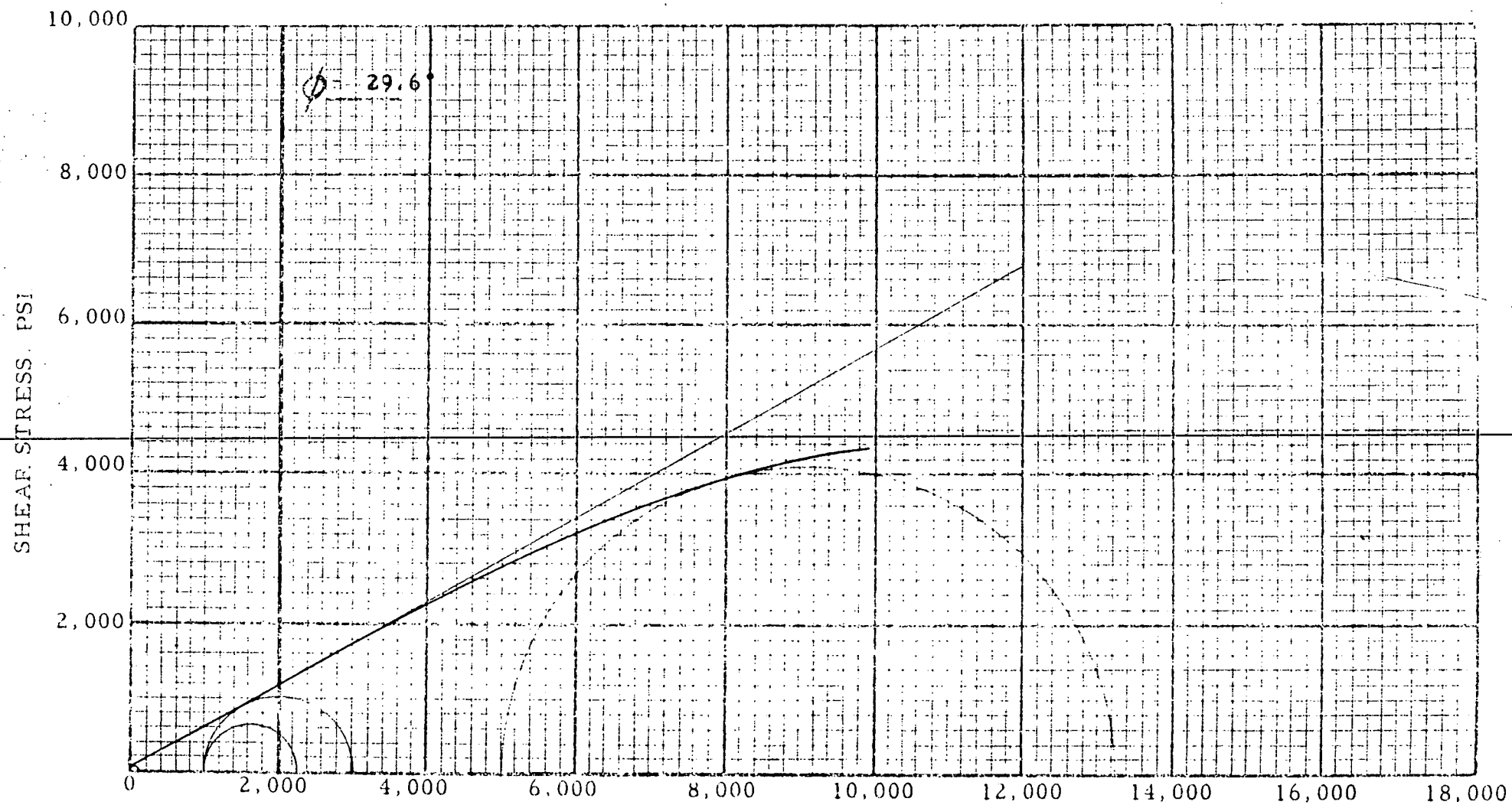
At Failure 17,135

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

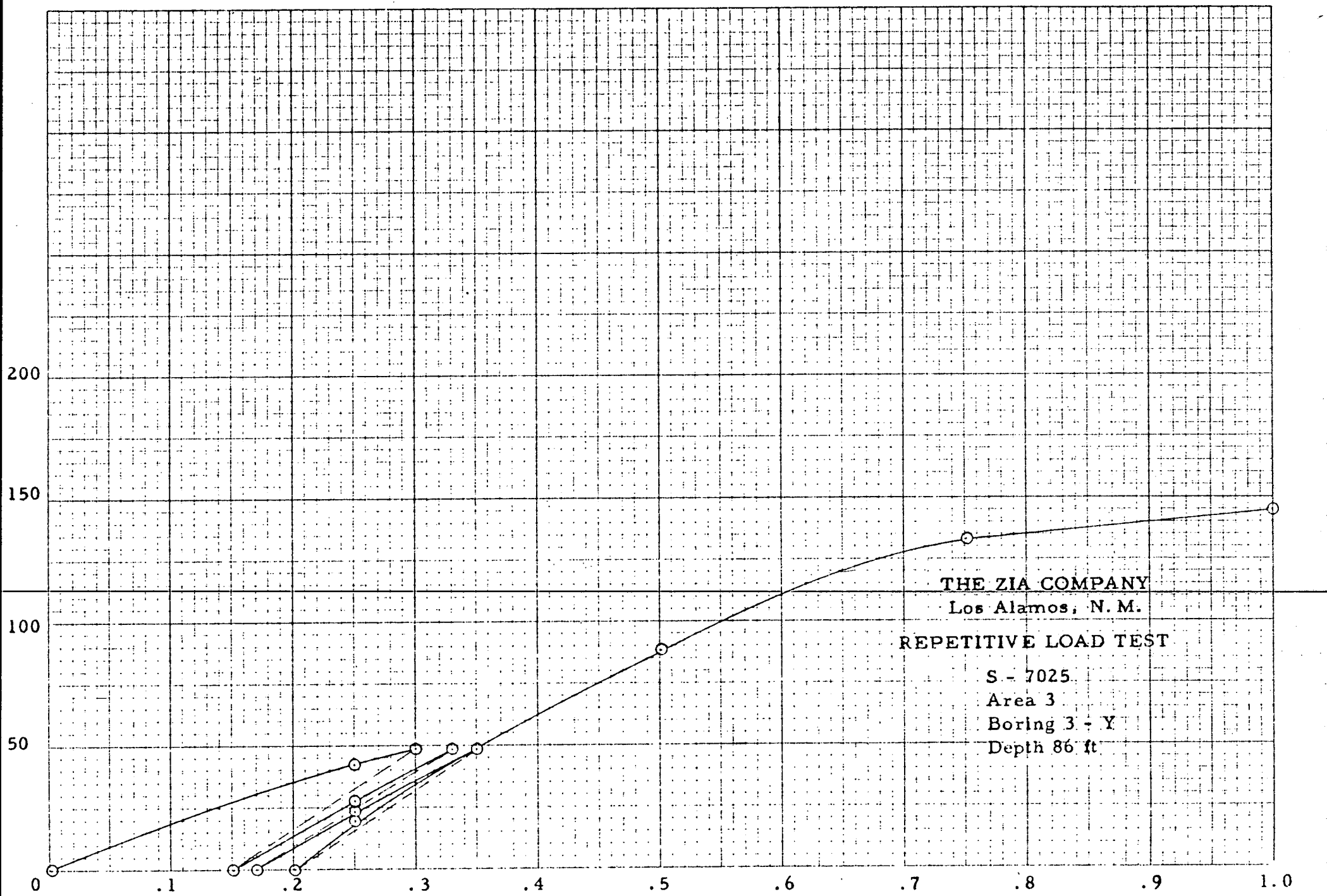
Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 3 - Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
7022	0	60			76.9	0	1.78	3.65
7025 (1)	1,000	1250			85.6	0	1.76	3.98
7025 (2)	1,000	2090			85.2	0	1.78	4.00
7024	5,000	8260			82.9	0	1.79	4.01



NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.



AREA FOUR

SOIL MECHANICS INCORPORATED

SUMMARY OF LABORATORY TESTS

Lab. No.	Boring	Depth, ft	Confinement psi	Max. Stress psi	Nat. Moist Content, %	Nat. Density pcf	Dry Density pcf	Testing Moist %	Wet Density pcf
*7004	Area 4	50±	1,000	4,325	1.5	111.7	110.0	5.0	137.2
*7005	Area 4	106±	1,000	2,750	0.6	83.8	83.3	5.0	95.6

* Chemical Analysis, Air Permeability and Mechanical Analysis Data Attached

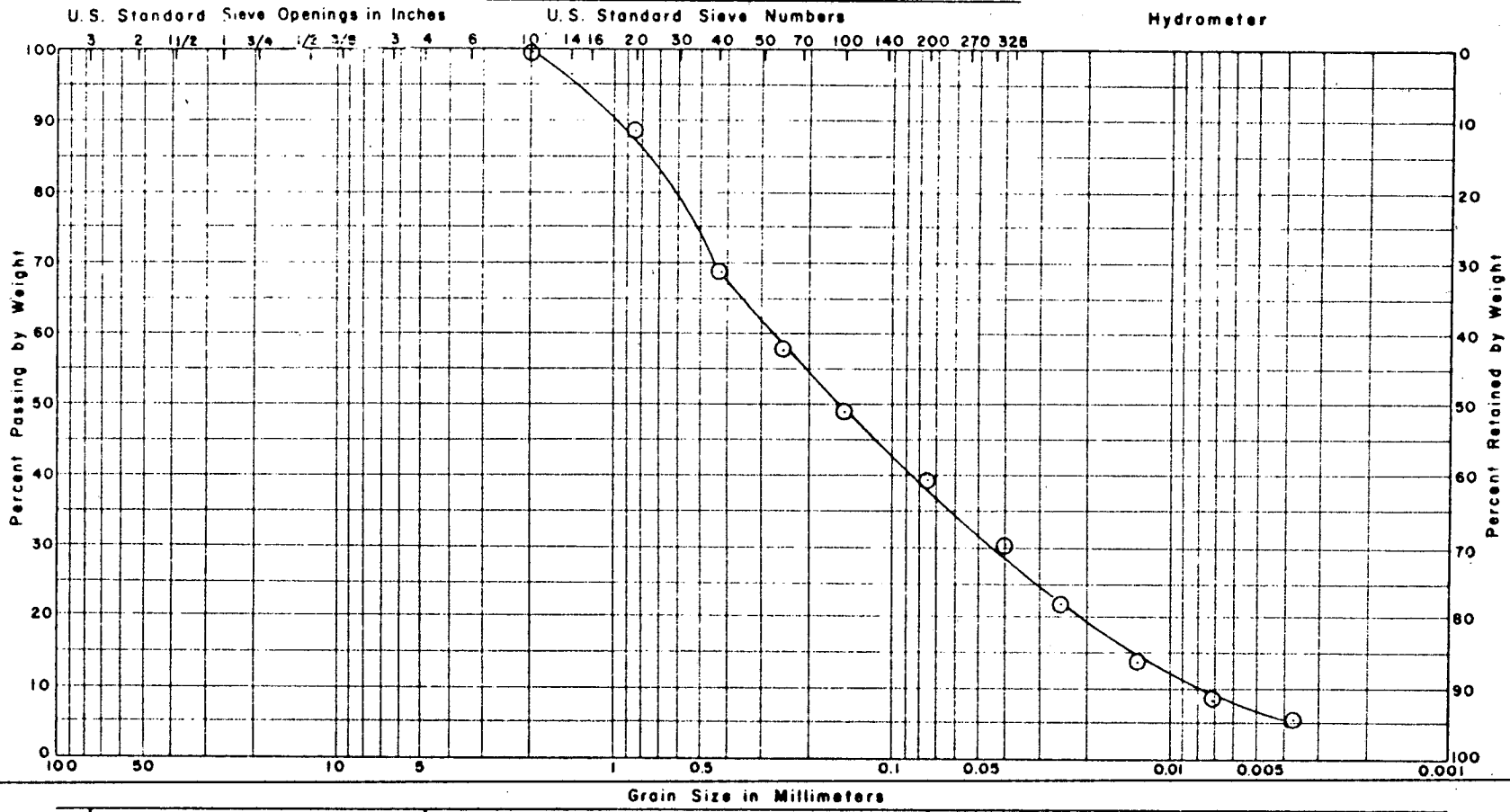
	Spec. Gravity
7004	2.530
7005	2.510

SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSIS

AREA FOUR-

Sample No.	7004	7005
Depth	50±	106±
Element	Approx. %	
Copper	0.004	0.006
Iron	1.	1.
Manganese	0.05	0.02
Nickel	Trace	Trace
Chromium	0.002	0.002
Aluminum	6.	6.
Magnesium	0.07	0.02
Calcium	3.	0.9
Titanium	0.1	0.08
Sodium	1.	1.
Barium	Trace	Trace
Potassium	1.	1.
Strontium	Trace	Trace
Zirconium	0.02	0.02
Silicon	35.	38.

MECHANICAL ANALYSIS CHART



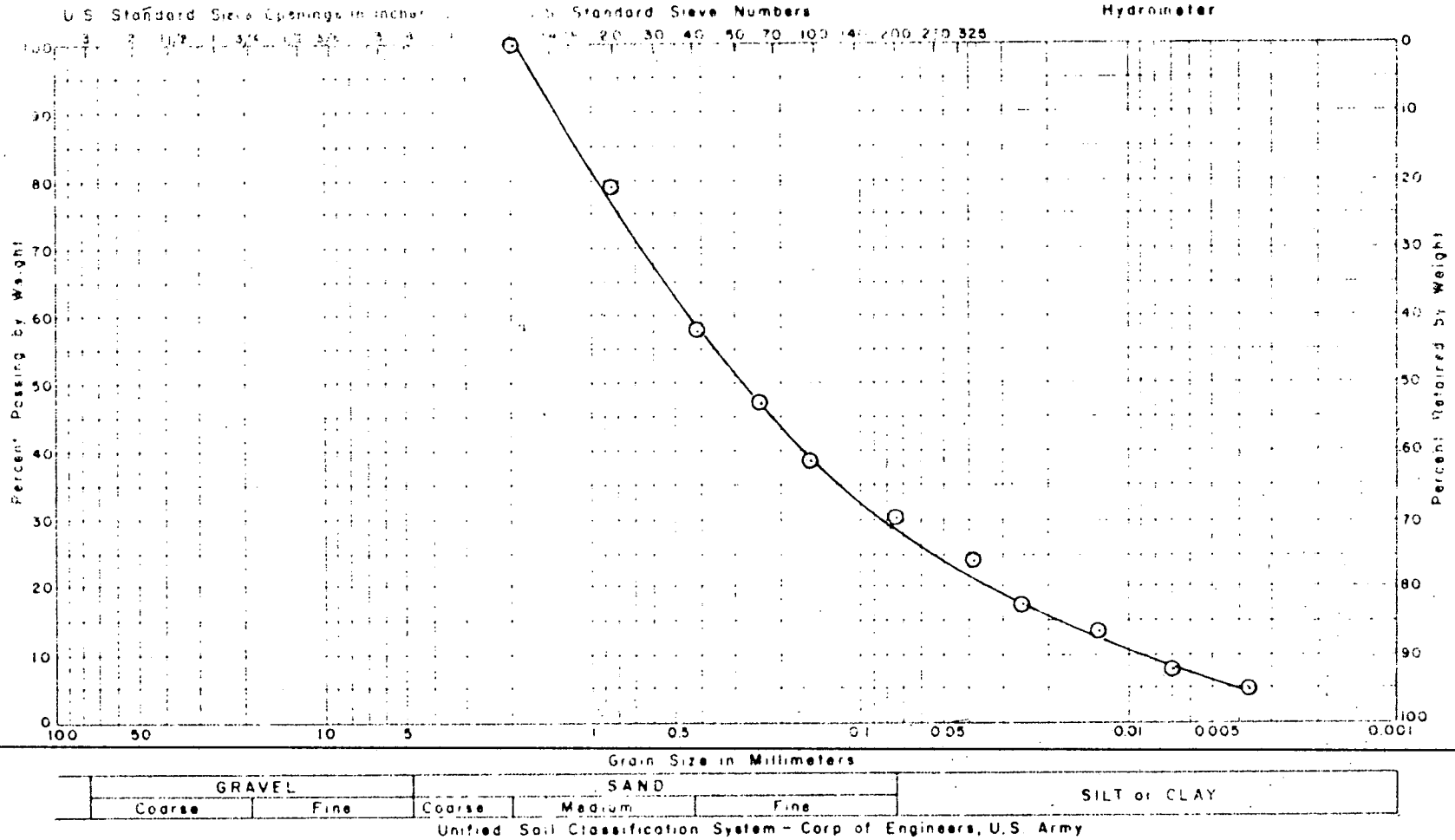
GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, New Mexico

Sample No. 7004
Area 4 50±

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, New Mexico

Sample No. 7005
Area 4 106±

SAMPLE NO. 7004 - AREA 4 - DEPTH 50±

This rock is a rhyolitic tuff similar to those previously examined. It consists of mineral and rock fragments in a matrix of volcanic glass shards, very fine-grained crystalline material, glass, and dust.

Its approximate composition is as follows (estimate only, from microscopic examination of thin sections):

	%	%	%
Fragments			8
Mineral fragments		7	
Orthoclase	4		
Quartz	2		
Augite	0.5		
Magnetite	0.5		
Rock fragments (fine-grained lava)		1	
Matrix			92
Fine granular tridymite and cristobalite	12		
Volcanic glass shards, partly devitrified	10		
Structureless glass and dust	70		

Alteration: Some of the augite has altered to an aggregate of small prismatic grains which are probably hornblende (uralite). Some of the magnetite appears to have come from the same source. Traces of clay minerals are also present.

In addition to the above, one or two grains of a brown hornblende and of plagioclase were also seen.

As in other samples, the greenish color of the augite and the optical properties of the orthoclase suggest a rather high sodium content for the rock.

Much of the fine-grained crystalline material in the matrix seems to be cristobalite rather than tridymite, although the two are difficult to distinguish and both appear to be present. The glass shards are considerably less devitrified then in Sample No. 7003. Most of the shards are collapsed, but unbroken, bubbled, and some of them wrap around mineral fragments as if they had been compacted while still plastic.

This rock is less devitrified than most of the other samples examined, as is shown by a smaller proportion of crystalline material both in the shards and in the matrix as a whole.

SAMPLE NO. 7005 - AREA 4 - DEPTH 106±

Like the samples previously examined, this rock is a rhyolitic tuff consisting of mineral and rock fragments in a matrix of volcanic glass shards, very fine-grained crystalline material, glass, and dust.

Its approximate composition is as follows (estimate only, from microscopic examination of thin sections):

	%	%	%
Fragments			20
Mineral fragments		17	
Orthoclase	10		
Quartz	6		
Augite	0.5		
Magnetite	0.5		
Rock fragments (fine-grained lava)		3	
Matrix			80
Fine granular tridymite and cristobalite		10	
Volcanic glass shards, partly devitrified		20	
Structureless glass and dust		50	

Alteration: Most of the magnetite is clustered around the augite as if originally derived from it. Otherwise the rock shows practically no alteration, and no weathering.

In addition to the minerals listed above, a little plagioclase was seen in one of the rock fragments.

The size of the optic angle, in a few grains on which it could be estimated, suggests that the feldspar is not sanidine but may be anorthoclase, a sodium-rick feldspar. The green color of the augite also suggests a high sodium content for the rock.

Many of the glass bubbles in this sample are unbroken and have their centers filled with tridymite and cristobalite. Most of the walls of these bubbles are more or less devitrified to a very fine crystalline aggregate. The interstitial material between the bubbles and shards appears to be a structureless glass full of very tiny microlites or "dust".

SUMMARY OF AIR PERMEABILITY TESTS

AREA FOUR

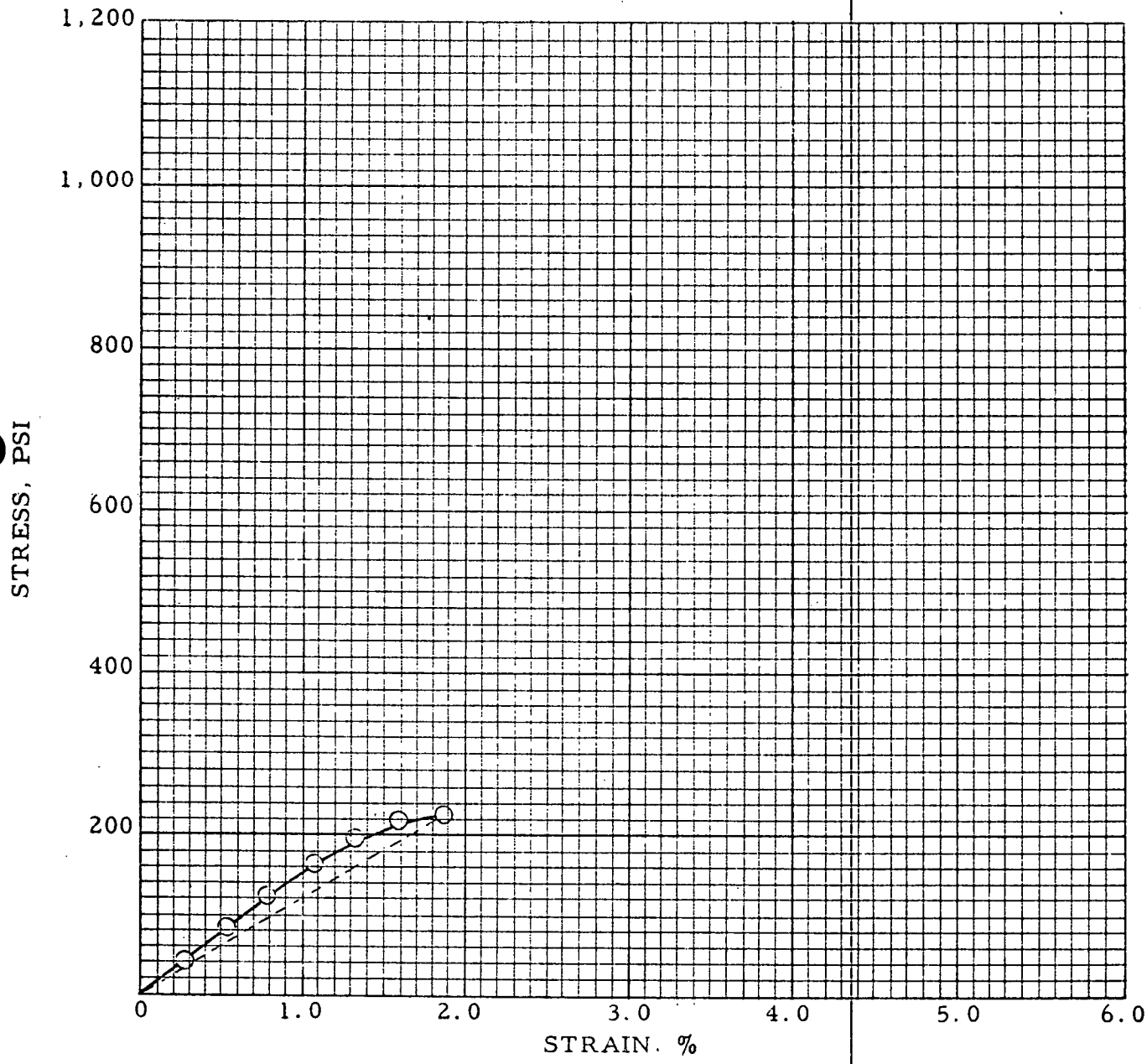
Sample No.	Depth	Vertical Permeability to Air, Millidarcys
7004	50±	86
7005	106±	.56

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6836 Boring 4 - A Depth, ft. 83' E



MODULUS OF ELASTICITY, PSI

Elastic Range 15,837

At Failure 12,500

POISSON'S RATIO

Elastic Range .050

At Failure .042

BULK MODULUS, PSI

At Failure 12,954

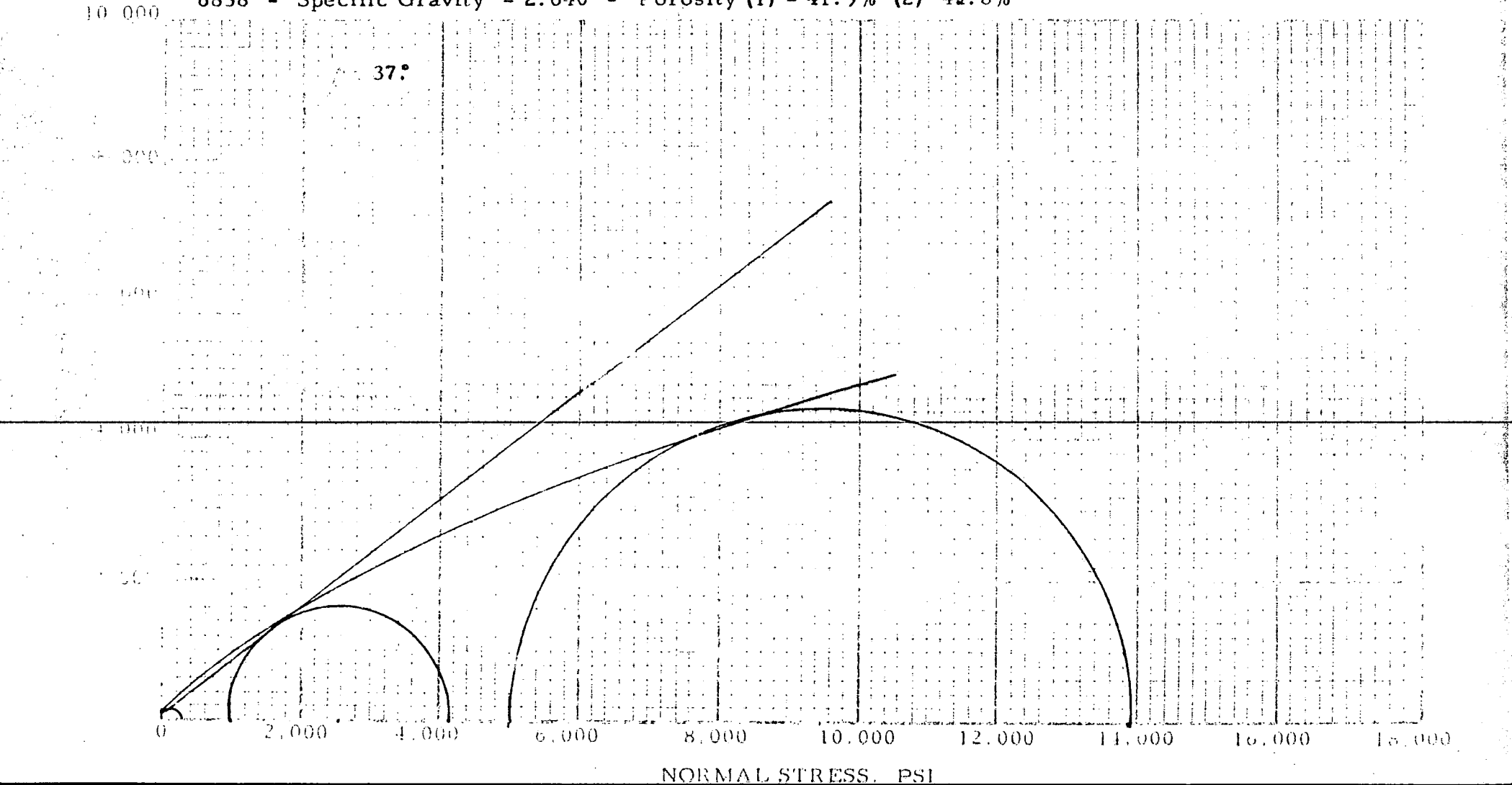
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY, Los Alamos, N. M. Boring 4 - A Job No. 59-154

Lab. No	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$, psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam., in.	Height, in.
6836	0	230		1.0	91.7	5.0	1.594	3.75
6838 (1)	1.000	3120	95.6	1.2	94.4	5.0	1.625	3.56
6838 (2)	1.000	3170	90.8	1.2	89.6	5.0	1.625	3.63
6841	5.000	8950		1.5	92.3	5.0	1.625	3.97

6838 - Specific Gravity = 2.640 - Porosity (1) = 41.9% (2) 44.8%

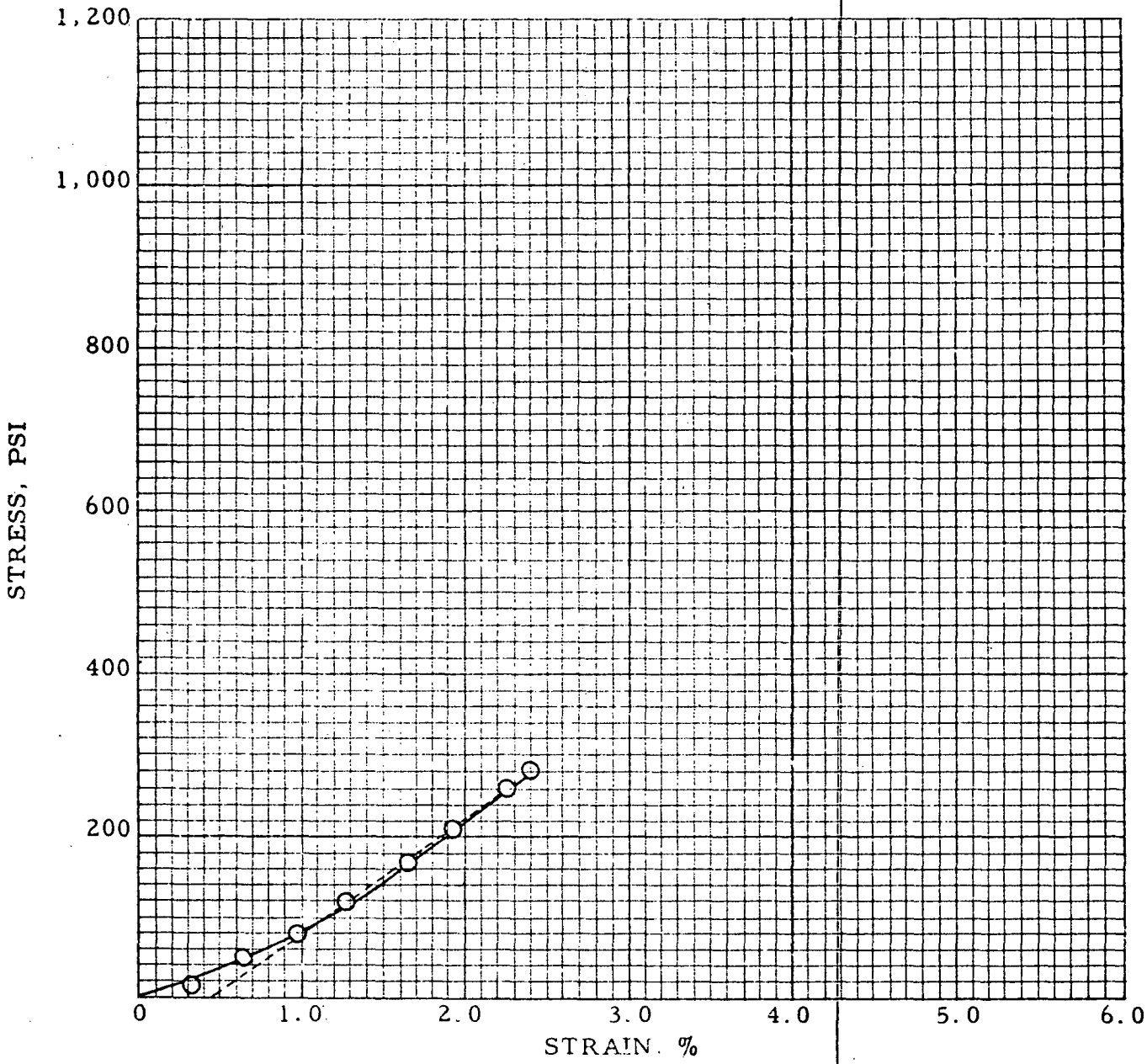


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6837 Boring 4 - A Depth, ft. 83' W



MODULUS OF ELASTICITY, PSI

Elastic Range 13,084

At Failure 13,084

POISSON'S RATIO

Elastic Range .040

At Failure .040

BULK MODULUS, PSI

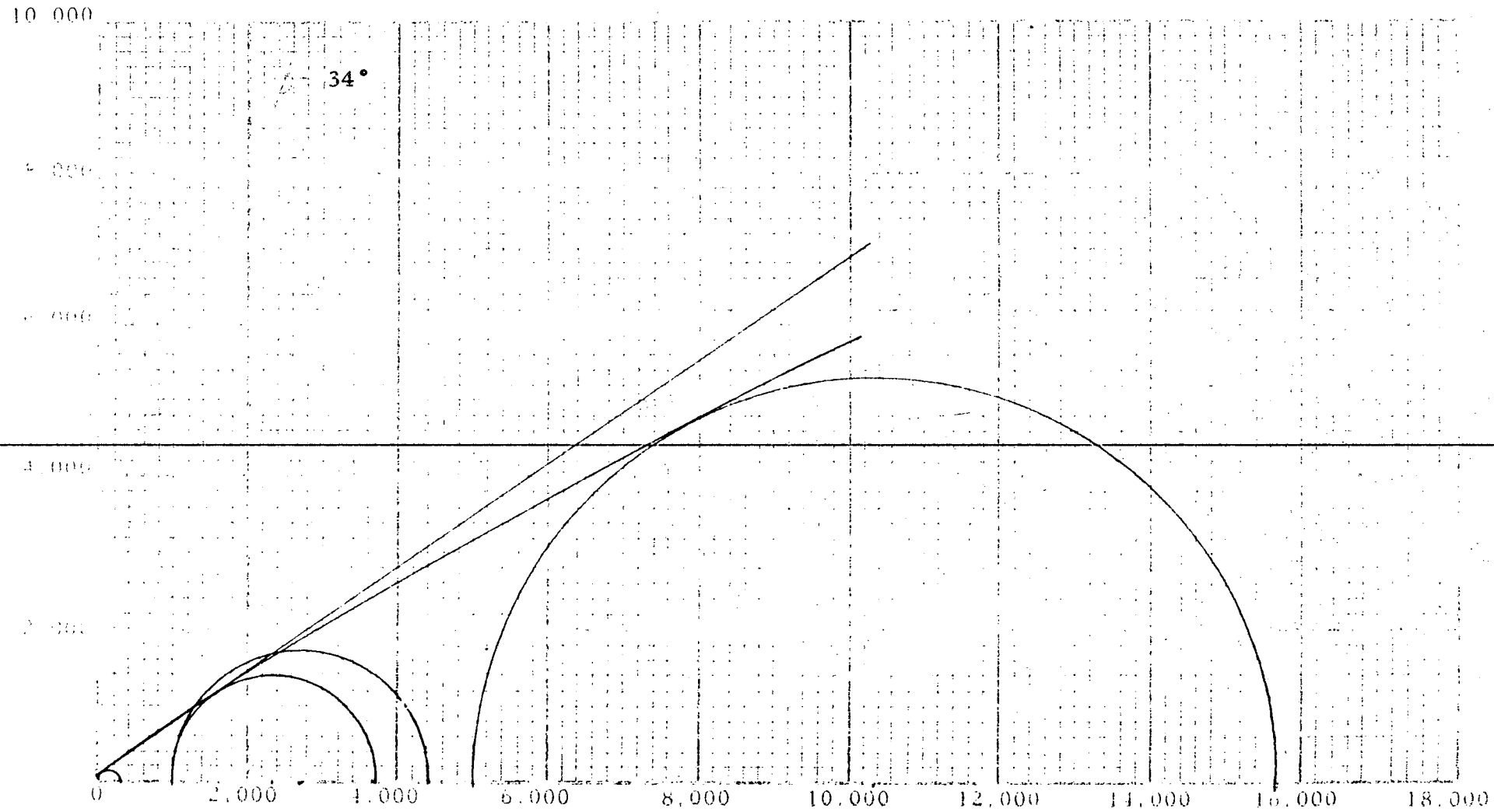
At Failure 13,720

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY, Los Alamos, N.M. Boring 4 - A Job No. 59-154

Lab No	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$, psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6837	0	280		1.7	91.2	Dry	1.594	3.09
6840 (1)	1,000	2675		2.1	86.6	"	1.625	3.81
6840 (2)	1,000	3410		2.1	90.3	"	1.531	2.81
6842	5,000	10690		1.9	92.2	"	1.594	3.00

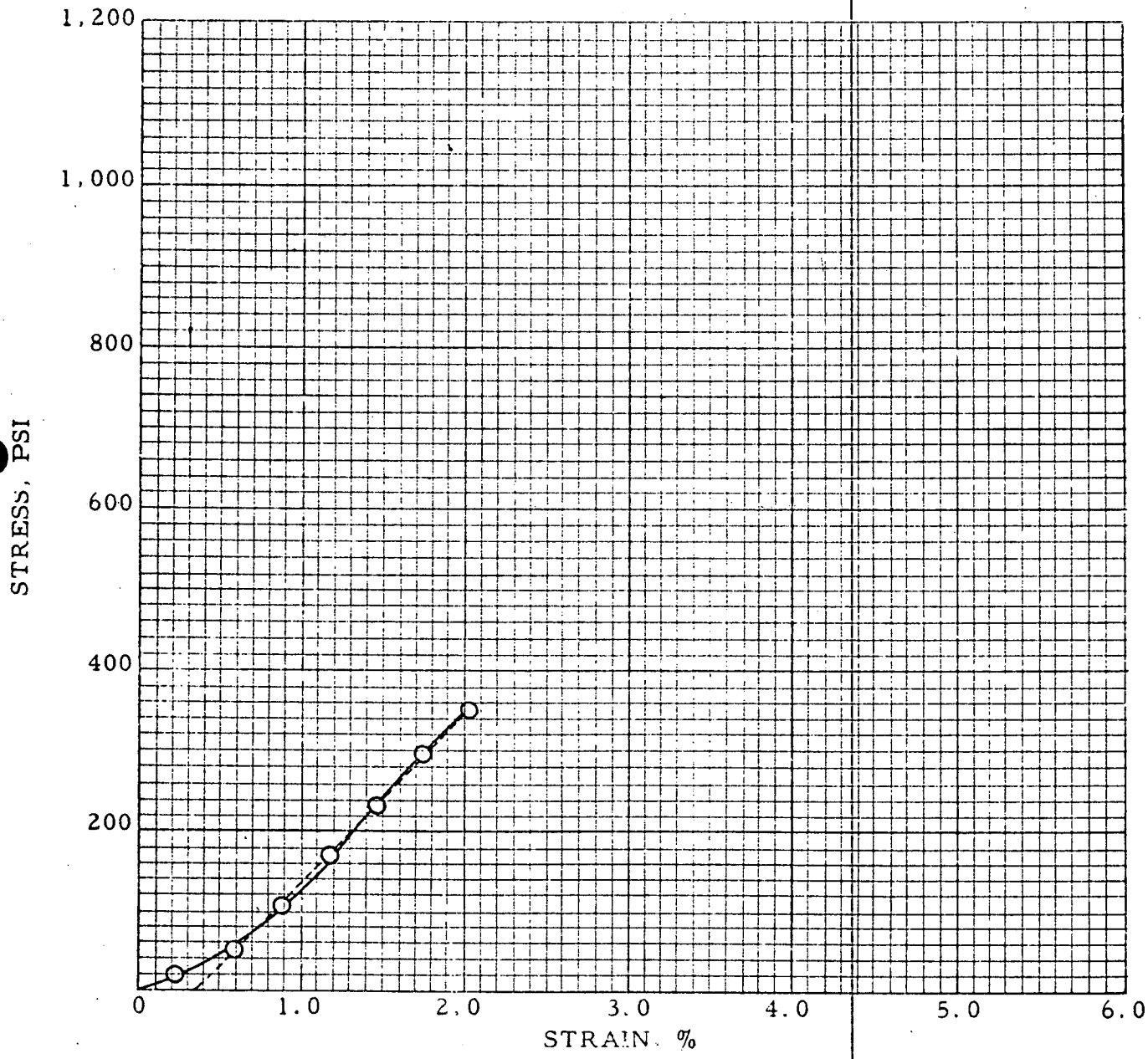


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N. M. Job No. 59-154

Lab No. 6859 Boring 4-C Depth, ft. 55'E



MODULUS OF ELASTICITY, PSI

Elastic Range 20,625

At Failure 20,526

POISSON'S RATIO

Elastic Range .054

At Failure .044

BULK MODULUS, PSI

At Failure 29,355

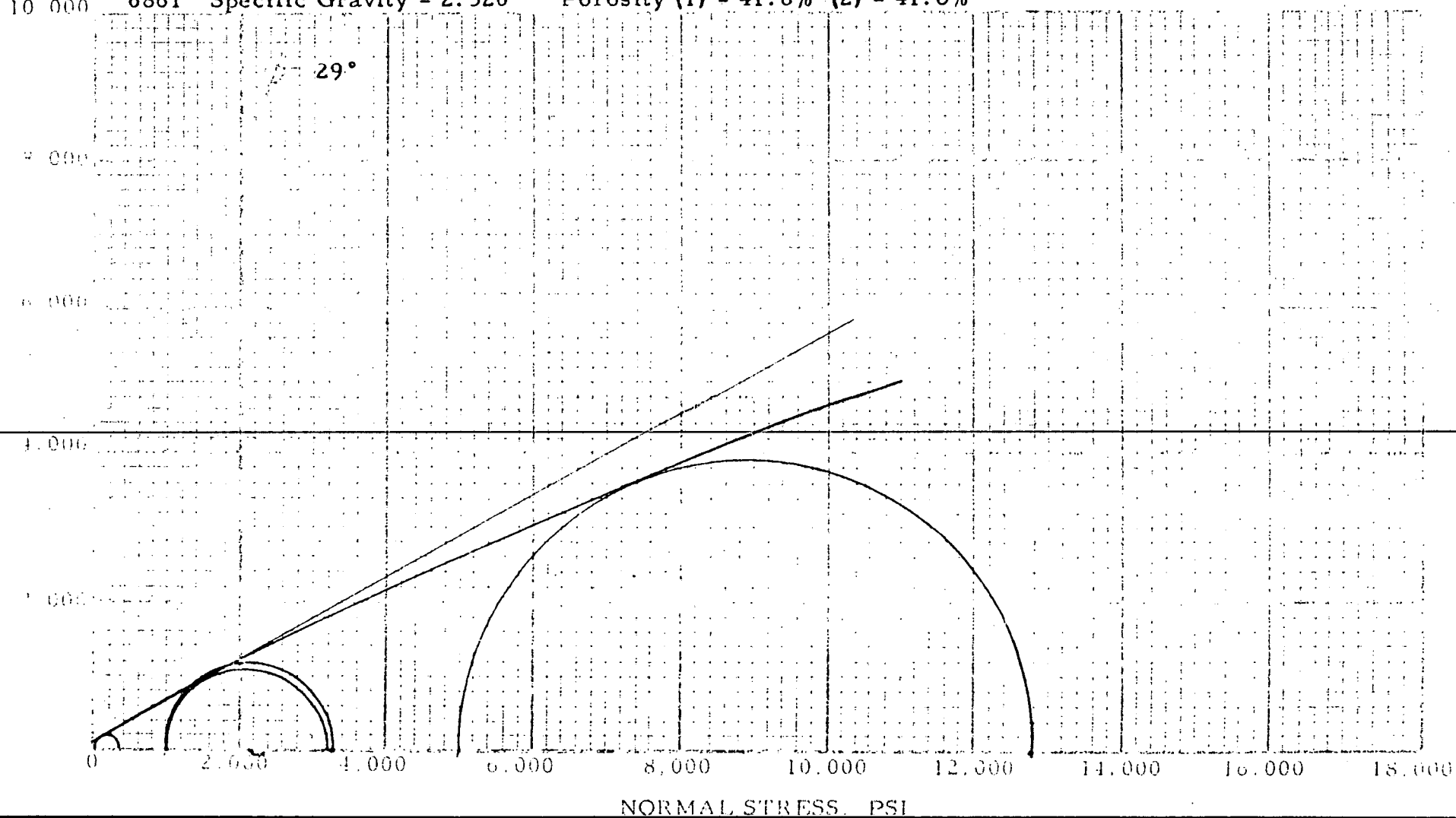
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project. THE ZIA COMPANY, Los Alamos, N. M. Boring 4 - C Job No. 59-154

Lab. No	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam in.	Height, in.
6859	0	351		4.31	86.5	5.0	1.781	3.41
6861 (1)	1.000	2270	91.5	3.71	88.2	5.0	1.781	4.03
6861 (2)	1.000	2180	91.5	3.71	88.3	5.0	1.781	3.78
6864	5.000	7760		4.58	86.2	5.0	1.750	4.03

6861 Specific Gravity = 2.520 Porosity (1) = 41.8% (2) = 41.8%

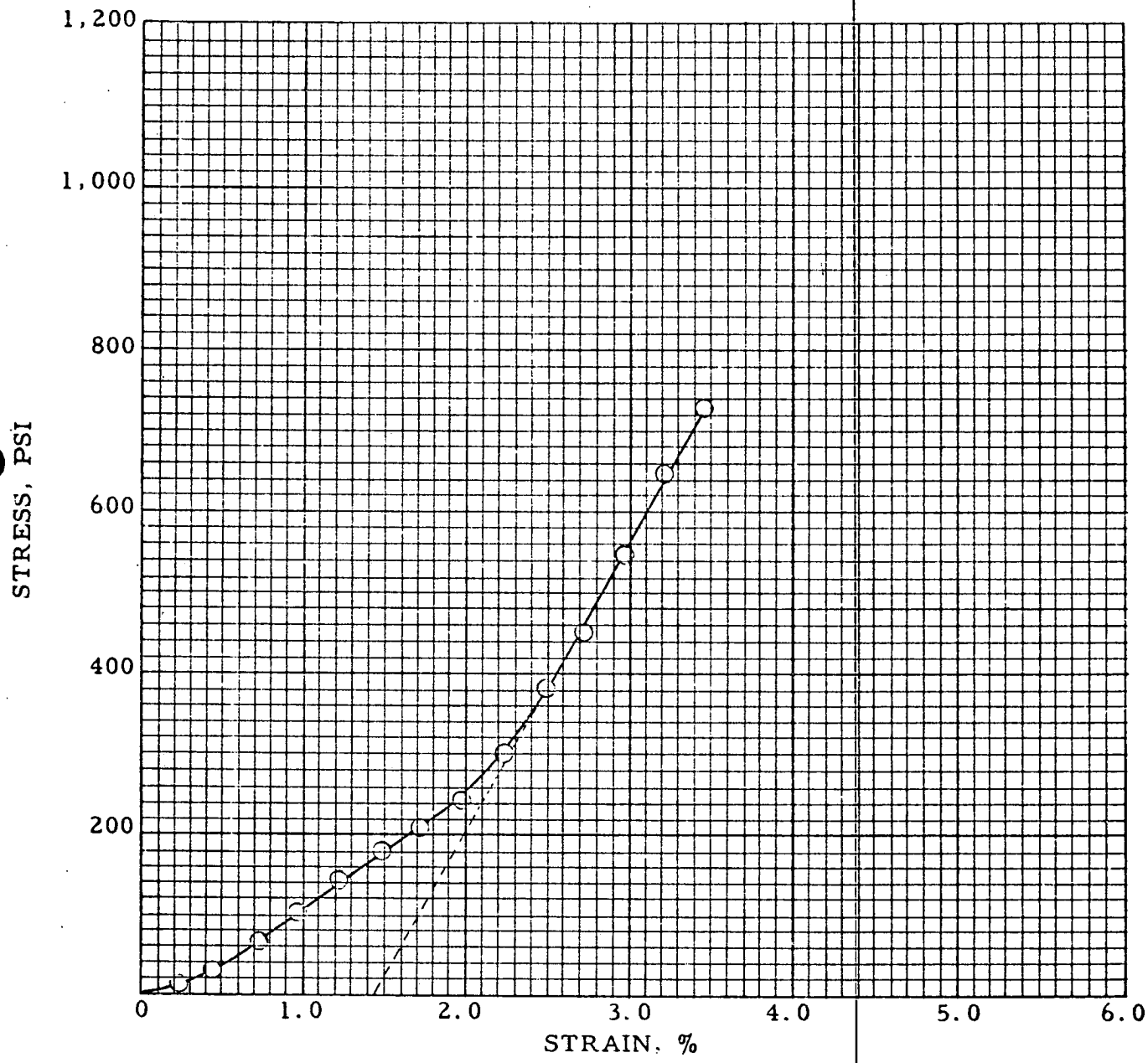


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6860 Boring 4- C Depth, ft. 55' W



MODULUS OF ELASTICITY, PSI

Elastic Range 36,274

At Failure 36,078

POISSON'S RATIO

Elastic Range .052

At Failure .036

BULK MODULUS, PSI

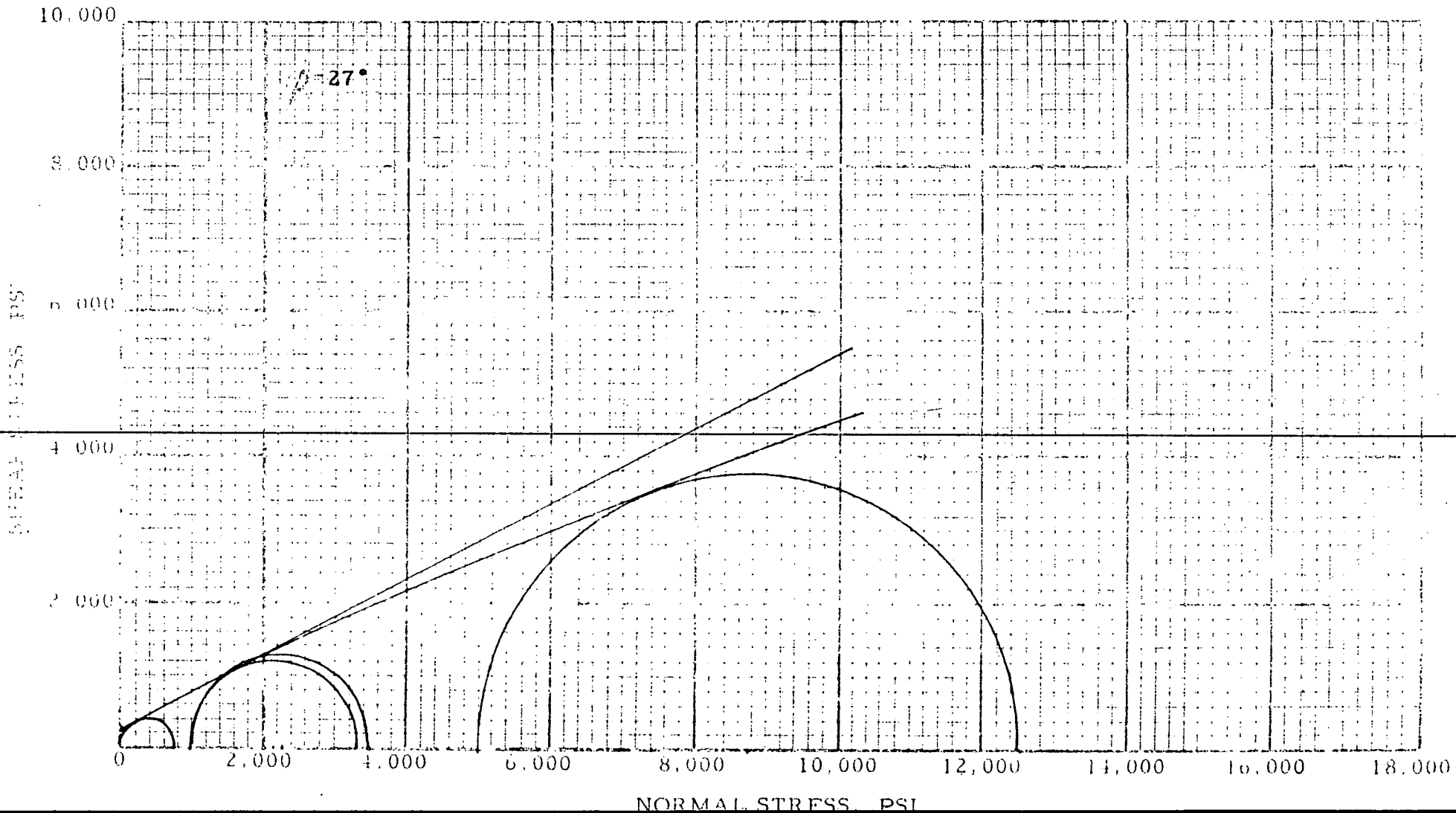
At Failure 38,756

SOIL MECHANICS INCORPORATED

TRIAXIAL C M ESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 4 - C Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam. in.	Height, in.
6860	0	736		4.05	88.9	Dry	1.766	4.031
6862 (1)	1.000	2500		3.89	87.2	"	1.766	4.031
6862 (2)	1.000	2330		3.89	88.4	"	1.750	4.031
8665	5.000	7510		4.57	87.2	"	1.766	4.031

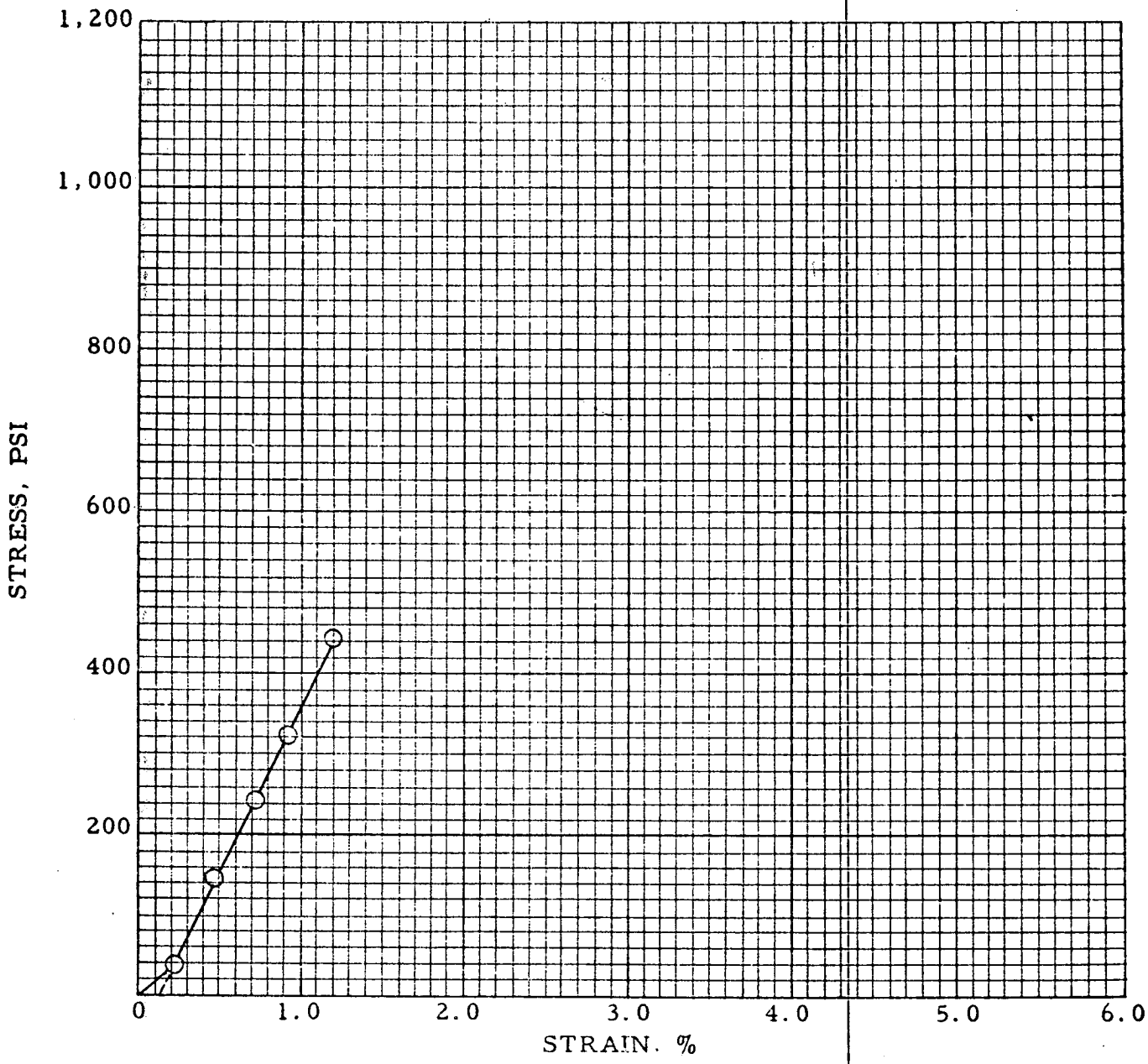


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6966 Boring 4 - K Depth, ft. 57' E



MODULUS OF ELASTICITY, PSI

Elastic Range 41,495

At Failure 21,495

POISSON'S RATIO

Elastic Range .572

At Failure .572

BULK MODULUS, PSI

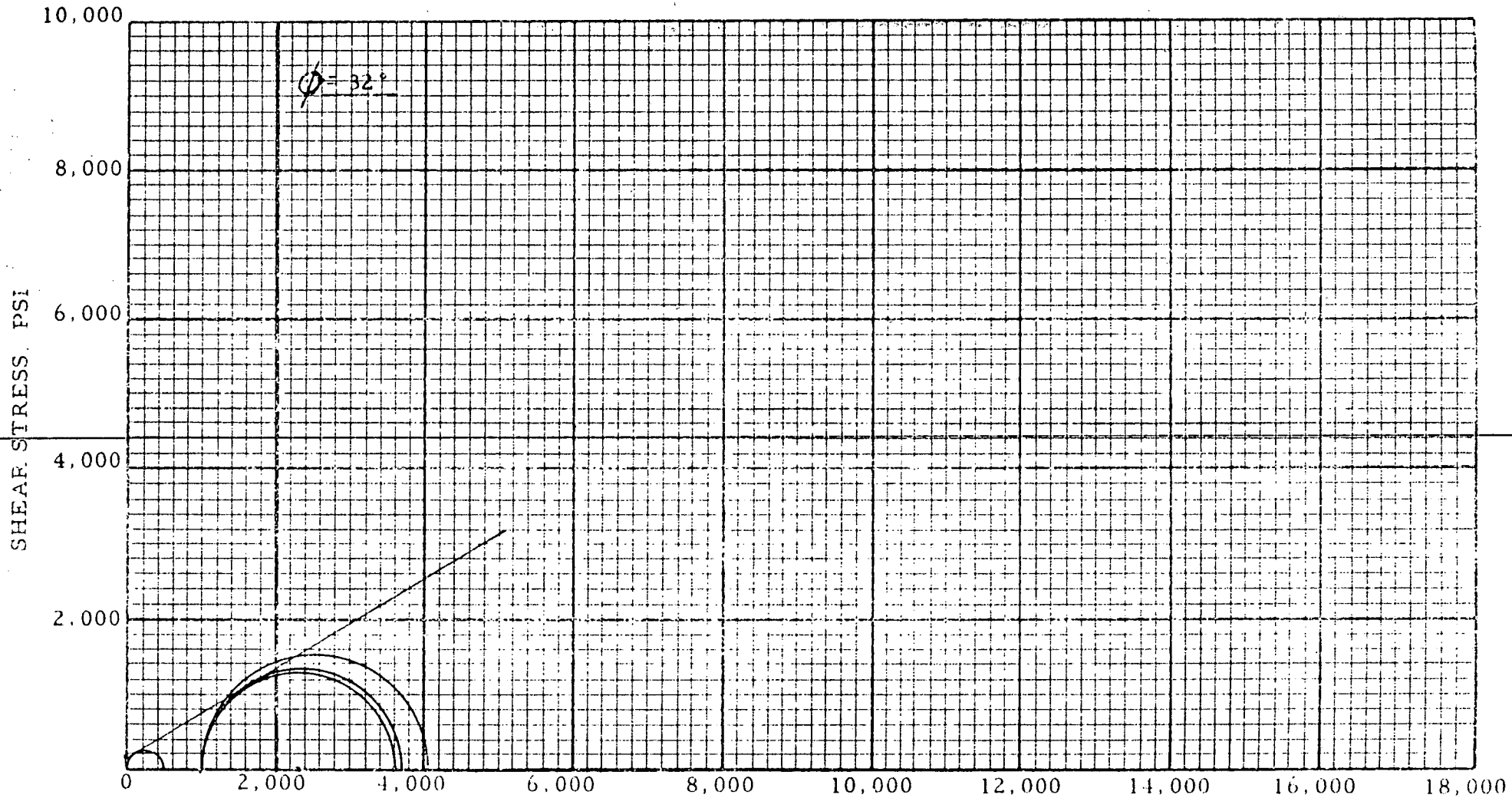
At Failure 65,689

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 4 - K Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6966	0	444		1.0		Dry	1.73	4.12
6964-1	1,000	2595		0.9		"	1.71	4.05
6964-2	1,000	2630		0.9		"	1.73	4.08
6962	1,000	3085		0.9		"	1.75	4.03

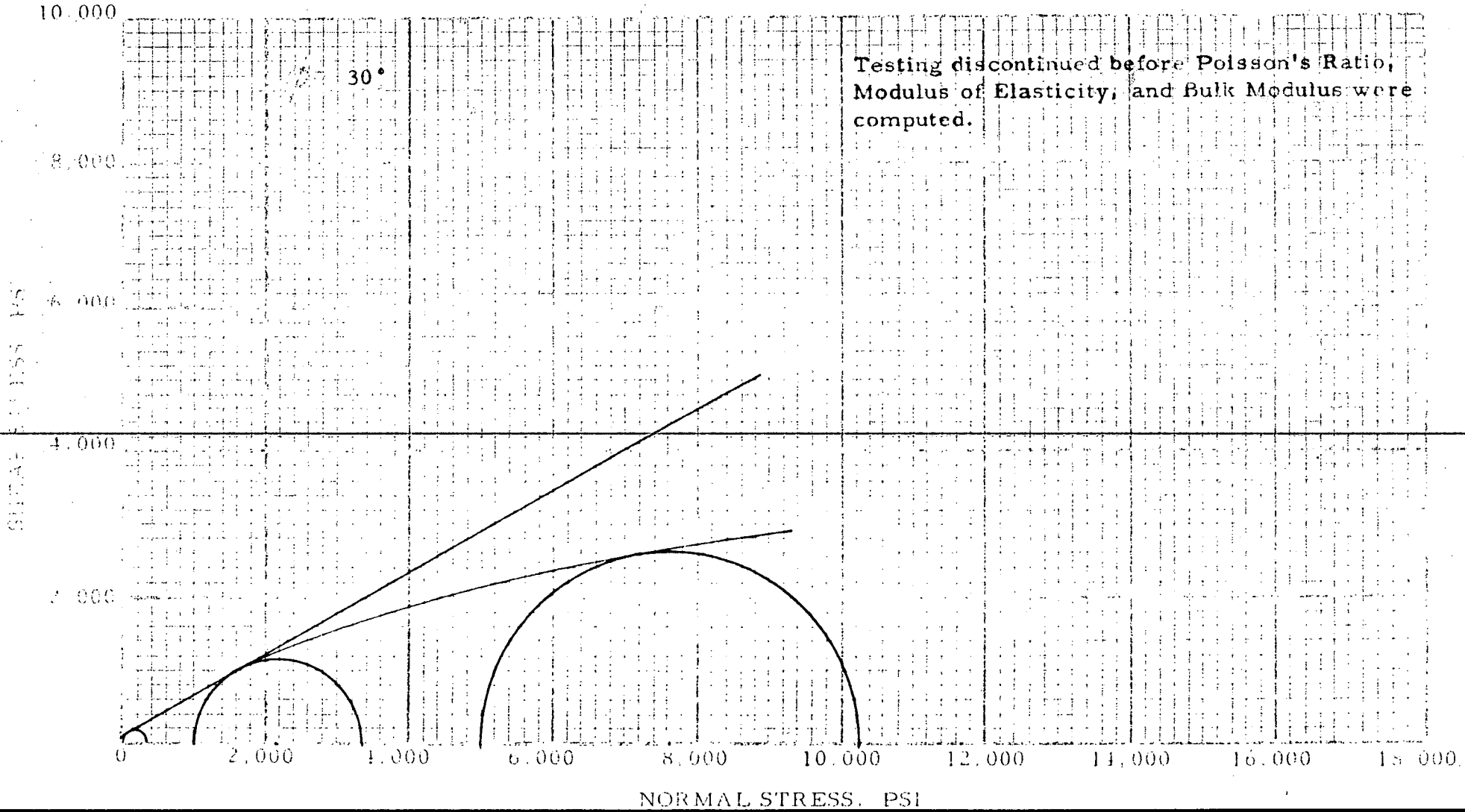


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 4 - K Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max Stress $\sigma_1 - \sigma_3$, psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density, pcf	Test Moist. Content, %	Diam., in.	Height, in.
6967	0	343		1.5		5.0	1.72	4.14
6965 (1)	1,000	2310		1.0		5.0	1.71	4.05
6965 (2)	1,000	2310		1.0		5.0	1.73	4.08
6963	5,000	5220		1.4		5.0	1.75	4.03

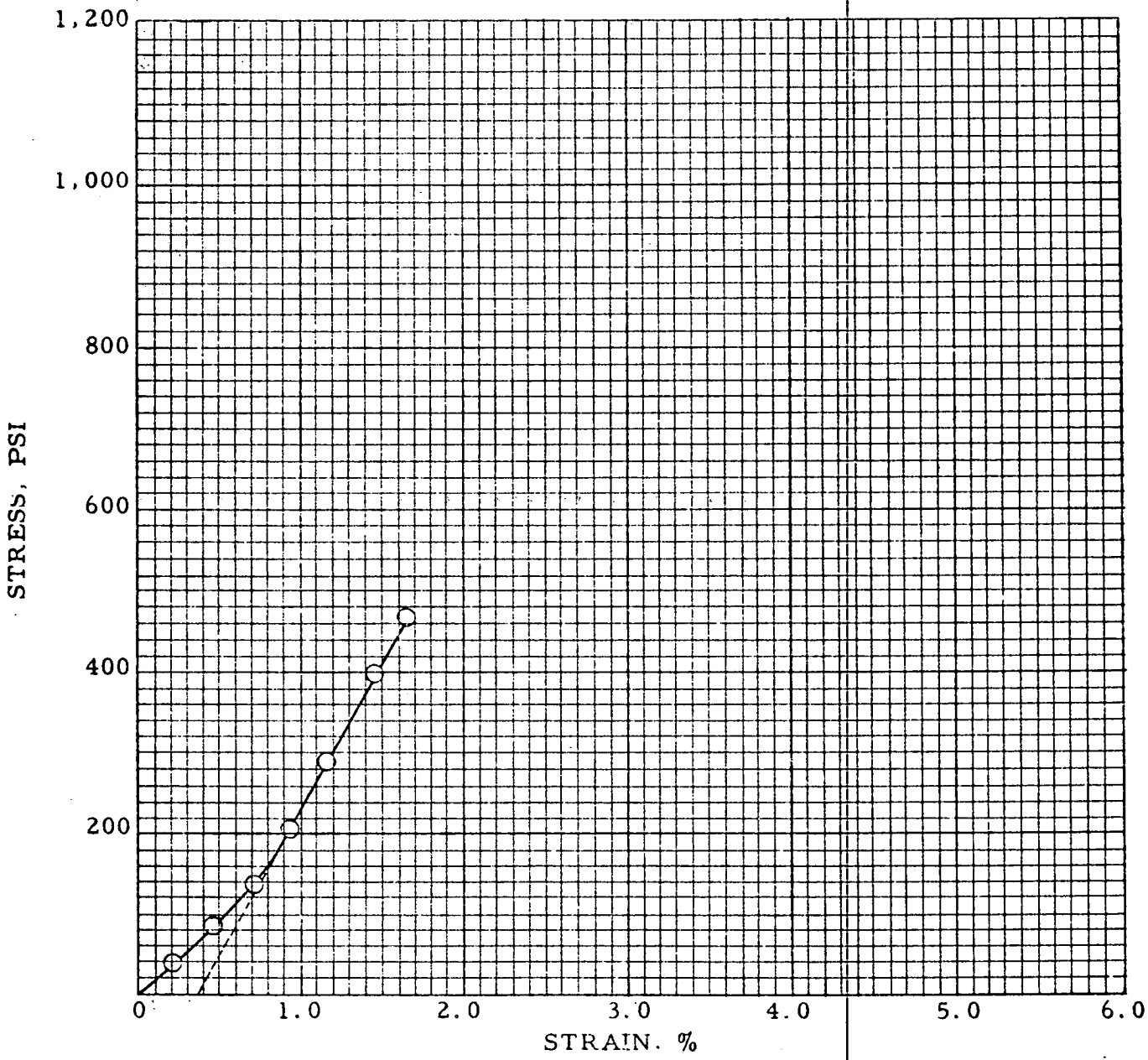


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6956 Boring 4 - O Depth, ft. 57' W



MODULUS OF ELASTICITY, PSI

Elastic Range 36,562

At Failure 36,562

POISSON'S RATIO

Elastic Range .860

At Failure .860

BULK MODULUS, PSI

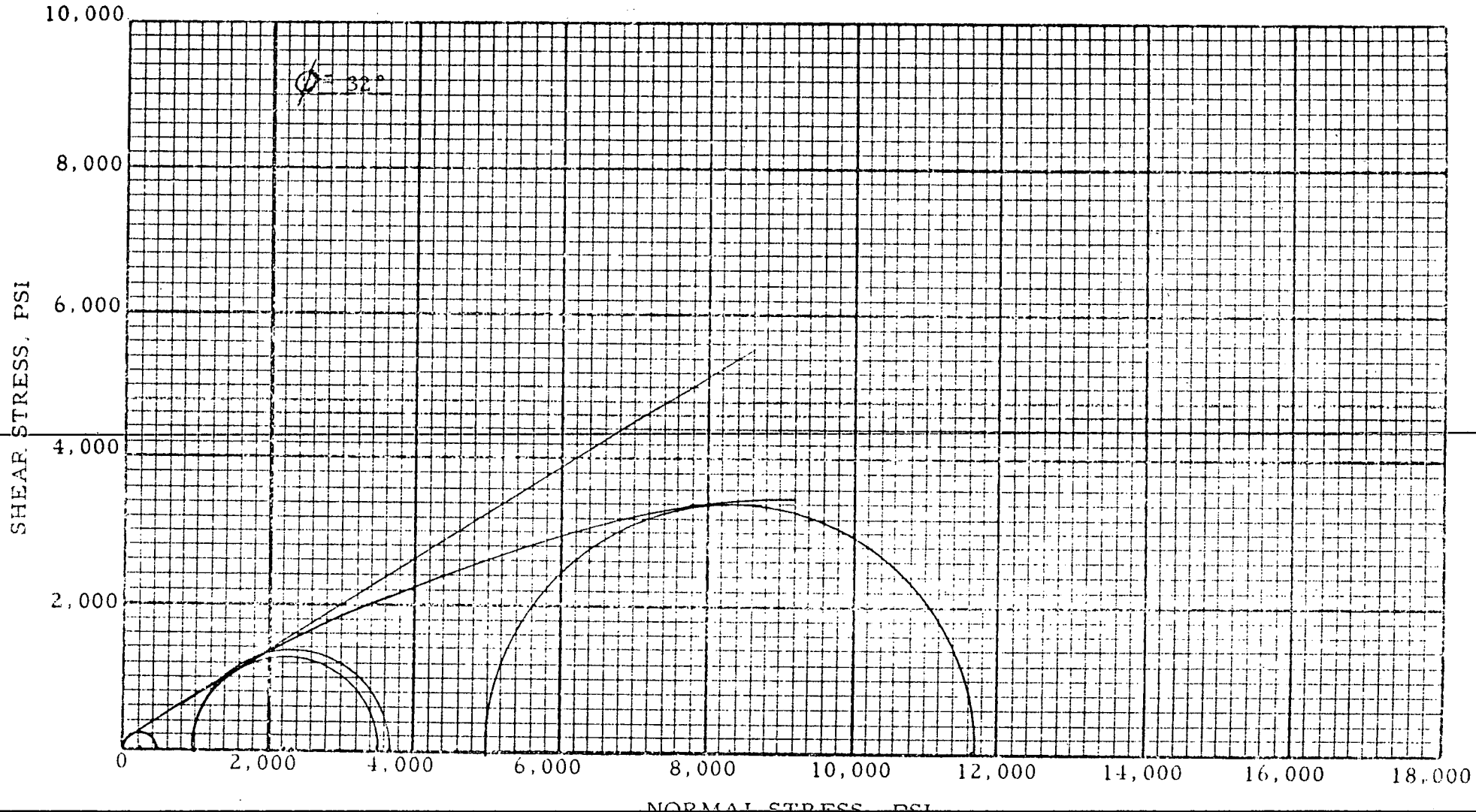
At Failure 38,995

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 4 - O Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6956	0	468		0.9		Dry	1.72	4.23
6954-1	1,000	2680		0.5		"	1.73	4.06
6954-2	1,000	2500		0.5		"	1.75	4.03
6952	5,000	6670		1.6		"	1.70	4.17

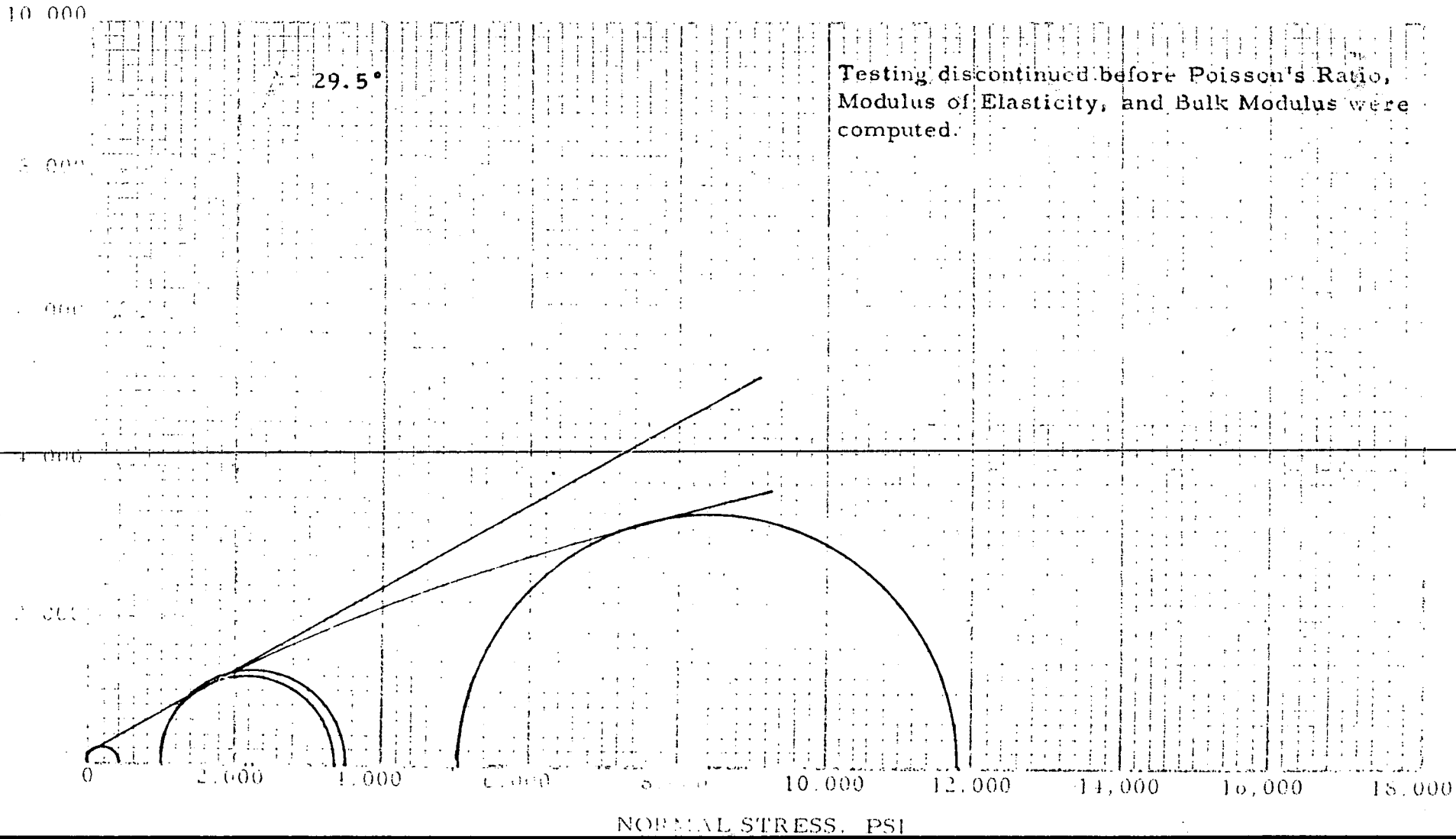


SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY, Los Alamos, N M Boring 4 - 0 Job No. 59-154

Lab. No.	Confinement σ_3 psi	Max Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam in.	Height in.
6957	0	419		0.5		5.0	1.69	4.03
6955 - 1	1.000	2480		0.6		5.0	1.75	4.00
6955 - 2	1.000	2390		0.6		5.0	1.77	4.00
6953	5.000	6840		0.6		5.0	1.69	4.11



Testing discontinued before Poisson's Ratio, Modulus of Elasticity, and Bulk Modulus were computed.

THERMAL CONDUCTIVITY & SPECIFIC HEAT DATA

AREA FOUR

Sample No. 6932

Depth: 101'W Boring No. 4-V

Thermal Conductivity: 0.41 BTU/hr sq ft °F/ft at an average temperature of 112.1°F, a density as received of 97.9 lb/cu. ft., and a moisture content as received of 0.46% of dry weight.

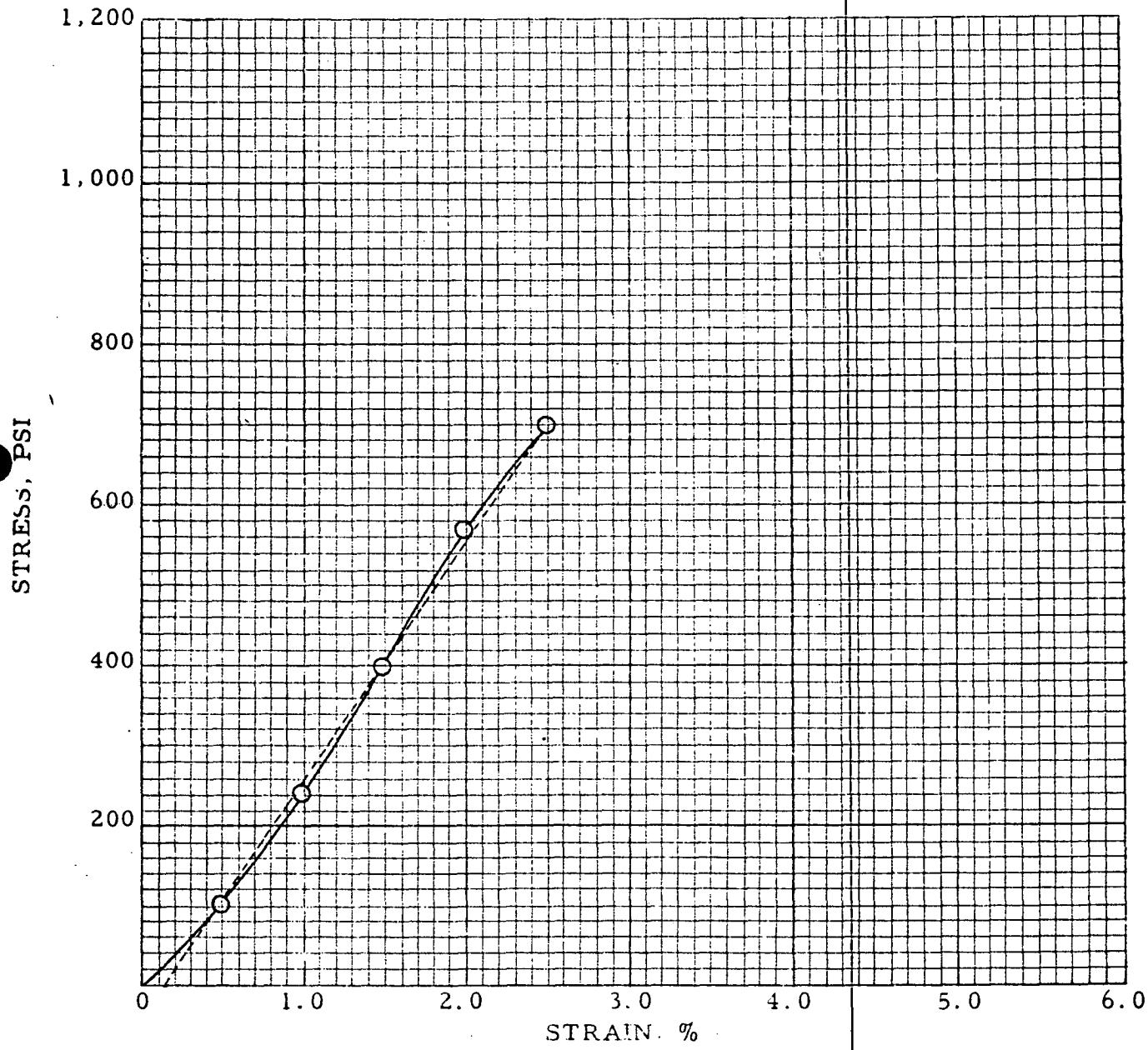
Specific Heat: 0.202 BTU/lb °F between the temperature limits of 76.6° F and 212°F for oven dried and ground sample passing a No. 200 sieve. 0.206 BTU/lb°F computed for soil at a moisture content of 0.46% of dry weight between the temperature limits of 76.6°F and 212°F.

SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6934 Boring 4 -V Depth, ft. 102' W



MODULUS OF ELASTICITY, PSI

Elastic Range 30,591

At Failure 29,661

POISSON'S RATIO

Elastic Range .022

At Failure .016

BULK MODULUS, PSI

At Failure 30,448

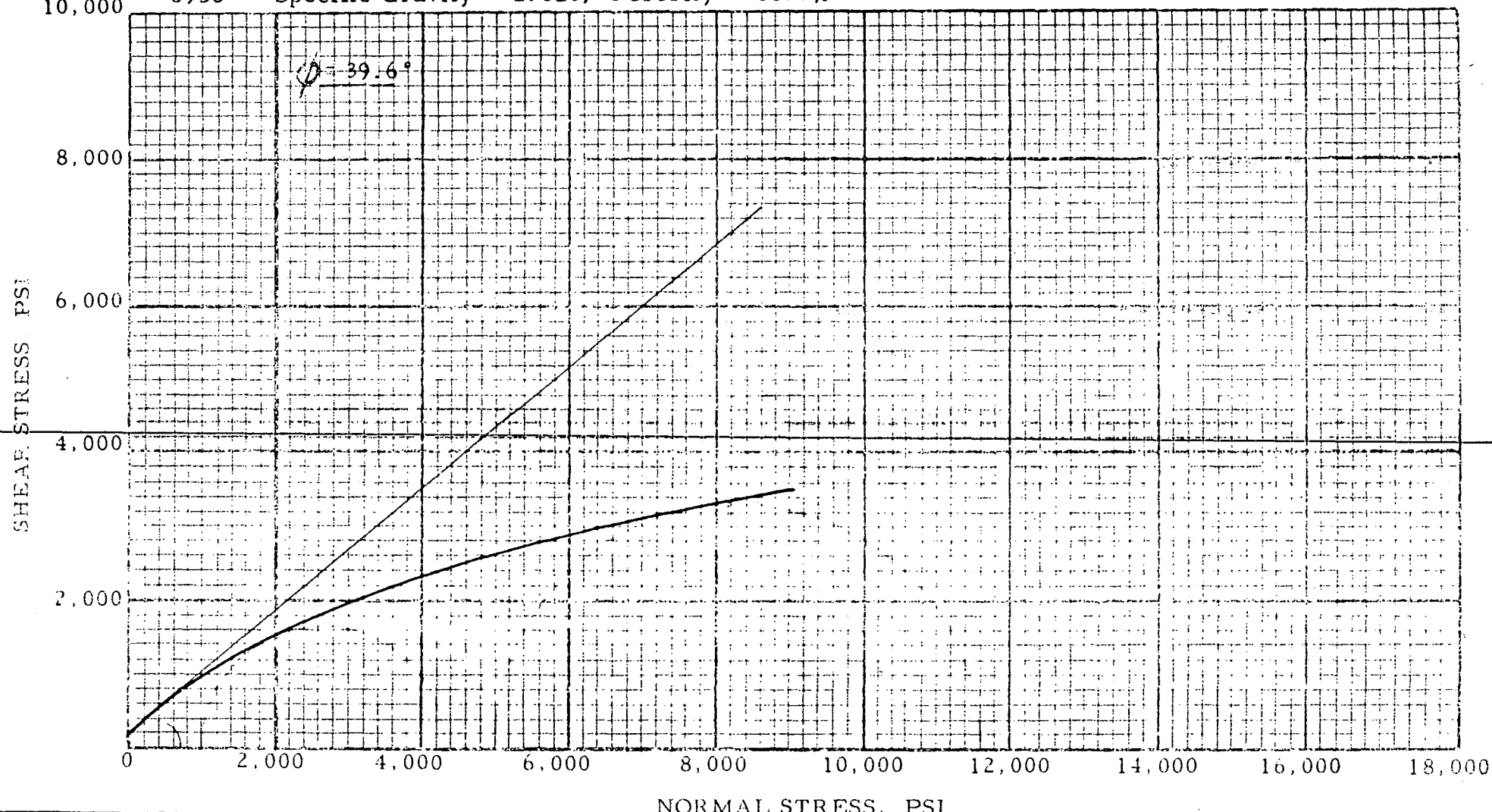
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 4 - V Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6934	0	700		0.9	100	5.0	1.75	3.94
6936 (1)	1,000	3220	112.1	0.4	111.6	5.0	1.75	4.03
6936 (2)	1,000	3280	112.4	0.4	112.0	5.0	1.73	3.34
6938	5,000	6590		0.6	108.3	5.0	1.75	4.03

6936 - Specific Gravity = 2.620; Porosity = 31.7%

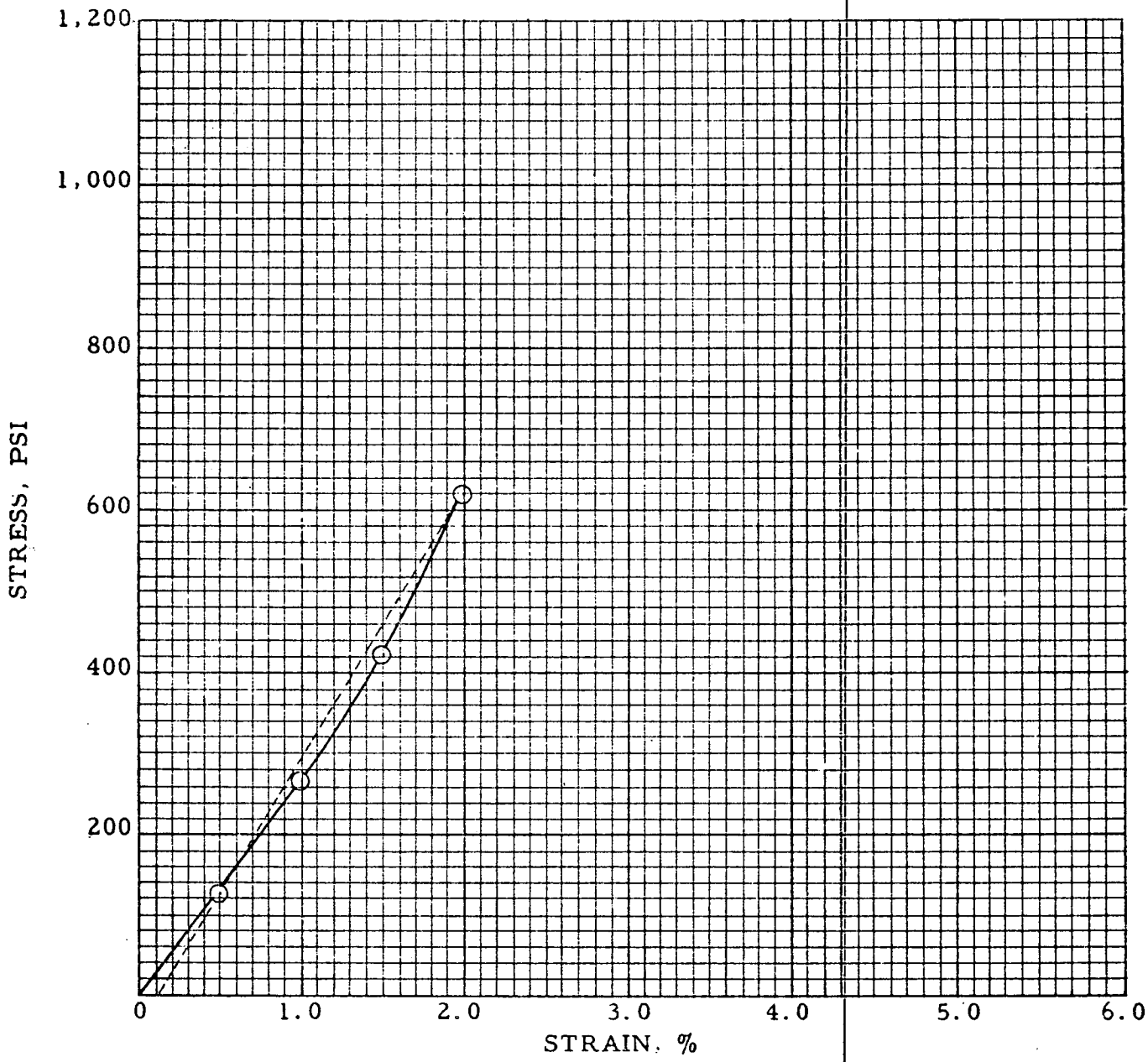


SOIL MECHANICS INCORPORATED

STRESS VS. STRAIN

Project: THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154

Lab No. 6937 Boring 4 - V Depth, ft. 103' W



MODULUS OF ELASTICITY, PSI

Elastic Range 30,337

At Failure 32,804

POISSON'S RATIO

Elastic Range .038

At Failure .024

BULK MODULUS, PSI

At Failure 33,251

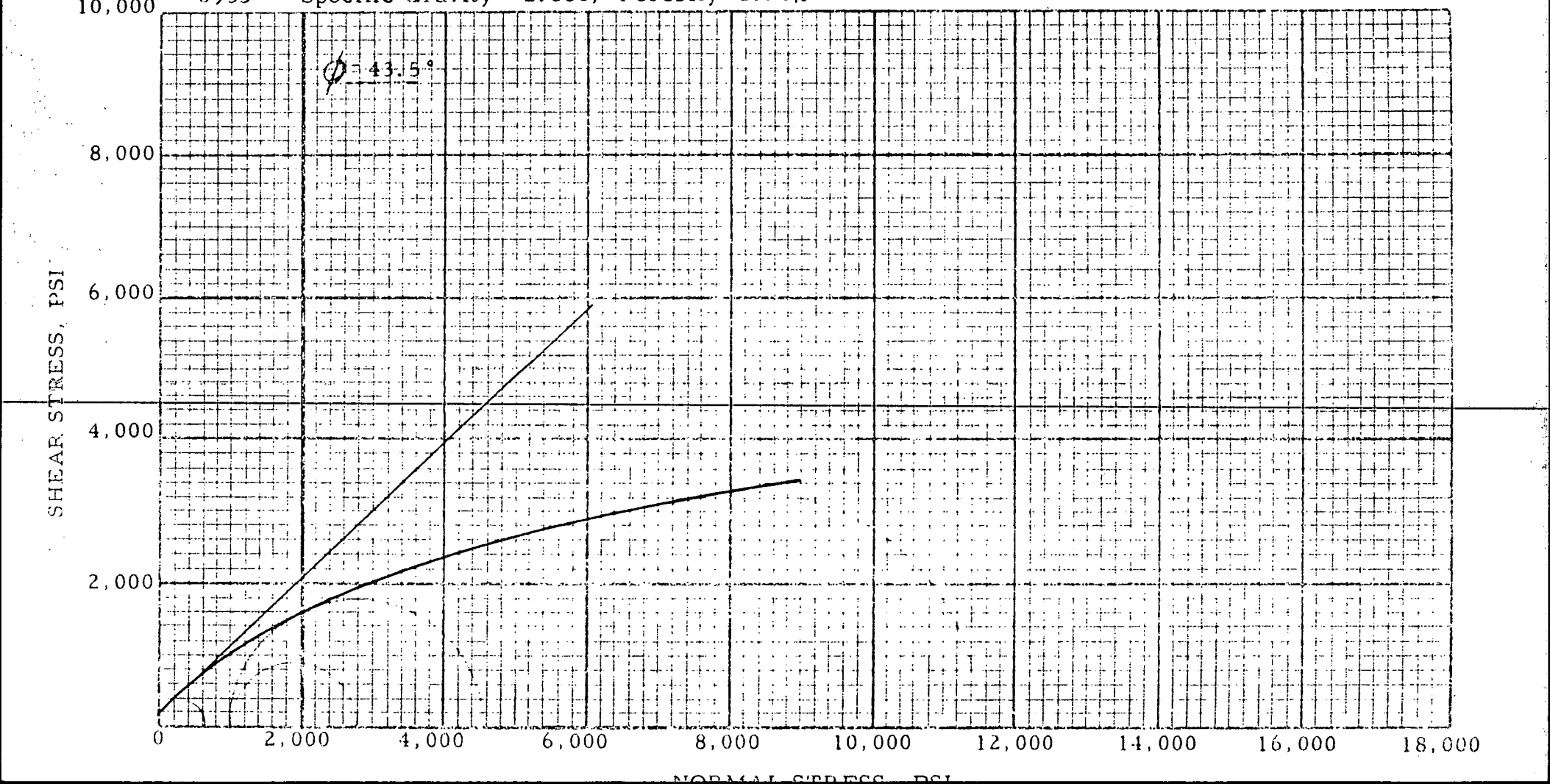
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 4 - V Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6937	0	620		1.2	99.7	5.0	1.72	4.03
6935 (1)	1,000	3480		1.1	99.0	5.0	1.72	4.17
6935 (2)	1,000	1800		1.1	97.7	5.0	1.72	4.19
6933	5,000	6500		0.9	82.3	5.0	1.72	3.56

6935 - Specific Gravity - 2.660; Porosity 40.4%



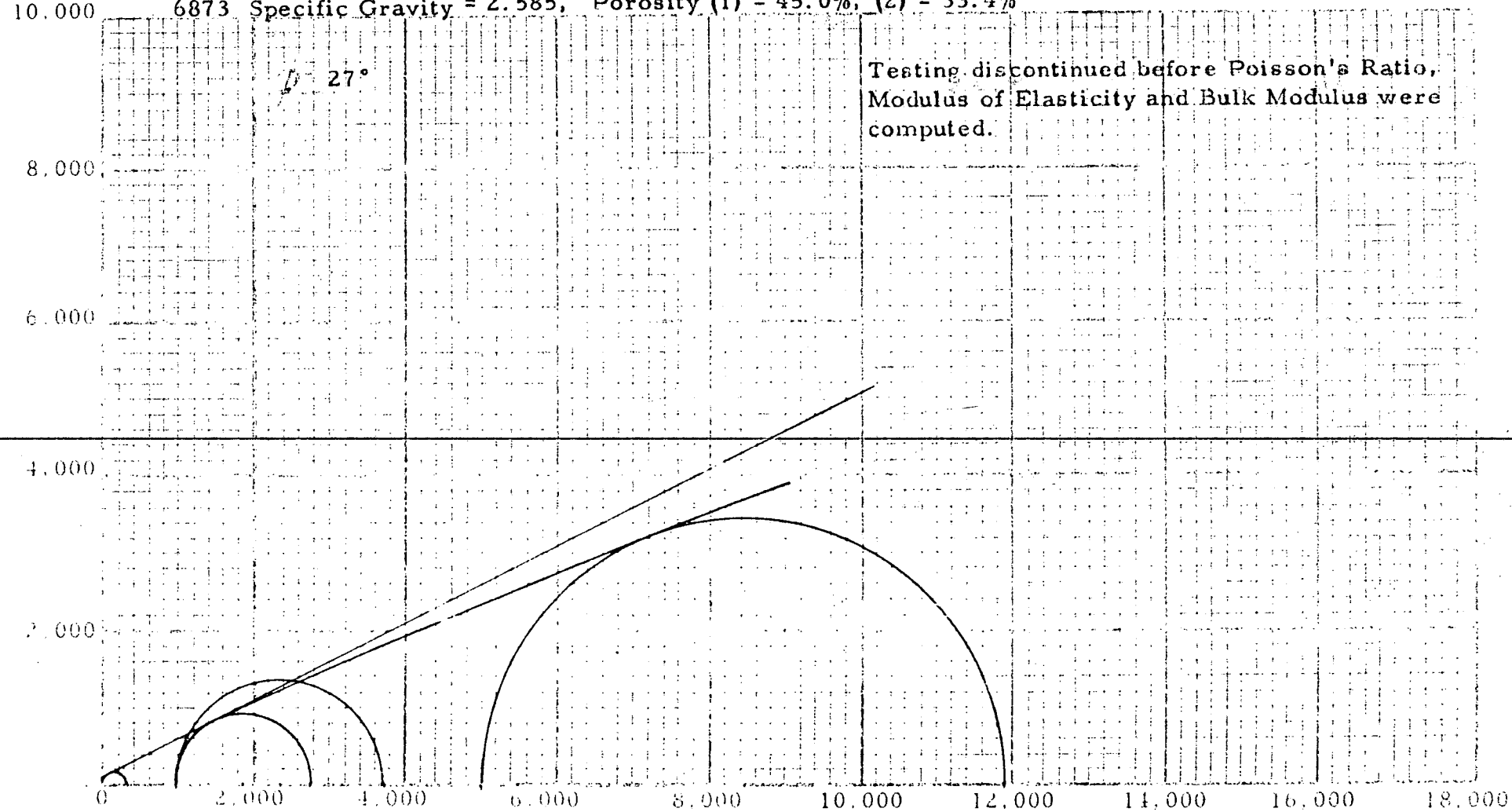
SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring 4 - Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6875	0	160		0.7	85.2	Dry	1.69	4.00
6873 (1)	1,000	2725	89.6	1.0		"	1.75	4.03
6873 (2)	1,000	1785	91.3	1.0		"	1.75	4.07
6871	5,000	6900		0.5	87.2	"	1.75	4.03

6873 Specific Gravity = 2.585, Porosity (1) = 45.0%, (2) = 33.4%



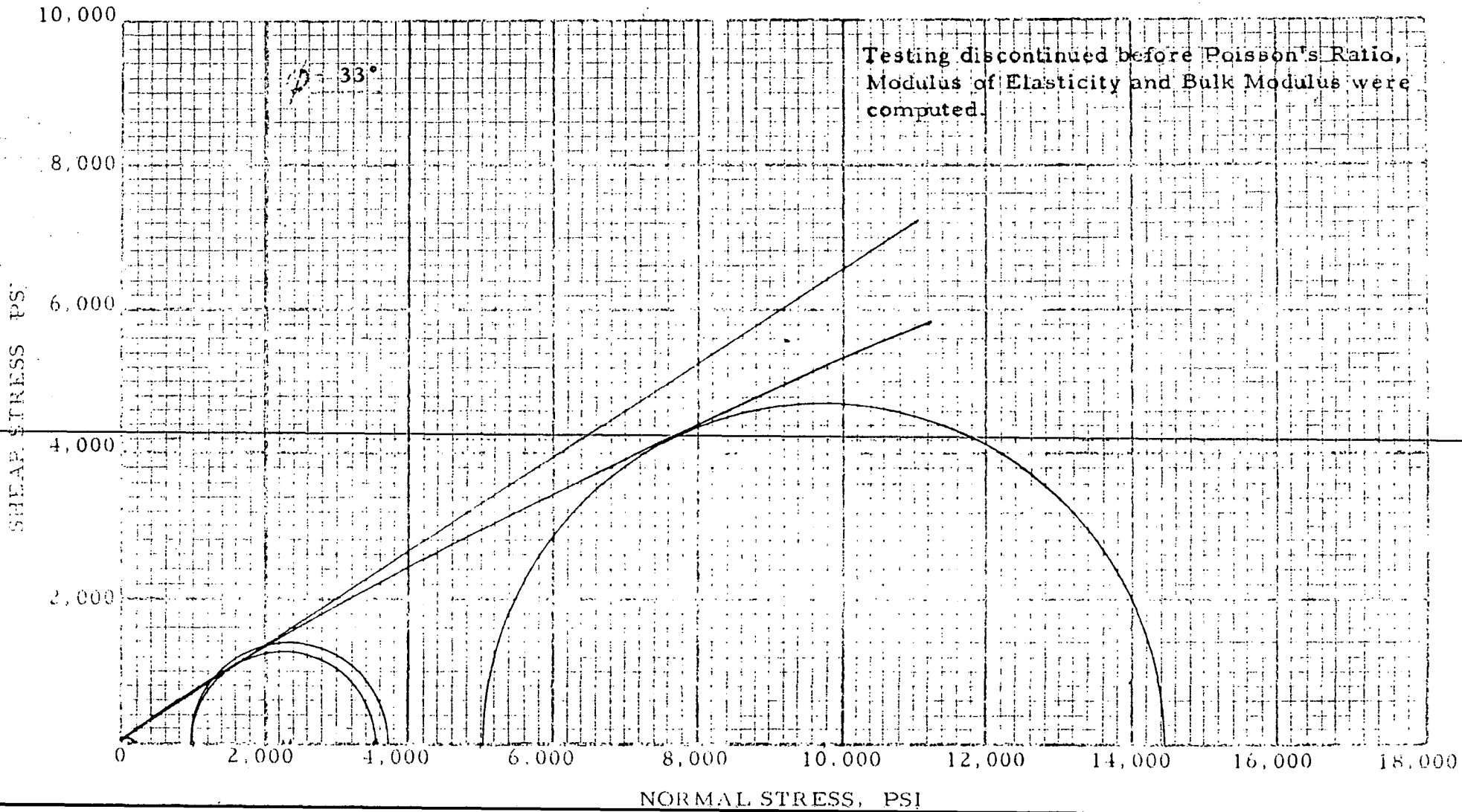
Testing discontinued before Poisson's Ratio, Modulus of Elasticity and Bulk Modulus were computed.

SOIL MECHANICS INCORPORATED

TRIAXIAL COMPRESSION TEST

Project: THE ZIA COMPANY, Los Alamos, N.M. Boring: 4 - Y Job No. 59-154

Lab. No.	Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$ psi	Natural Density, pcf	Nat. Moist. Content, %	Dry Density pcf	Test Moist. Content, %	Diam, in.	Height, in.
6876	0	162		0.7	86.0	5.0	1.75	4.13
6874 (1)	1,000	2700		0.4	87.7	5.0	1.75	4.03
6874 (2)	1,000	2550		0.4	87.0	5.0	1.70	2.48
6872	5,000	9490		0.7	85.0	5.0	1.70	3.11



ANALYSIS OF SAND DATA

ANALYSIS OF BACKFILL SANDS

1. Material. The sand material submitted for analysis consisted of three samples. The first two were obtained from the concrete sand stockpile at the Zia Company Batch Plant. These samples are identified throughout as Lab. Nos. 6784 and 6785. The third sample was obtained from Test Hole 2E in the testing area, and is identified as Lab. No. 6803.

2. Natural Moisture Content. The natural moisture content of the sands, as received in the laboratory, was determined from small samples which were shipped in moisture-proof plastic bags. The moisture content for all 3 samples ranged between 4.4 and 4.6 percent based upon dry weight of the sand.

3. Specific Gravity. The specific gravity of the three samples, both absolute and apparent, is shown by the tabulated data. Samples 6784 and 6785 had identical test values. Sample 6803 had a slightly lower value, and a check test confirmed this slightly lower value. Visual observation does not reveal a reason for the variation.

4. Grain Size. The grain size, or gradation, of the three samples as received is shown by the respective Mechanical Analysis Charts. Sieve analyses were used, without recourse to Hydrometer analysis, since only about 5 percent by weight of particles passed the No. 200 sieve. When classified in accordance with the Unified Soil Classification System adopted by the U. S. Army Corps of Engineers, these sands fit the SW - well graded sand - classification, however they are borderline with the SW-SM classification. (SM is the silty sand category.)

5. Unit Weight. Our opinion was requested of the average unit weight that might be achieved in the sand backfill when dropped into a hole approximately 3 to 5 ft. in diameter and 50 to 100 ft deep. In order to determine this value, several types of laboratory tests were performed.

Initially the relative density test was performed for both the dry and saturated conditions. This information determined the minimum (loosest possible condition) and maximum (densest possible condition) unit weights obtainable by normal laboratory procedures. The minimum density procedure involved placing the sand into a mold by dropping it a short distance through a small funnel. The maximum density procedure involved compacting the sand by a combination of vibrations, tamping and surcharge, but not squeezing under high pressures. It may be noted from the data tabulation that the minimum unit weight was obtained for the dry condition, and varied from 91.5 pcf for 6784 to 97.5 pcf for 6785. The maximum unit weight for the dry condition varied from 119.5 pcf for 6803 to 120.5 pcf for 6785. The minimum unit weight for the saturated condition varied from 106.1 pcf for 6785 to 110.0 pcf for 6803. The maximum unit weight for the saturated condition varied from 118.9 pcf for 6803 to 120.1 pcf for both 6784 and 6785.

It is our opinion that the density obtained in the test holes will vary between the minimums and maximums given above, for any degree of field moisture content used. As a further check of these data, we next performed a compaction test (moisture vs density test) using the procedure outlined in ASTM D 698-58T. These results are shown for Sample 6784 on the data

sheet entitled Soil Compaction Curve. It may be noted that the dry unit weights obtained by this method, which values will approach the maximum obtainable with normal construction techniques, vary between 111.5 psf and 114.3 pcf dry weight. It is noted further that the natural moisture content of about 4.6 percent is in the "bulking range" and will not permit as great a density for the same compactive effort as will moisture contents much drier or wetter. It is our conclusion therefore that, notwithstanding high pressures induced by shocks, the average dry unit weight of the sand placed in the test holes will approximate 107 pcf, or about 112 pcf wet unit weight. The smaller diameter test holes will cause arching in the sand as it is placed, and possibly reduce its average density slightly, whereas the larger diameter test holes may have slightly higher average densities.

6. Retention Moisture. Determination of the maximum moisture content which could be retained in the sand was requested. The procedure involved placing of a small sample of the sand, in its loosest possible condition, in a pan, and in turn placing it is a 100% humid cabinet. The maximum moisture content achieved was 17.7 percent for Sample 6784. Any slight disturbance of the sand however, caused the grains to rearrange and moisture flowed from the specimen, reducing the retained moisture to 15 or less percent. It is our opinion that the probable maximum obtained for any field conditions would approximate 13 or 14 percent.

7. Air Permeability. Permeability to air was determined for the three sand samples at densities approximating those estimated to exist in the

sands in the test holes. The test procedure followed that suggested on Page 588 of "Applied Sedimentation", by Parker D. Trask, John Wiley & Sons, 1950. The specimen was placed dry in a cylindrical mold 1-inch in diameter and 7-inches long at a dry density of approximately 106 pcf. Permeabilities varied between 15.14 and 24.97 darcys. The reason for the lower value for 6784, when compared to 6785 and 6803, is not disclosed.

8. Thermal Conductivity. Thermal conductivity tests were performed for steady state conditions using a 4-inch diameter by 1-inch thick specimen placed at an average dry density of 107 pcf and moisture content in the range of 8.7 to 13 percent. Copper plates retained the specimens within a thick cement-asbestos ring. Values of thermal conductivity are shown by the tabulation on the respective data sheets. Variations in both unit weight and moisture content would result in minor changes in thermal conductivity.

9. Specific Heat. Specific heat tests were performed on the three sand samples using the procedures outlined in "Final Report, Laboratory Research for the Determination of the Thermal Properties of Soils", by Prof. Miles Kersten, Engineering Experiment Station, University of Minnesota, June 1949. The tests are performed on dry loose specimens. The results are corrected mathematically for moisture content. It may be noted that the tabulated results are corrected for 8 percent moisture content in Samples 6785 and 6803, and for 12 percent in Sample 6784. Essentially all those samples would have similar values when corrected

to identical moisture contents.

10. Porosity. A plot of porosity vs density (dry unit weight) is shown for each sample, and is a linear function based upon the specific gravity of the sand. As expected, the curves for both 6784 and 6785 are identical since their specific gravities were identical.

11. Strength Tests. Determination of the strength characteristics of the three sand samples was made by use of both low and high pressure triaxial tests and by direct shear (box shear) tests. In all tests the density attained in the sample was to approximate the average anticipated in the field installation. Moisture contents ranged from dry to probable field maximums.

a. Triaxial Tests. Triaxial specimens of the sands at the beginning of all tests were approximately 1.75 inches in diameter by 3.25 inches in height. The low lateral pressure, 60 psi or less, test specimens were contained within a very thin latex rubber membrane. The confining pressure was applied to the sample by using compressed air within a transparent lucite test cell. Vacuum methods were used to retain the shape of the specimen until the lateral pressure was applied. Loading was applied by an electrically actuated constant-strain loading machine. Loads were determined by calibrated proving rings. Strains were measured by extensometer dial gages of .001 in. accuracy. During testing, the pore pressures which might develop within the test specimen were permitted to be relieved to room atmosphere through perforated base plates and valves.

The high lateral pressure (1,000 and 5,000 psi) tests were performed with a thick-walled steel test cell which utilized hydraulic oil for lateral pressure confinement. The test specimens were placed within a very thin rubber membrane, and in turn within a thicker flexible rubber membrane of about .0469 in. wall thickness. Loading was accomplished through a hydraulically loading 200,000 lb. capacity compression machine. The high and low range recording gages on the loading machine were calibrated to National Bureau of Standards specifications by an independent calibrating service specifically for this testing project.

Results of the low confining pressure triaxial tests, at 20, 40 and 60 psi lateral pressure, and for both the dry and field moisture conditions, showed slight deviations from a theoretical envelope when plotted on the Mohr diagram and, in our opinion, the deviation is attributed primarily to the relative relation between maximum particle size and specimen diameter. The coarse sand particles vary up to 3/8-inch in maximum dimension, and exceed the desirable maximum size for a 1.75 in. specimen diameter. By screening out all plus - No. 10 sieve size particles, more consistent results were obtained. These latter results compared very closely with those of the natural unsieved sand. The following tabulation shows the comparison of low pressure triaxial results for the three samples.

	Angle of Internal Friction		
Sand Condition	Lab No. 6784	No. 6785	No. 6803
Natural, dry	35.7°	35.7°	33.0°
Natural, moist	35.0°	35.2°	38.0°
Minus #10 Sieve, dry	35.0°	37.2°	39.0°
Minus #10 Sieve, moist	35.3°	34.4°	34.5°

It may be concluded from these tests that, in the low ranges of lateral pressure, the angle of internal friction is virtually unaffected by moisture content variations for a constant unit weight. Though slight variations occurred in the unit weights of the test specimens, they are considered to be within the range of experimental variation, and the angles of internal friction are valid. It is our conclusion that a value of 34° to 35° be assigned as the internal friction angle of these sands.

The high lateral pressure triaxial tests presented further variations in the test results. It was noted that application of 1,000 psi lateral pressure to the natural sand, placed at about the same unit weight as in the low lateral pressure triaxial tests, caused reduction in volume of the specimen (both diameter and length) and increased the unit weight. Measurements of all three sand samples revealed that the lateral pressure of 1,000 psi reduced the specimen area by about 3.7 percent, and its height by about 2.3 percent. At 5,000 psi lateral pressure the average area was reduced about 7.2 percent and the height was reduced about 4 percent.

As a consequence of the volume change, direct comparison of the angle of internal friction for the low lateral pressure tests cannot be made with the high lateral pressure tests - due primarily to the higher densification. The Mohr diagrams for the high pressure tests show that the envelope is not a tangent, as is usually typical for low pressure testing, but is a decreasing curve. The friction angles determined for the Mohr diagrams are based upon the apparent virgin tangent portion, rather than the curve. Summary of the angles of internal friction determined for the

three high pressure sands tests are as follows:

Sand Condition	Angle of Internal Friction Lab No. 6784	No. 6785	No. 6803
Dry	43.5°	44.0°	43.0°
Moist	41.0°	42.0°	41.3°

It may be concluded that the effect of high lateral pressure results in an increase in the unit weight of the sand, and consequently an increase in the effective angle of internal friction. The effect of moisture is a reduction of approximately 2° in the angle of internal friction, which conforms to the conclusion cited on Page 83 of "Soil Mechanics In Engineering Practice", by Terzaghi and Peck, John Wiley & Sons, 1948, wherein it states "the results of slow-shear tests on saturated samples are identical with those on the same sand at equal relative density in a dry state, except that the angle (of internal friction) is likely to be 1° to 2° smaller for the saturated sand".

It was noted visually that, upon removal of the sand specimens from the high lateral pressure triaxial tests, the sand had been crushed and degraded. In order to determine the extent of degradation, we performed sieve analyses on the samples after testing. The results revealed that the percentage of particles passing the No. 200 mesh sieve is increased by an average 13 percent following the 1,000 psi lateral pressure triaxial test, and by 21 percent following the 5,000 psi test. The degradation in itself may affect the determined angles of internal friction, and in part account for the curvature of the Mohr failure envelope between the 1,000 and

5,000 psi lateral pressures. Mechanical analysis charts for the "before" and "after" conditions of each sand sample are attached.

b. Direct Shear Tests. Direct shear, oftentimes termed box-shear, tests were performed on each of the three sand samples, using confining pressures in the low range (0 to 60 psi). Sample size was 3 in. by 3 in. by 0.8 in. thick. Sand specimens were placed in the confining box at both dry and anticipated field moisture conditions, and at unit weights comparable to those anticipated in field conditions. Results of each test are plotted to show the volume and stress changes during loading. The average angles of internal friction are shown for each laboratory sample, and for both the dry and moist conditions, on separate data sheets. A summary of the angles of internal friction are as follows:

	Angle of Internal Friction					
Sand Condition	Lab No. 6784		No. 6785		No. 6803	
	Peak	Ultimate	Peak	Ultimate	Peak	Ultimate
Dry	36.5°	34.9°	32°	29.3°	36.4°	34.8°
Moist	37.5°	35.4°	33°	32.3°	34.5°	33.2°

The above values compare very favorably with the average of 34° to 35° determined from the low lateral pressure triaxial tests.

12. Pressure vs Specific Volume. At Mr. Newman's request for the relationship between confining pressure and specific volume, a test procedure was adopted in which a specimen of the sand was confined within a floating steel ring, and plunger pressures from 0 to 10,000 psi or more applied. It was anticipated that crushing and degradation of particles would occur, and that the ratio of sample thickness to sample height would likewise

affect the results. The latter is a function of the wall friction area and sample volume, and possibly a function of arching within the sand in thick samples. Inasmuch as Samples 6784 and 6785 were reasonably identical, only the 6784 was tested. The 6803 sample was also tested. The results are plotted in a manner similar to that used for soil type consolidation tests, and show Density vs Log of Pressure.

It may be noted that the initial height of sample affects directly the change in density (and volume) with increase in pressure. Consequently we tested initial sample thicknesses of 1, 2 and 3 inches, in the 4-inch diameter mold. The capacity of our loading machines permitted loading in excess of 10,000 psi, so we continued some of the tests to as high as 20,000 psi. for academic reasons. Rebound curves were obtained to the extent possible, however it was difficult to determine the point of final release of load.

It was obvious from visual inspection the high pressures degraded the sands. Consequently mechanical analyses tests were made, and the results plotted, for the six samples after testing. By comparison with the original gradation, the percentage of fines passing the No. 200 mesh sieve increased approximately 5 to 13 percent, depending upon sample thickness and pressure. On the other hand, this type of static load test did not degrade the sand nearly as much as the high pressure triaxial tests.

SUMMARY OF LAB TESTS ON SAND SAMPLE 6784

1.	Natural Moisture Content	4.4
2.	Specific Gravity - Absolute	2.615
	- Apparent	2.615
3.	Minimum Dry Density - Dry	91.5 pcf
	-	91.6 pcf
4.	Maximum Dry Density - Dry	119.9 pcf
	-	120.1 pcf
5.	Minimum Dry Density - Saturated	109.4 pcf
	- Moisture	15.2 %
	- Saturated	108.9 pcf
	- Moisture	15.2 %
6.	Maximum Dry Density - Saturated	120.1 pcf
	- Moisture	11.2 %
	- Saturated	118.7 pcf
	- Moisture	11.2 %
7.	Retention Moisture (humid Atmosphere - drained)	17.7%
8.	Air Permeability (pack density 105.9 pcf)	15.14 darcys

9. Thermal Conductivity: 0.89 BTU/Hr-sq ft - °F/ft at an average temperature of 111.3° F., a dry density of 107 lb/cu ft, and a moisture content of 13.0% of dry weight.

10. Specific Heat: 0.288 BTU/lb-°F between the temperature limits of 77.6 and 212.0°F. and a moisture content of 12% of dry weight for loose soil as received.

11.	Standard Compaction Curve	attached
12.	Grain size curve	attached
13.	Porosity vs Density Curve	attached
14.	Mohr Diagrams (low lateral pressure)	attached
15.	Mohr Diagrams (high lateral pressures)	attached
16.	Grain size curve (after high pressure tests)	attached

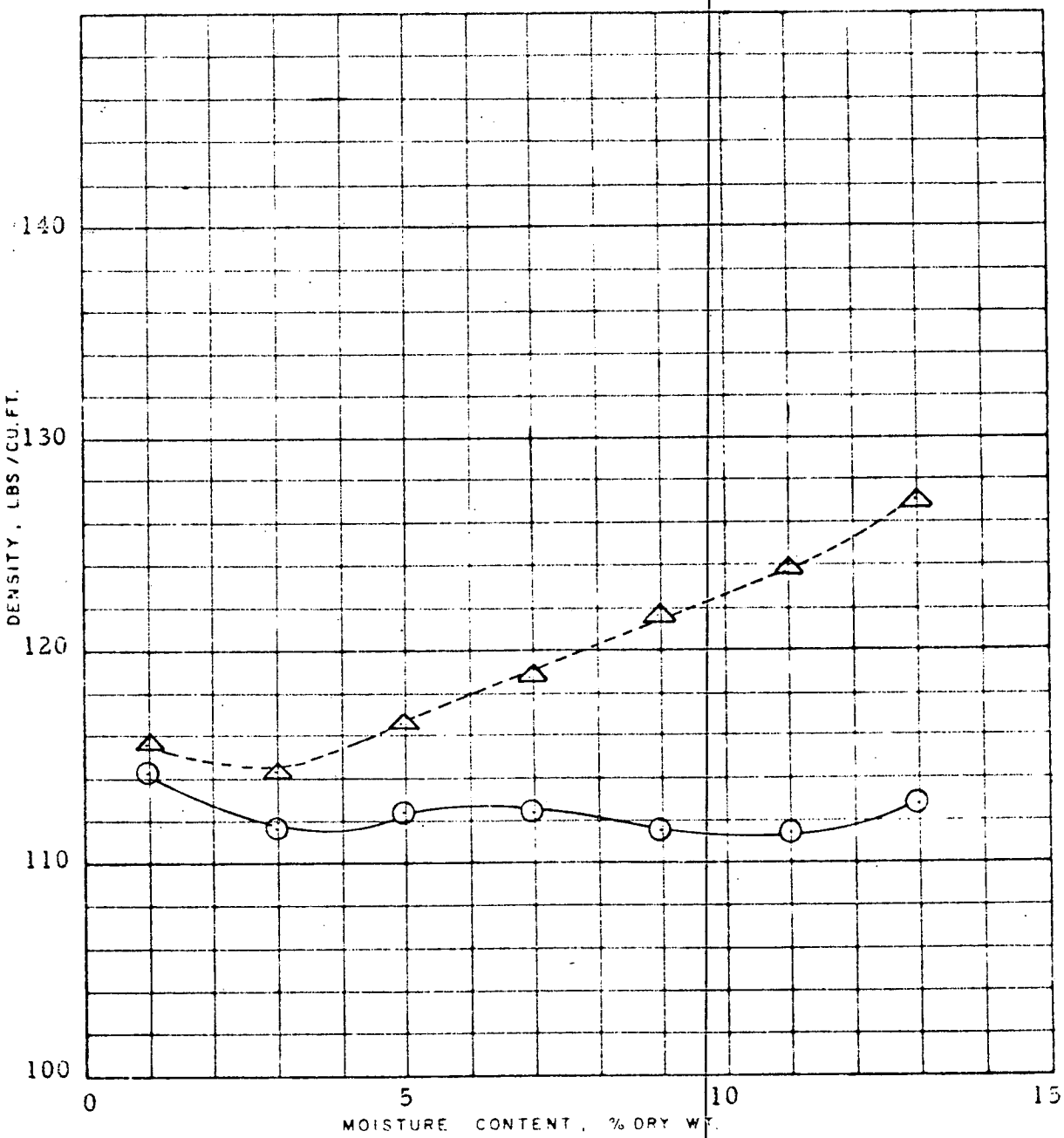
17.	Direct Shear Tests	attached
18.	Density vs Log Pressure Curve	attached
19.	Grain size Curve (log pressure curve)	attached

SOIL COMPACTION CURVE

PROJECT The Zia Company JOB NO 59-154 DATE

BORING NO. SAMPLE NO 6784 DEPTH

METHOD OF COMPACTION Standard TECHNICIAN



OPTIMUM MOISTURE CONTENT _____ %

MAXIMUM DENSITY DRY _____ LBS/CU FT

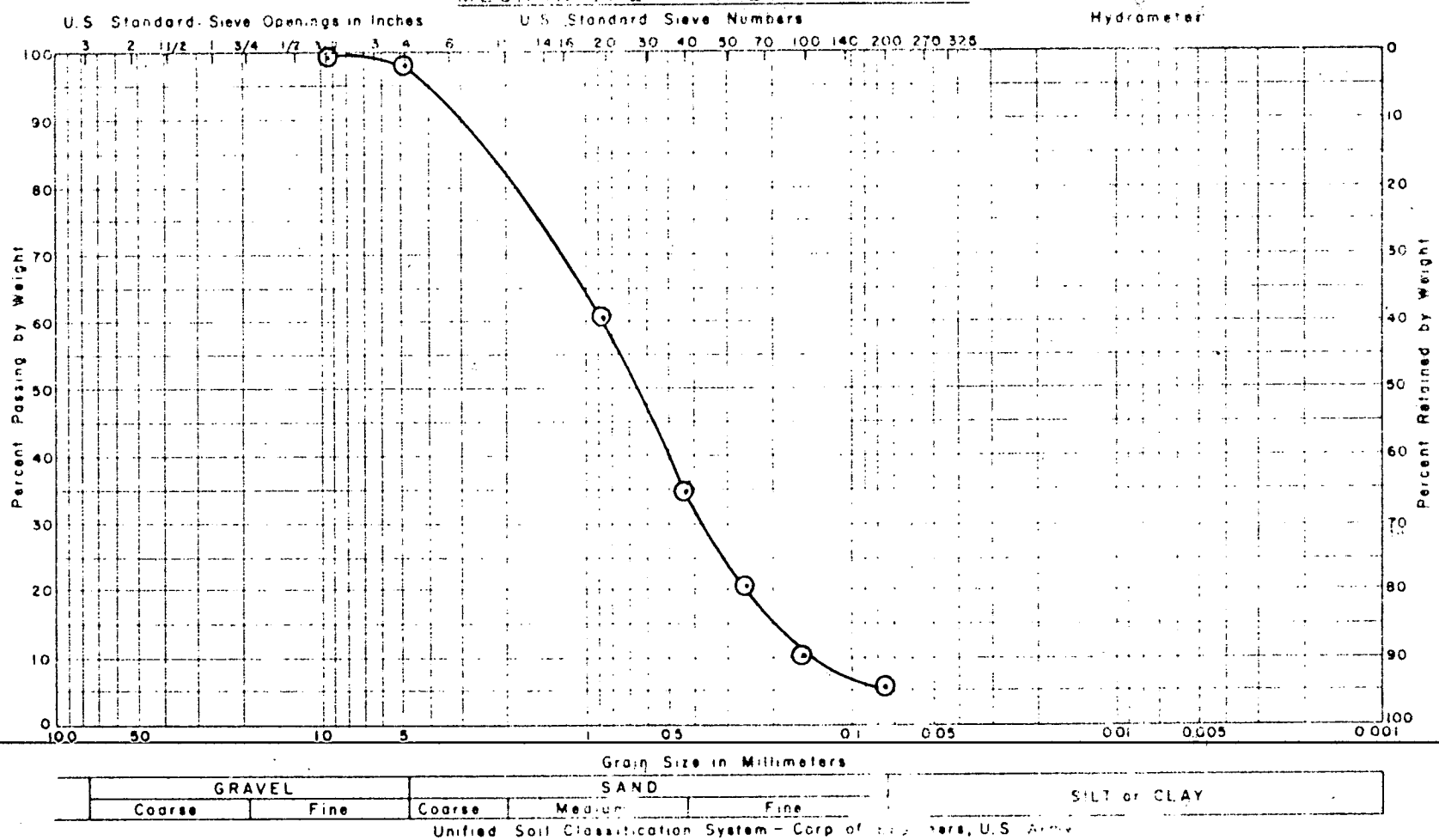
MAXIMUM DENSITY WET _____ LBS/CU FT

LEGEND

DRY DENSITY ————

WET DENSITY — — — —

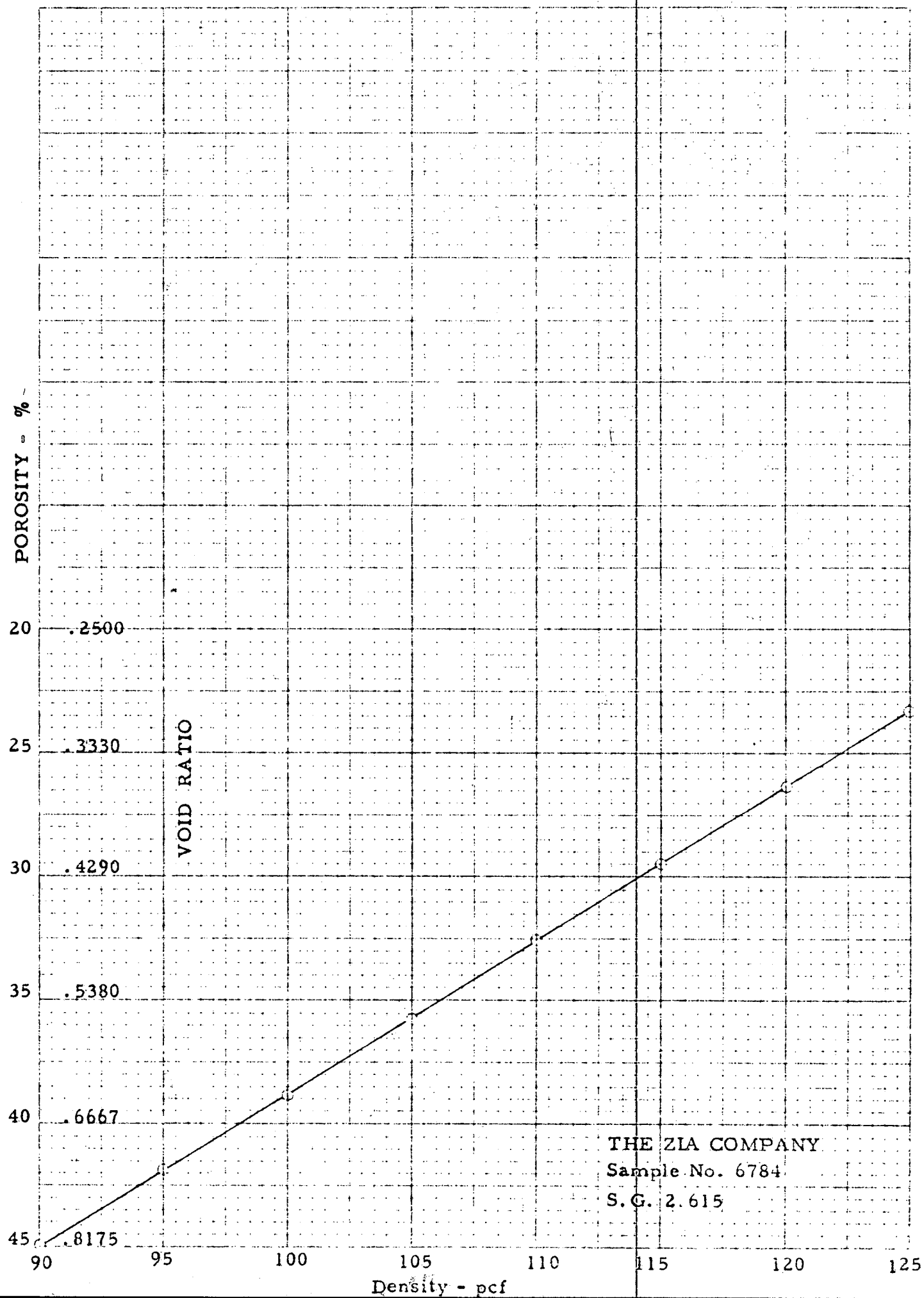
MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

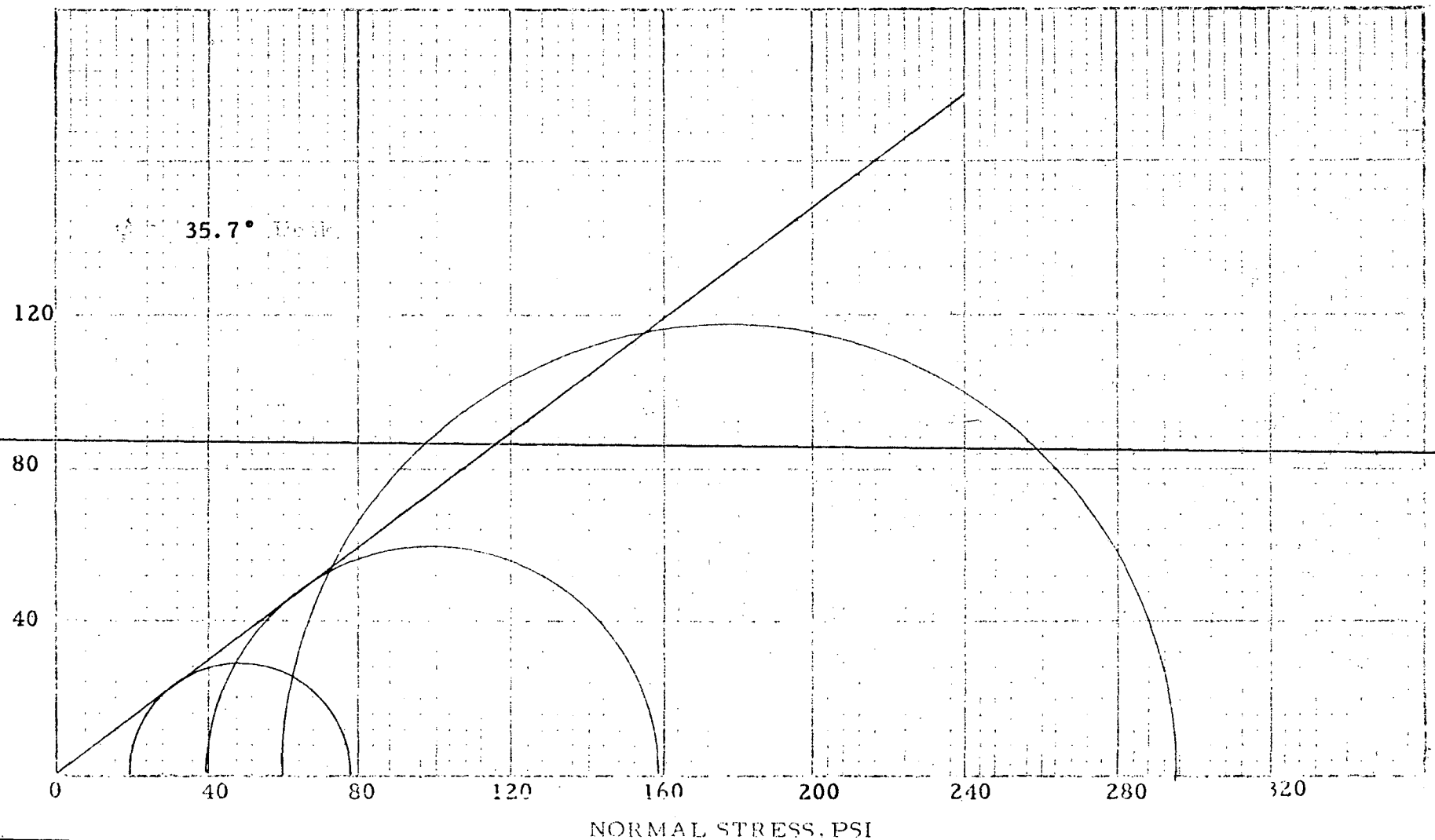
The Zia Company
Sample No. 6784


POROSITY - %
VOID RATIO
20 .2500
25 .3330
30 .4290
35 .5380
40 .6667
45 .8175
90
95
100
105
110
115
120
125
Density - pcf
THE ZIA COMPANY
Sample No. 6784
S.G. 2.615

SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6784

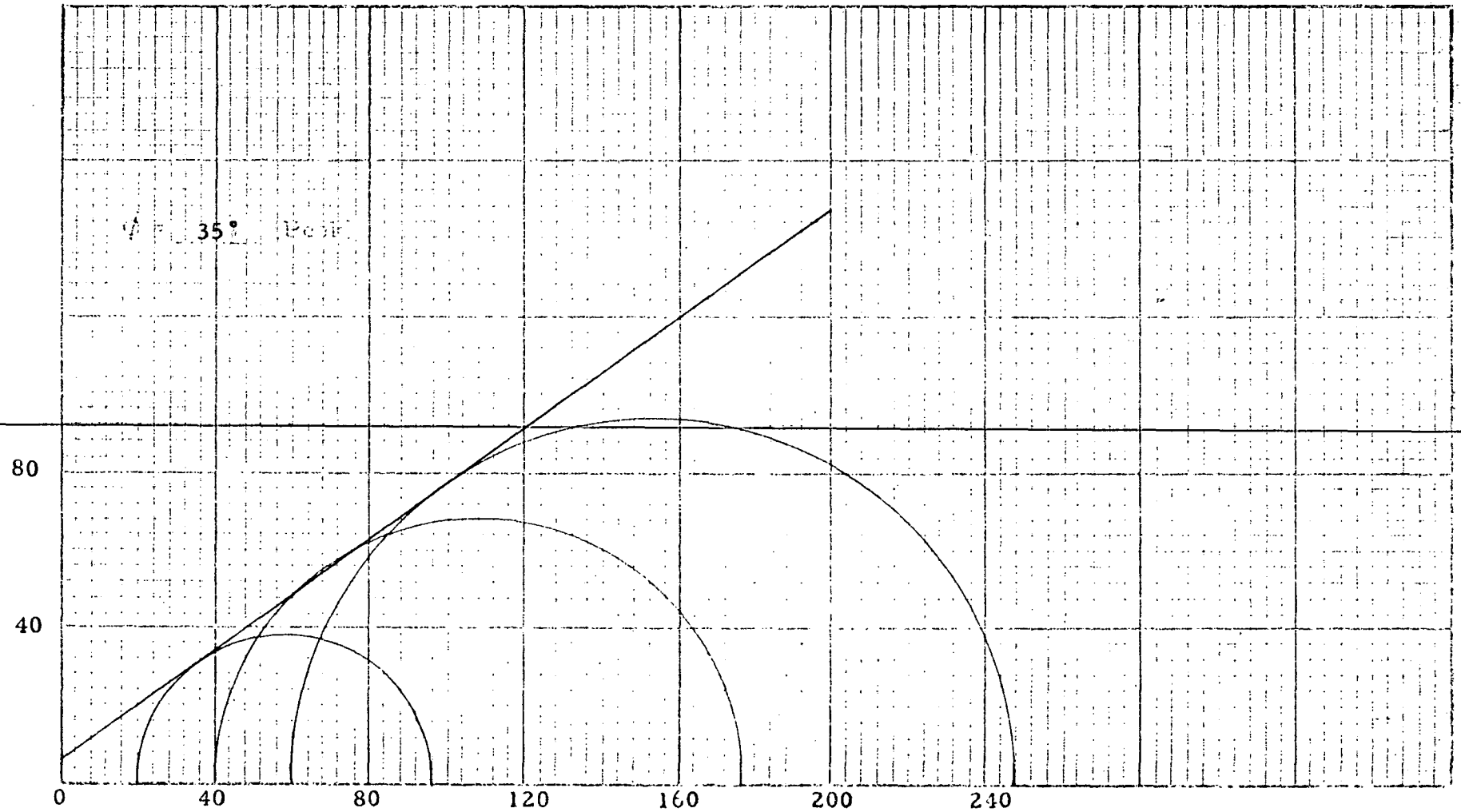
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ pcf	Moisture content, %	Remarks:
20	58.4	102	0	
40	119	106	0	
60	234	107.6	0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6784

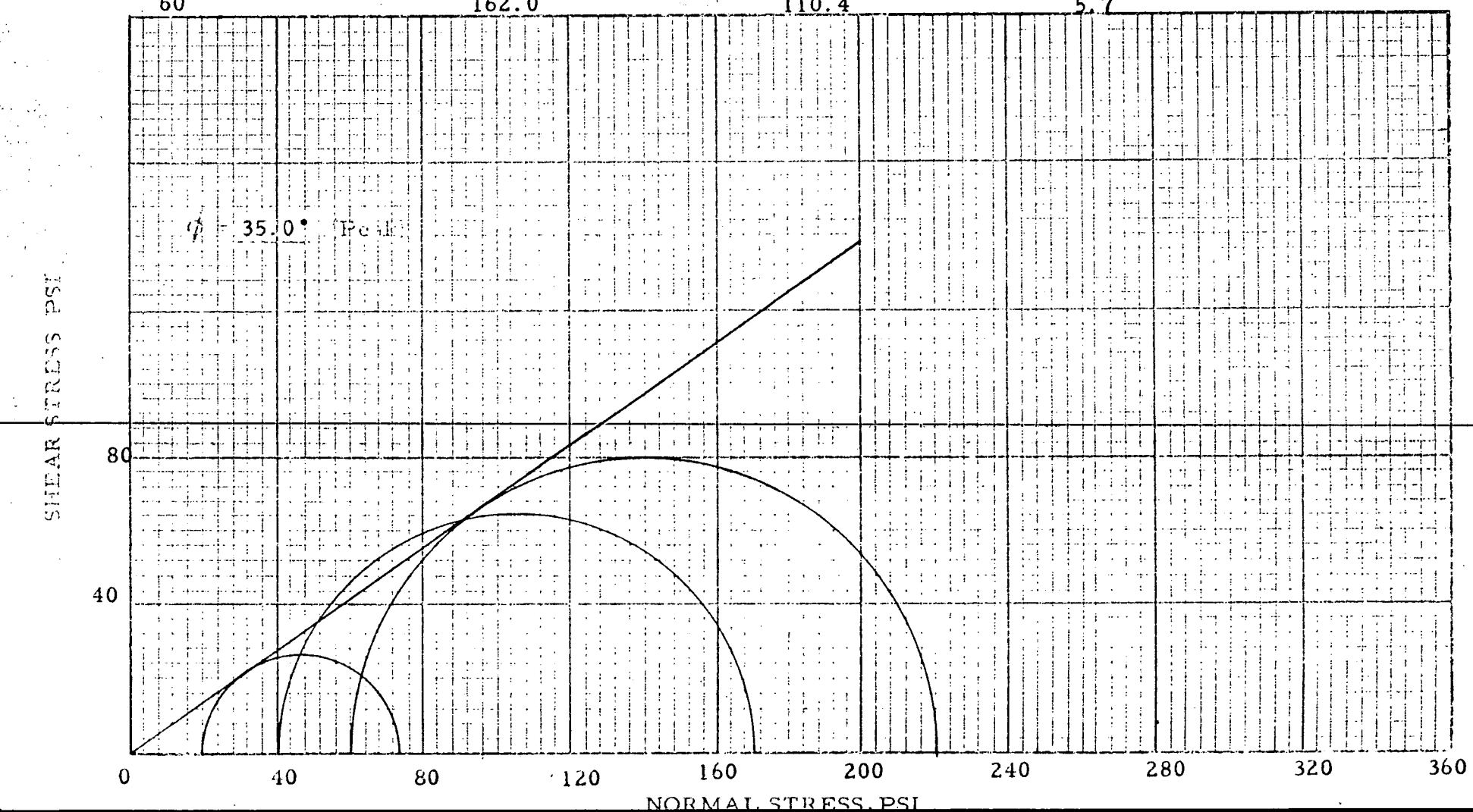
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	75	105.4	0	Material Passing
40	137	105.4	0	No. 10 Sieve
60	186	105.4	0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6784

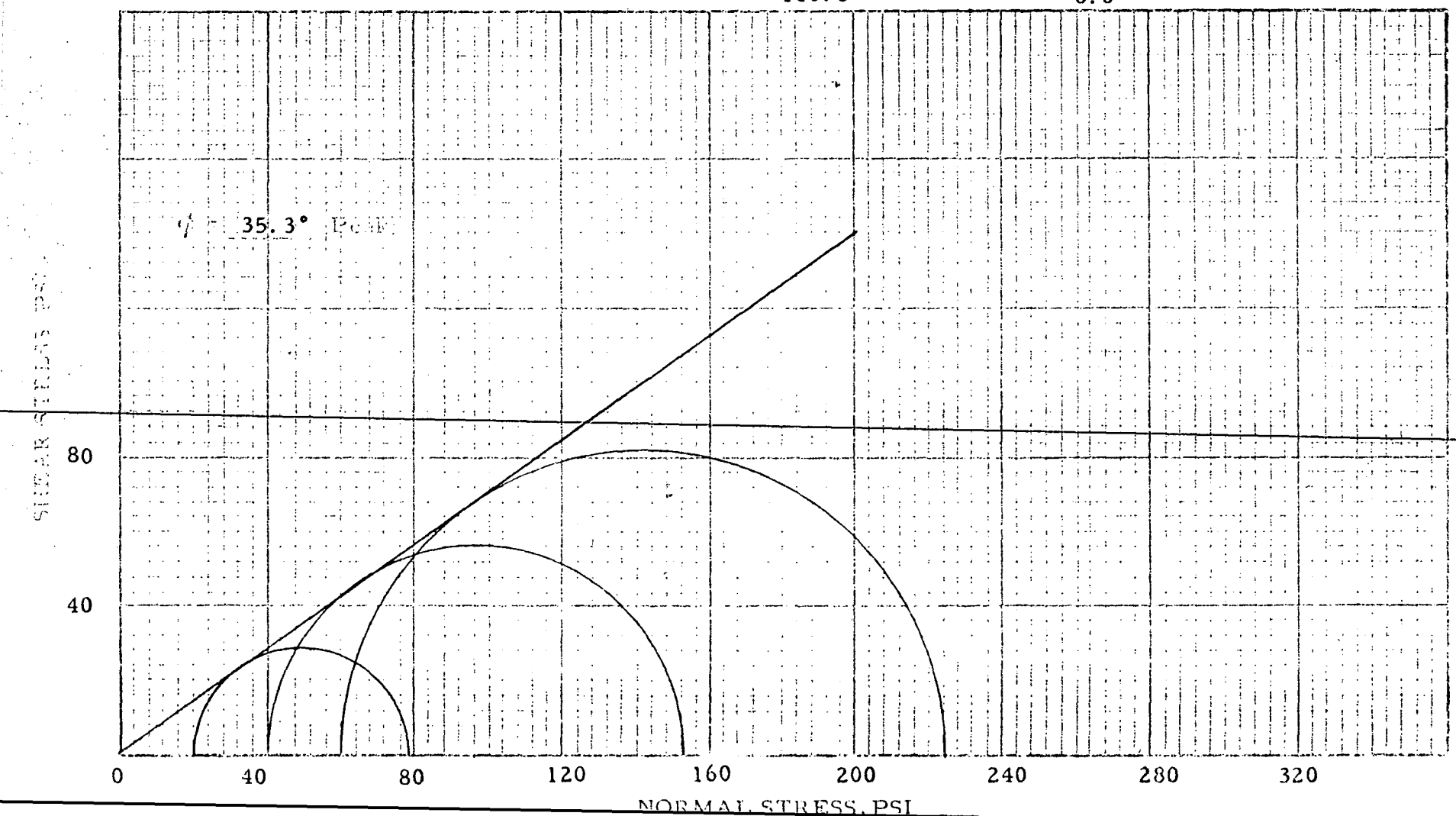
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	54.4	111.0	4.4	
40	131.0	103.0	7.4	
60	162.0	110.4	5.7	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6784

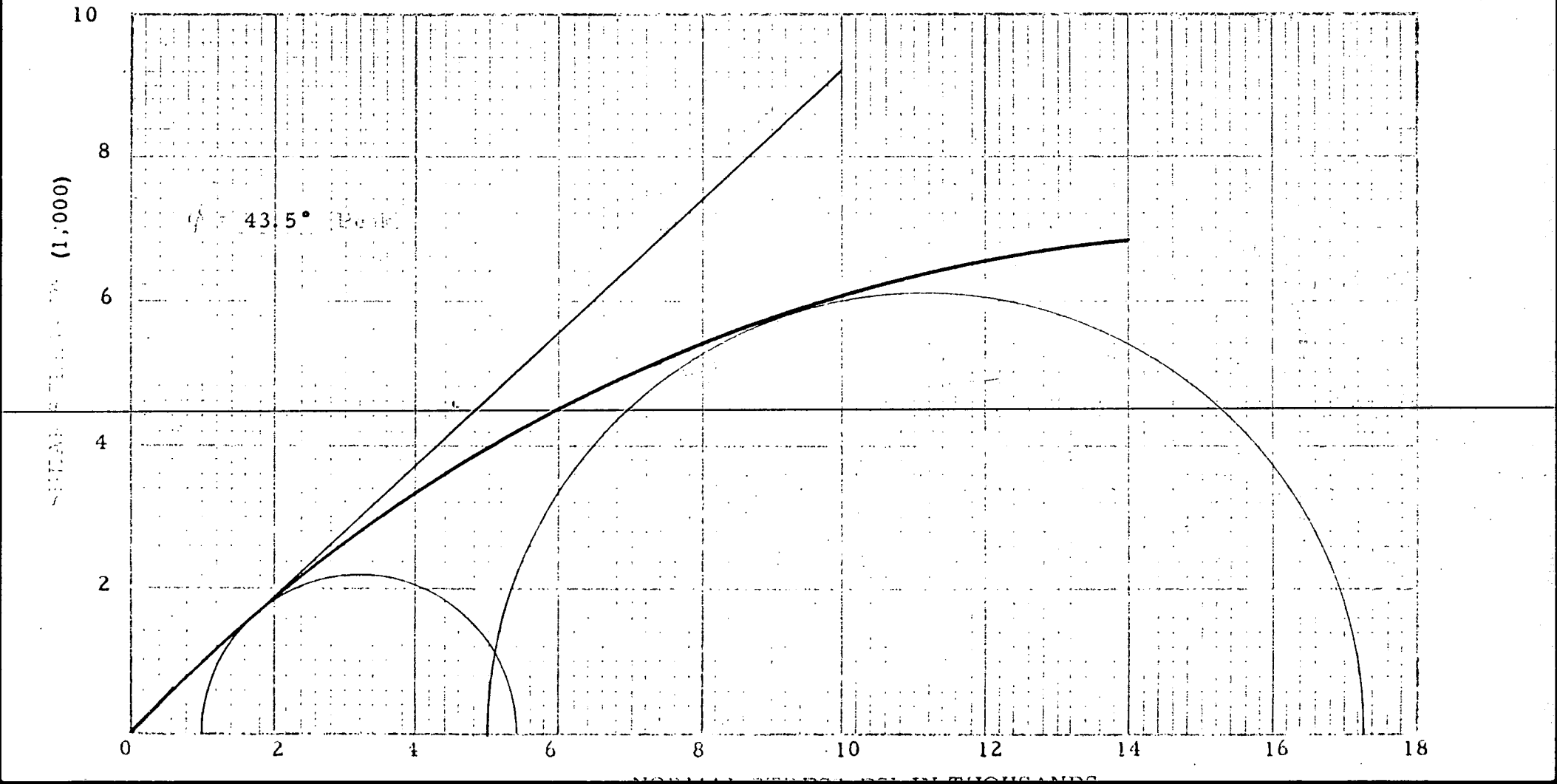
Confinement σ_3, psi	Max. Stress $\sigma_1 - \sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	58	106.8	6.9	Material Passing No. 10 Sieve
40	112	110.4	6.5	
60	164	110.8	6.0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6784

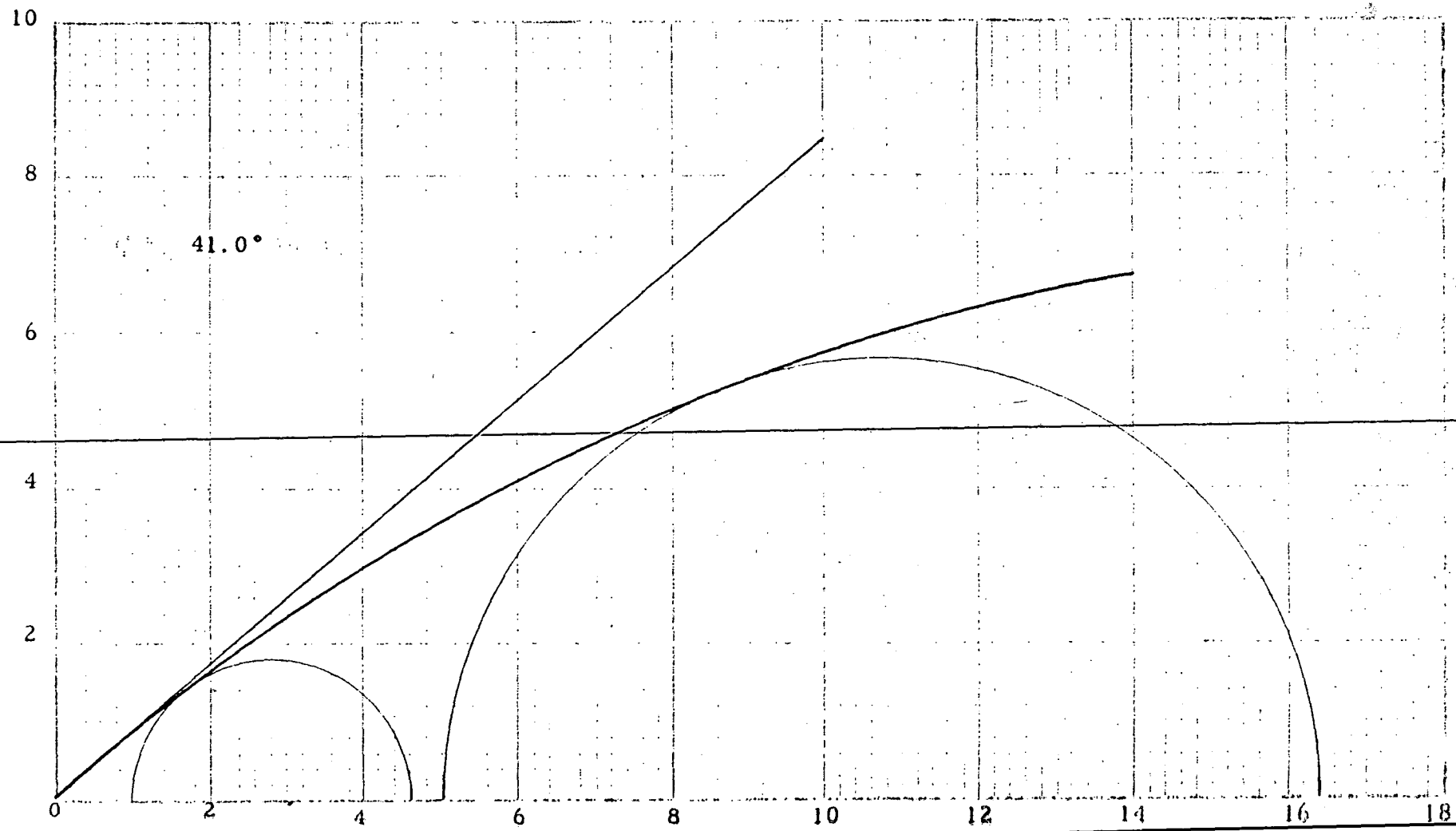
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density Before test, pcf	Dry Density After Applying Lateral Press.	Moisture content, %	Remarks: Before Test
1,000	4,430	112.0	119.8	0	Dia. 1.75 in. Length 3.06 in.
5,000	12,330	109.6	123.4	0	Dia. 1.75 in. Length 3.12 in.



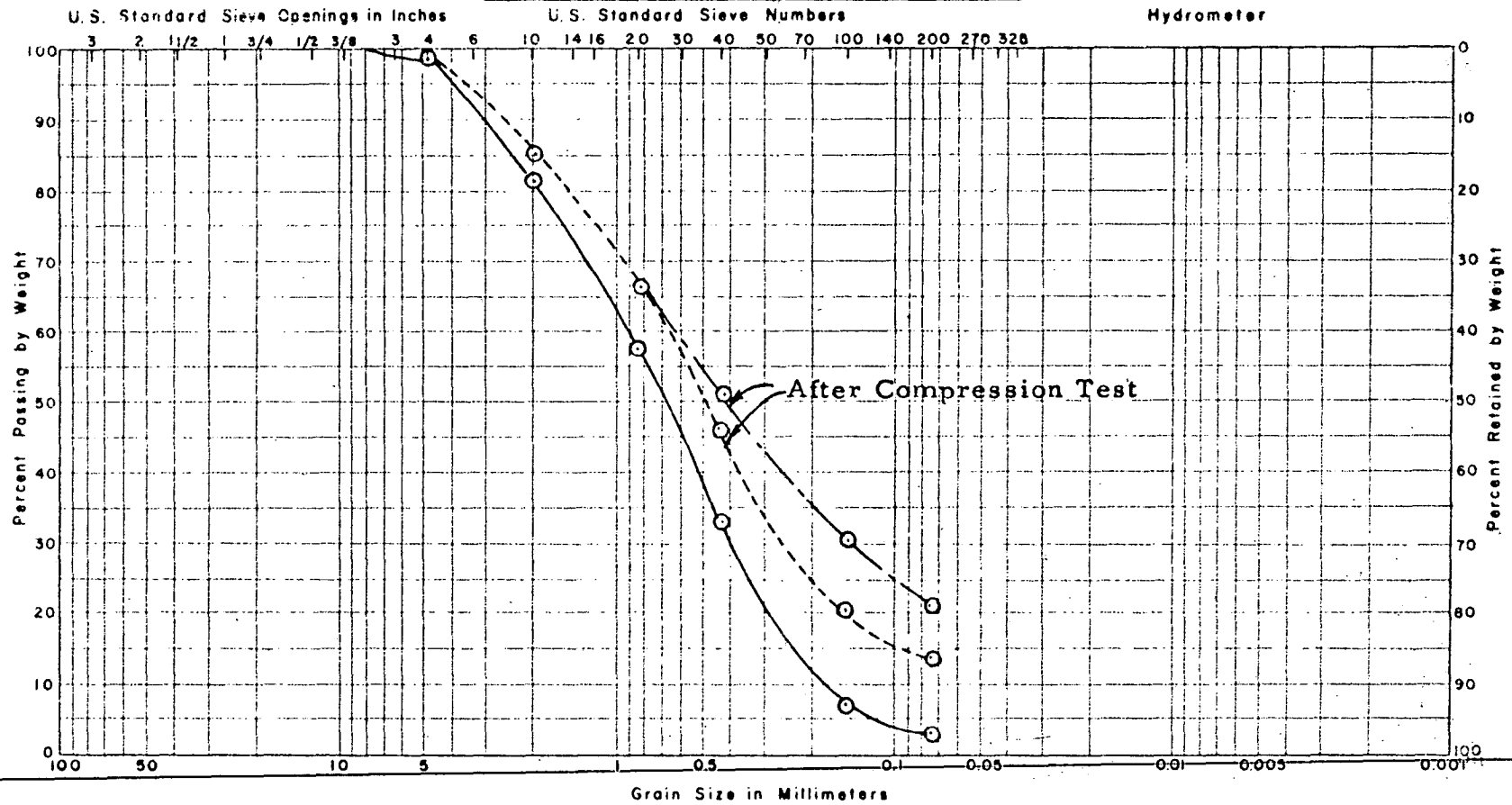
SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6784

Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density Before Test, pcf	Dry Density After Applying Lateral Press.	Moisture content, %	Remarks: Before Test
1,000	3,600	108.5	115.4	6.8	Dia. 1.75 in. Length 3.19 in.
5,000	11,540	109.8	123.2	5.5	Dia. 1.75 in. Length 3.19 in.



MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

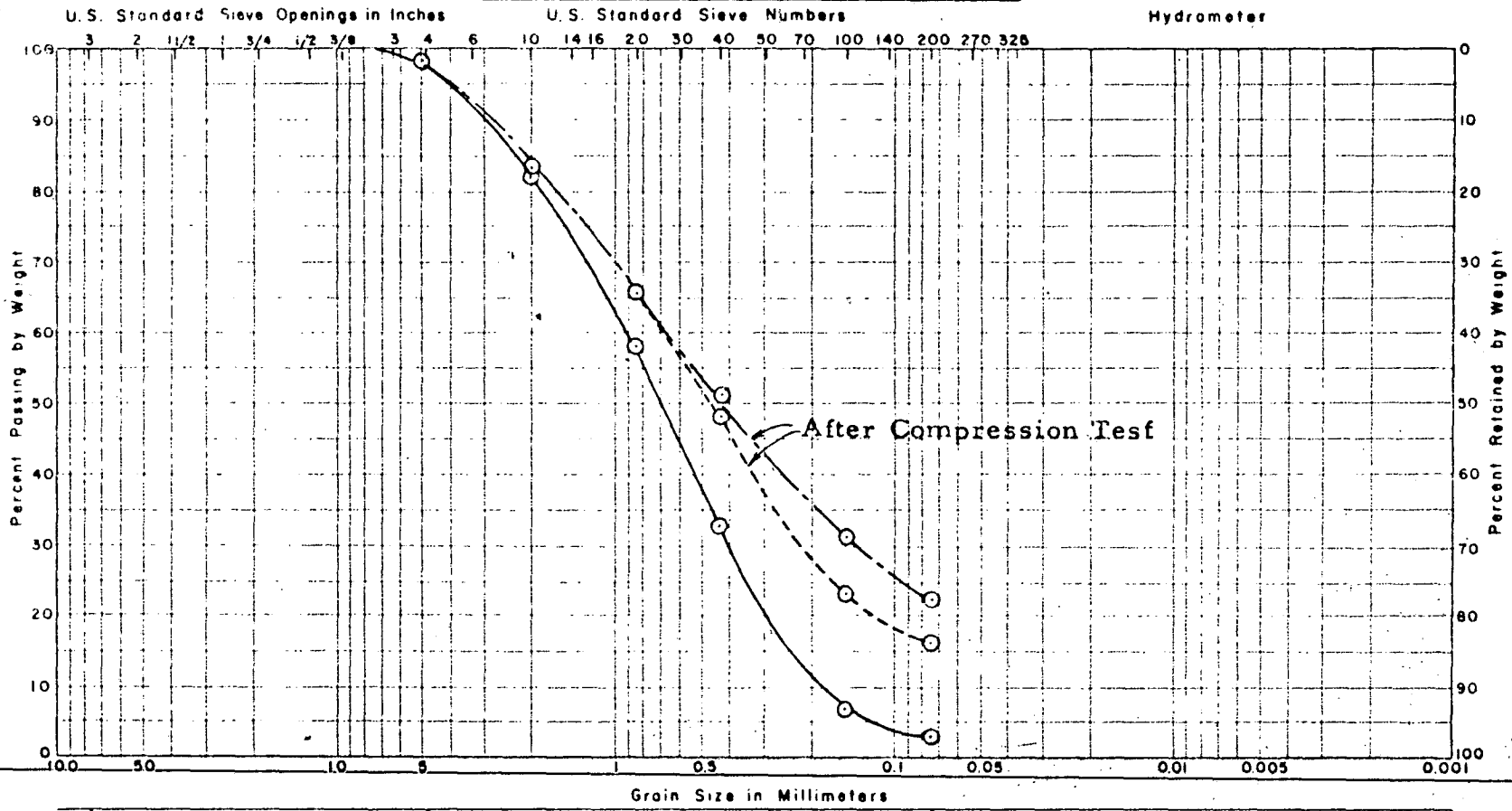
THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab No. 6784

LEGEND	MOISTURE CONTENT
———— Natural Condition	0
- - - - - - - - After 1,000 psi Lateral Pressure	0
—— - - —— After 5,000 psi Lateral Pressure	0

Concrete Sand

SOIL MECHANICS INCORPORATED

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

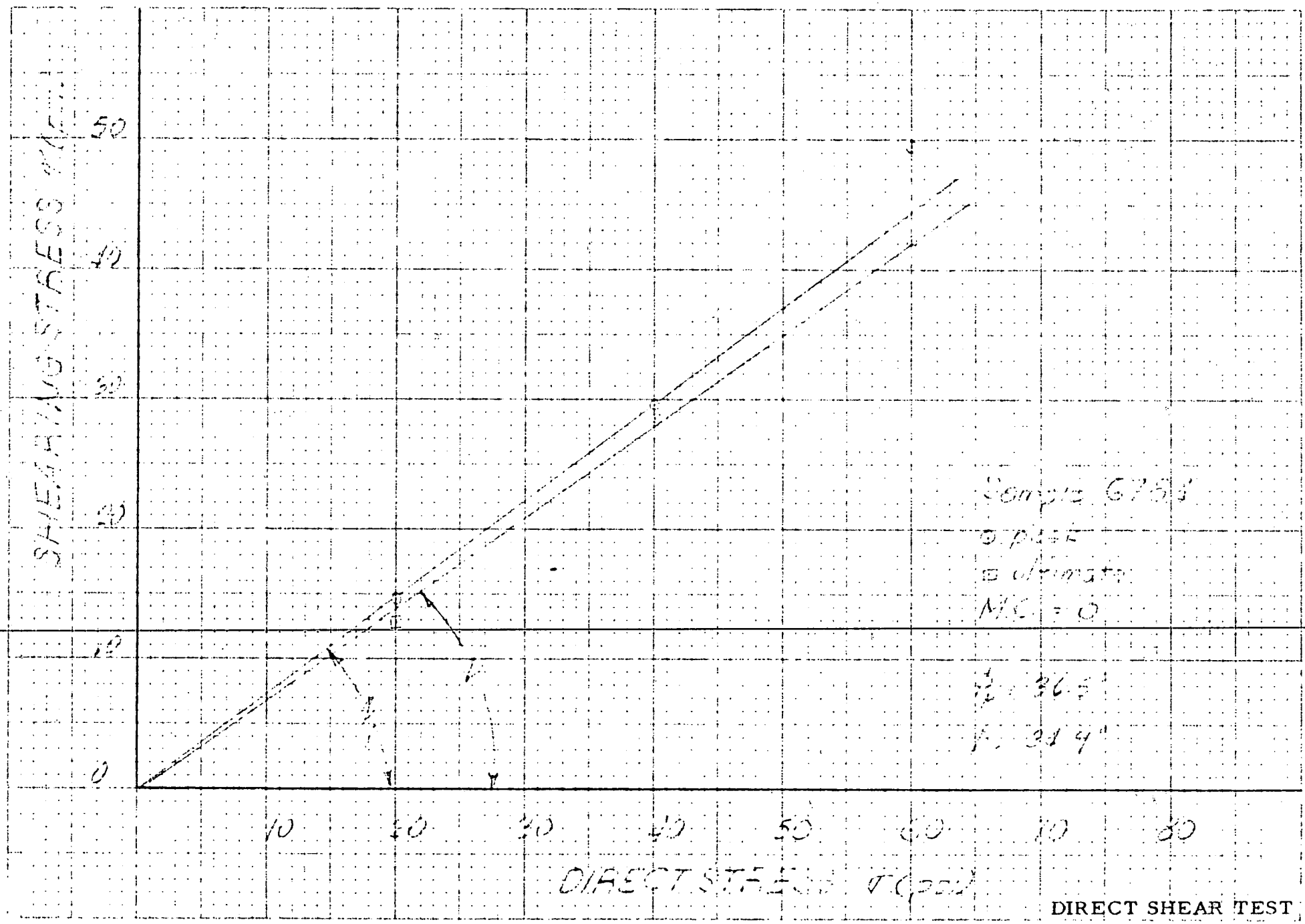
THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab No. 6784

Concrete Sand

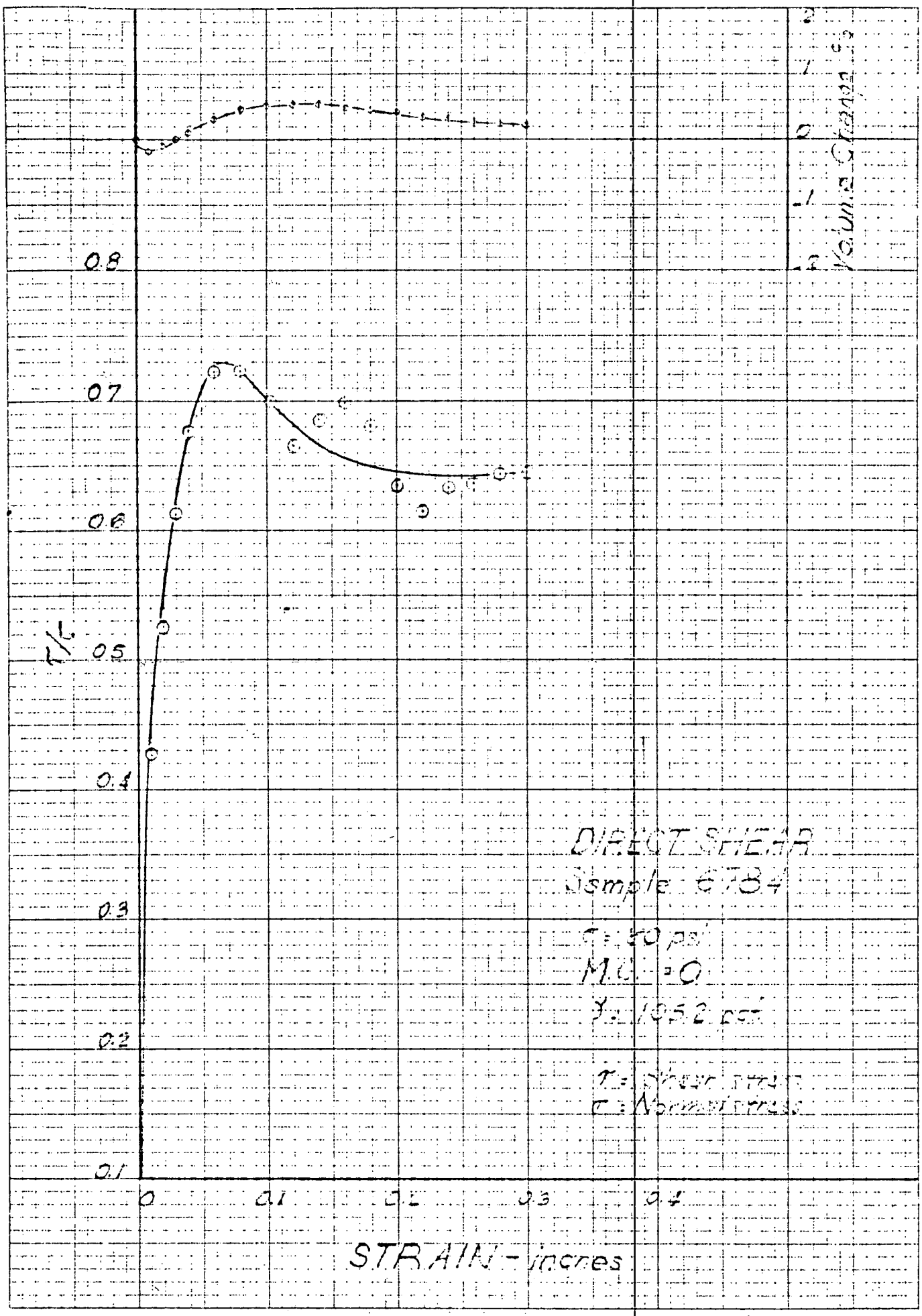
LEGEND	MOISTURE CONTENT
———— Natural Condition	-
- - - - - - - After 1,000 psi Lateral Pressure	6.8
—— · —— After 5,000 psi Lateral Pressure	5.5

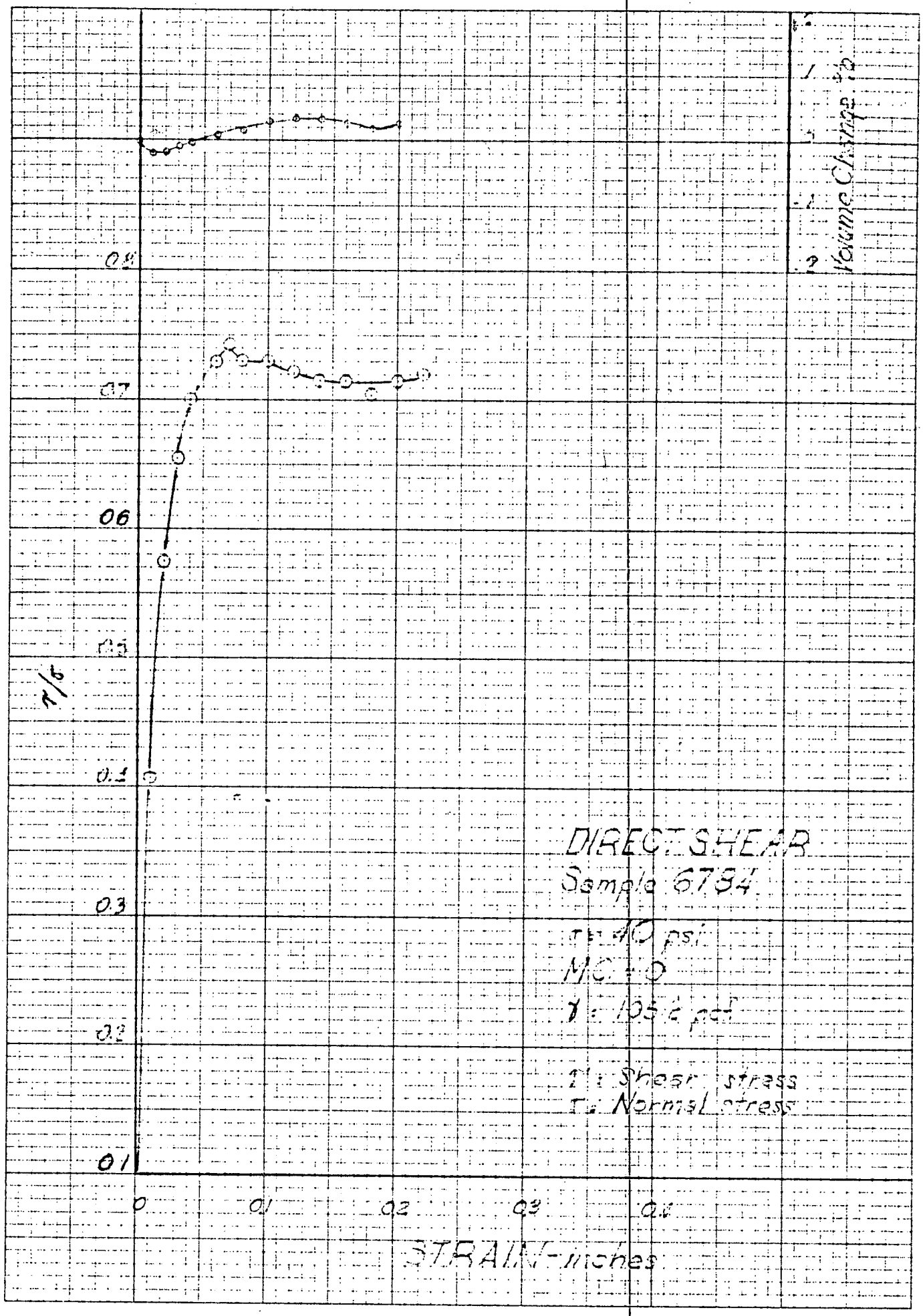
SOIL MECHANICS INCORPORATED

NO 340 10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.

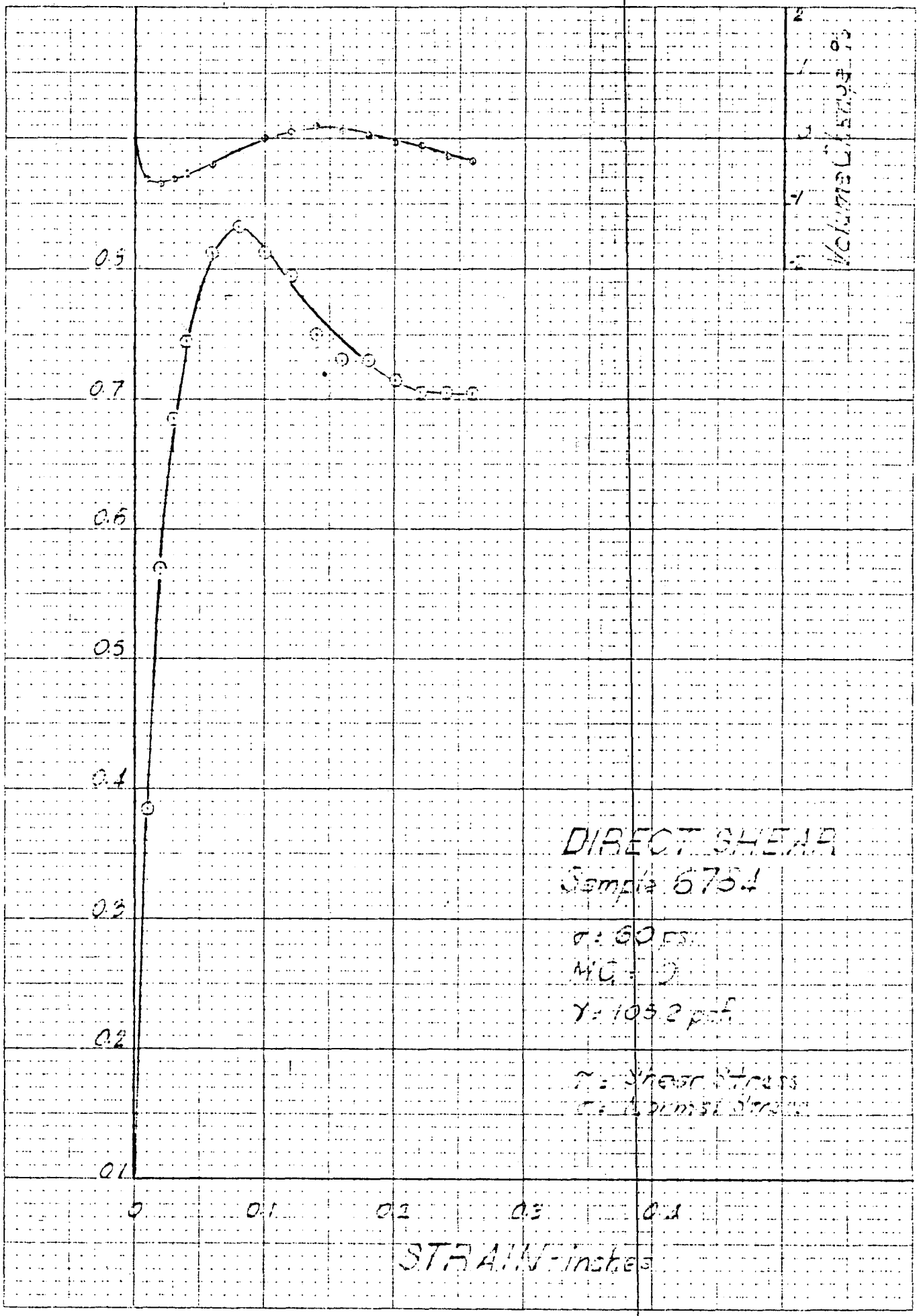


DIRECT SHEAR TEST

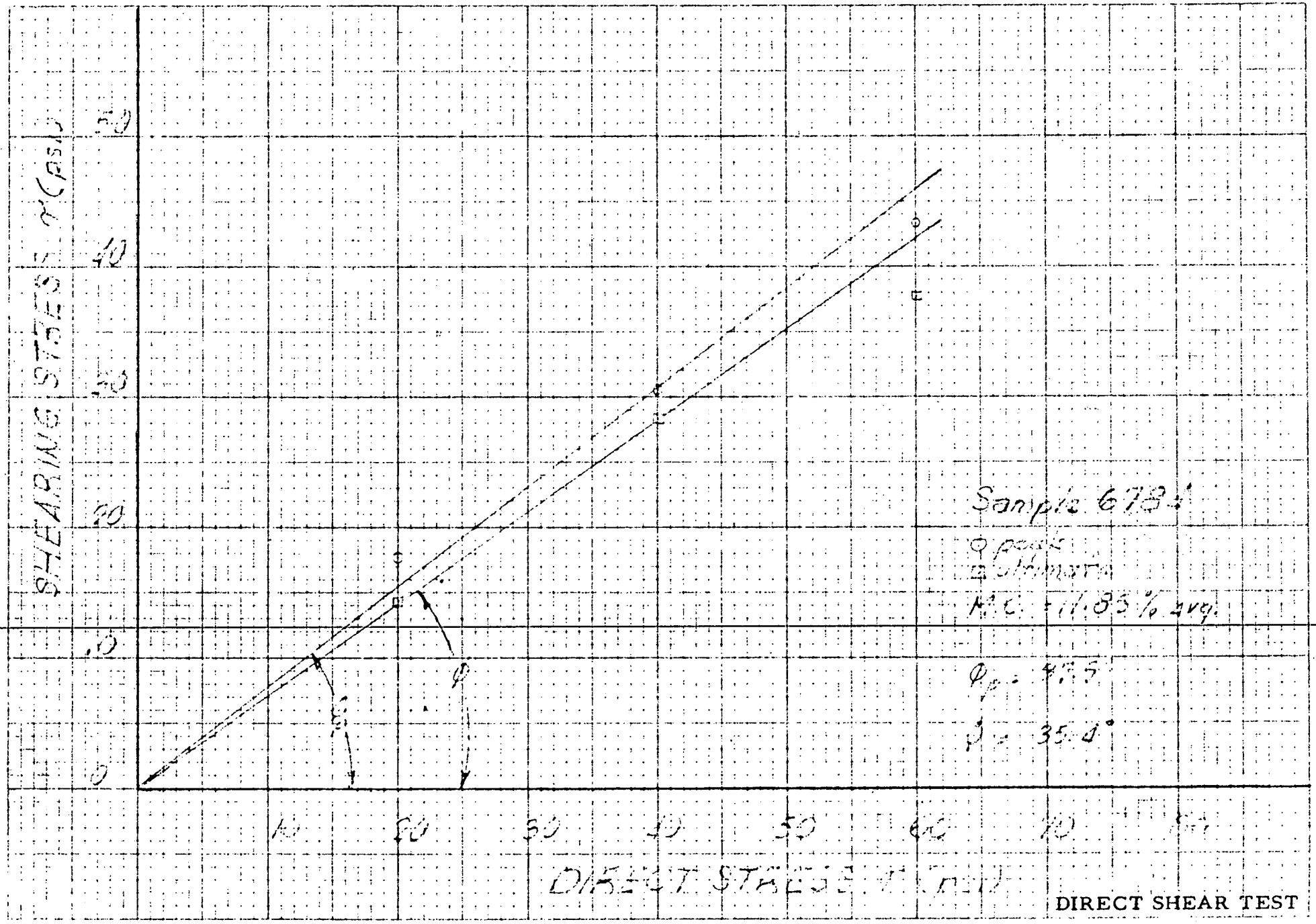

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
τ/σ
0
0.1
0.2
0.3
0.4
STRAIN - inches
2
1
0
-1
-2
VOLUME CHANGE
DIRECT SHEAR
Sample 6784
σ = 50 psi
M.C. = 0
γ = 105.2 pcf
τ = Shear stress
σ = Normal stress



EUGENE DIETZGEN CO.
NO. 3-10R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH


0.9
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
STRAIN-inches
VOLUMETRIC STRAIN
DIRECT SHEAR
Sample 6754
σ = 60 psi
MC = 0
γ = 105.2 pcf
τ = shear stress
σ = normal stress

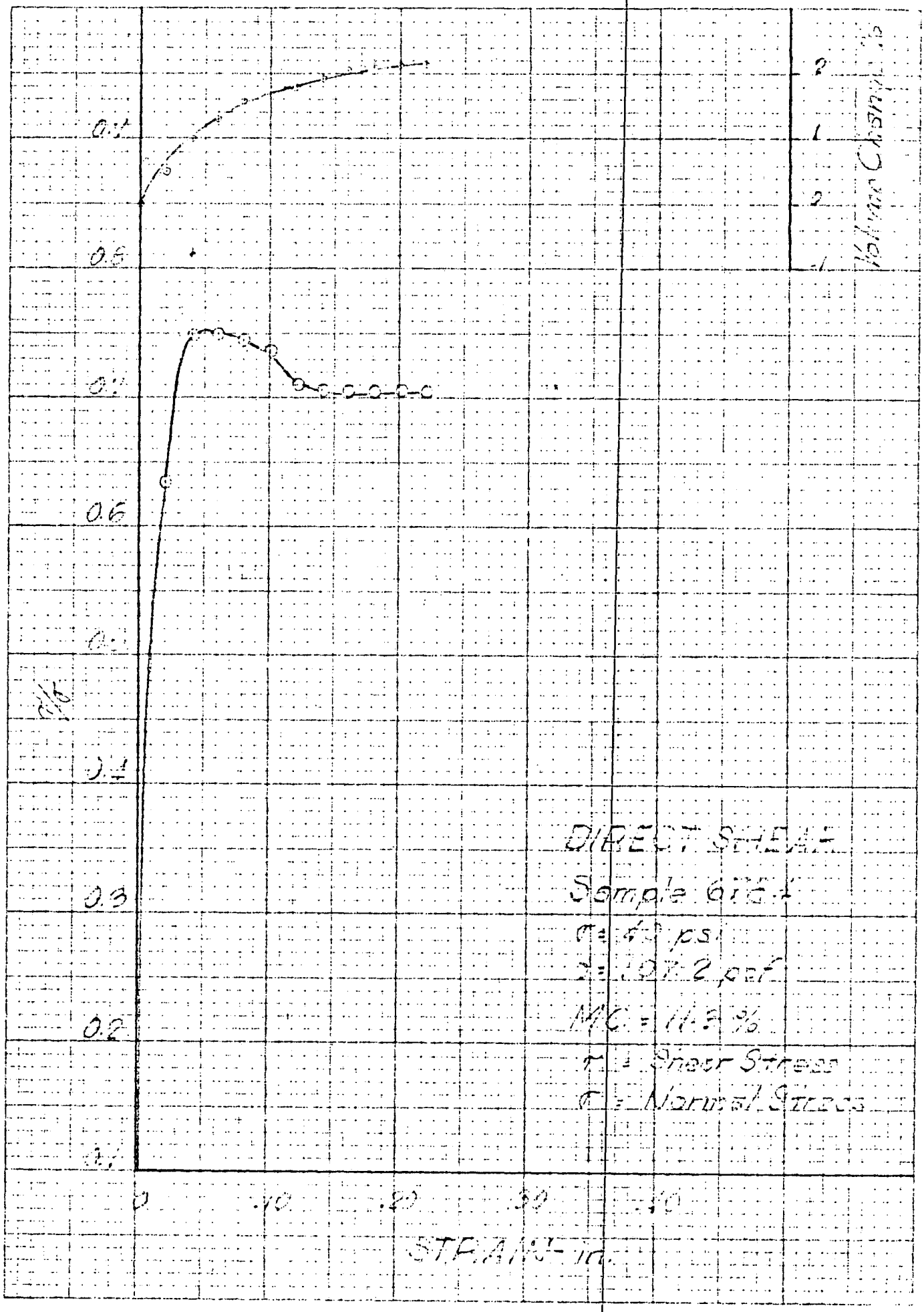
NO 340 10 DIETZGEN GRAPH PAPER
10 x 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.



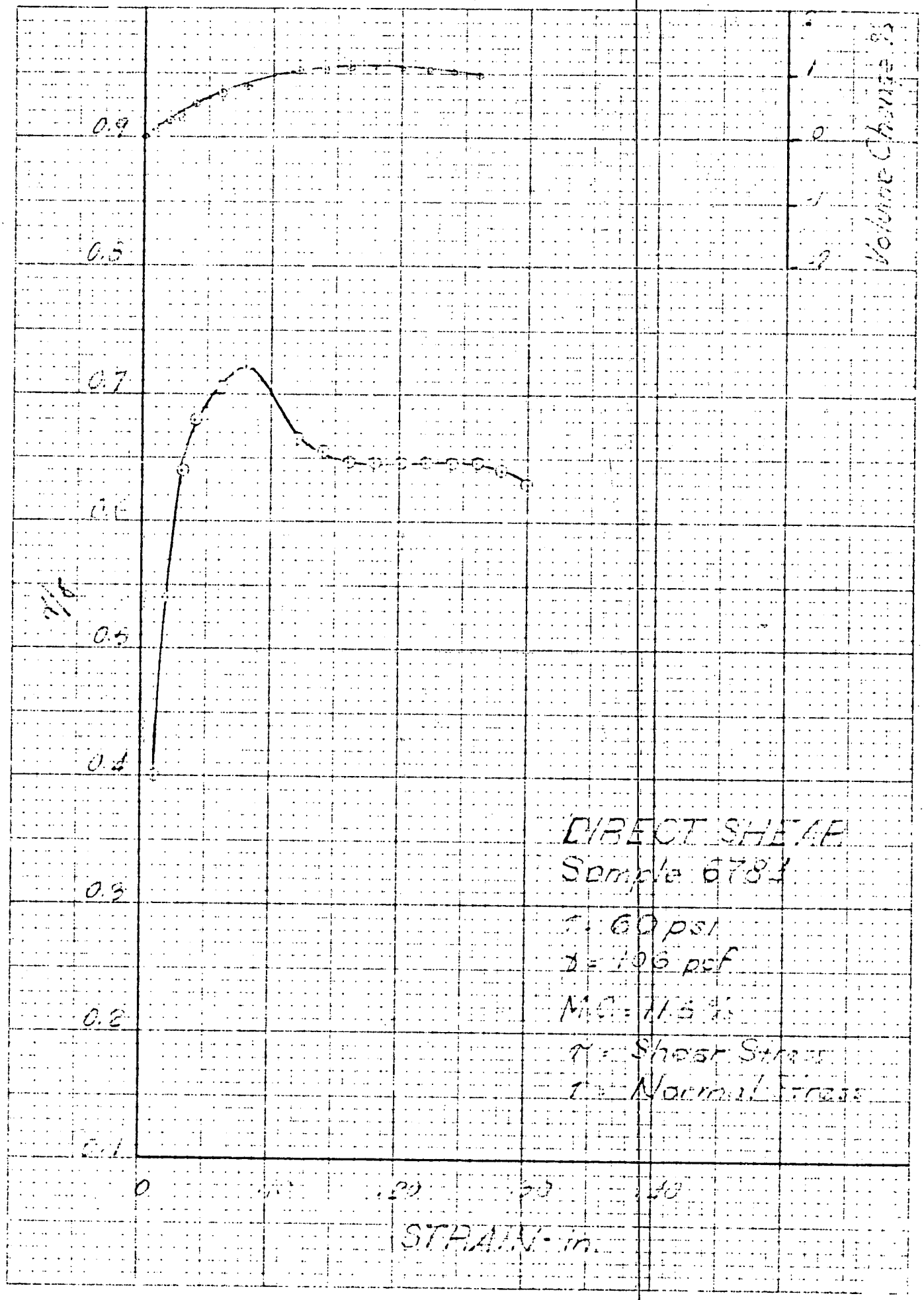
DIRECT SHEAR TEST

NO 340 - 10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

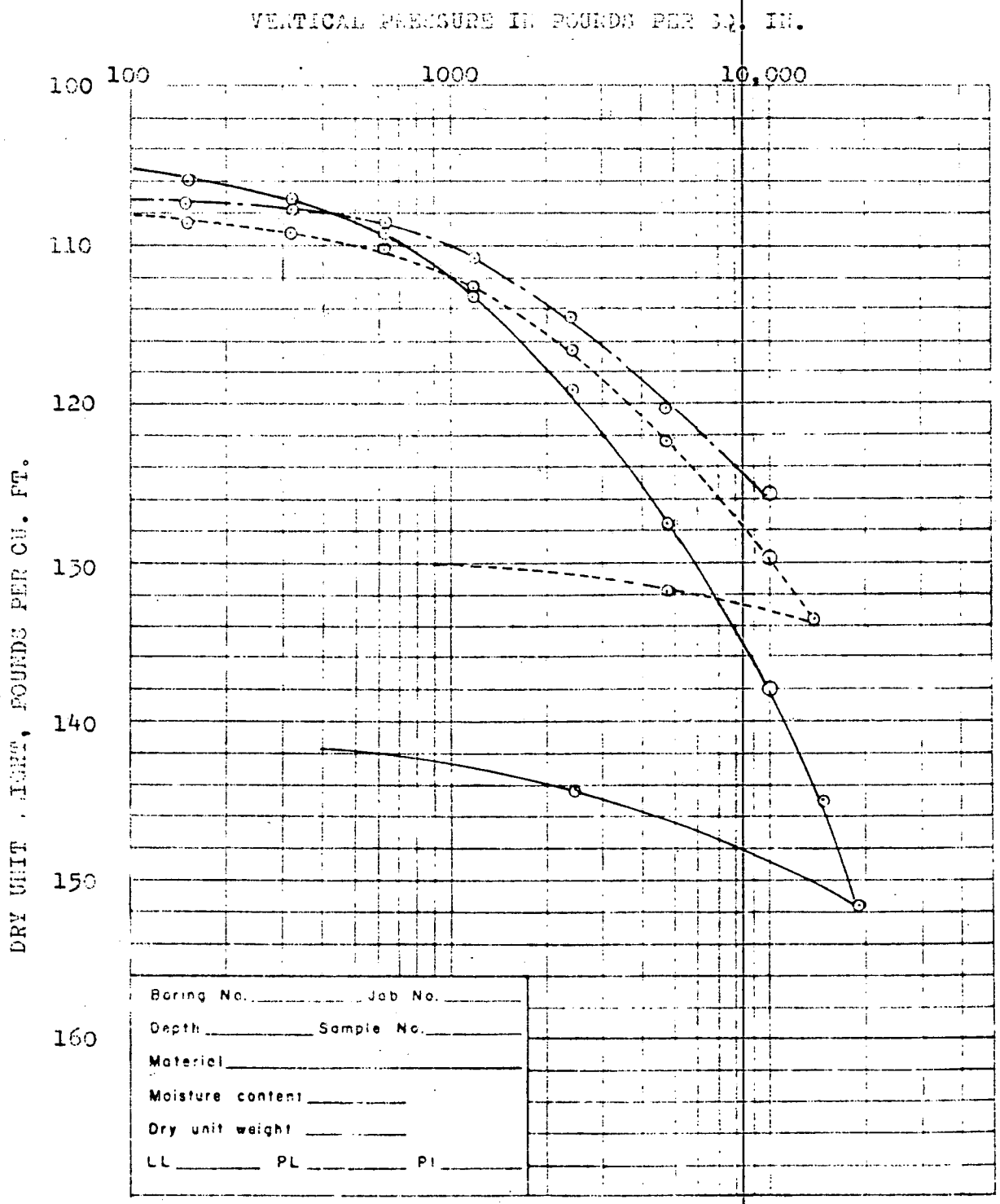
EUGENE DIETZGEN CO.
MADE IN U.S.A.



EUGENE DIETZGEN CO
MADE IN U.S.A.
NO 340 10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH



EUGENE DIETZGEN CO.
MADE IN U.S.A.
NO. 340 10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH



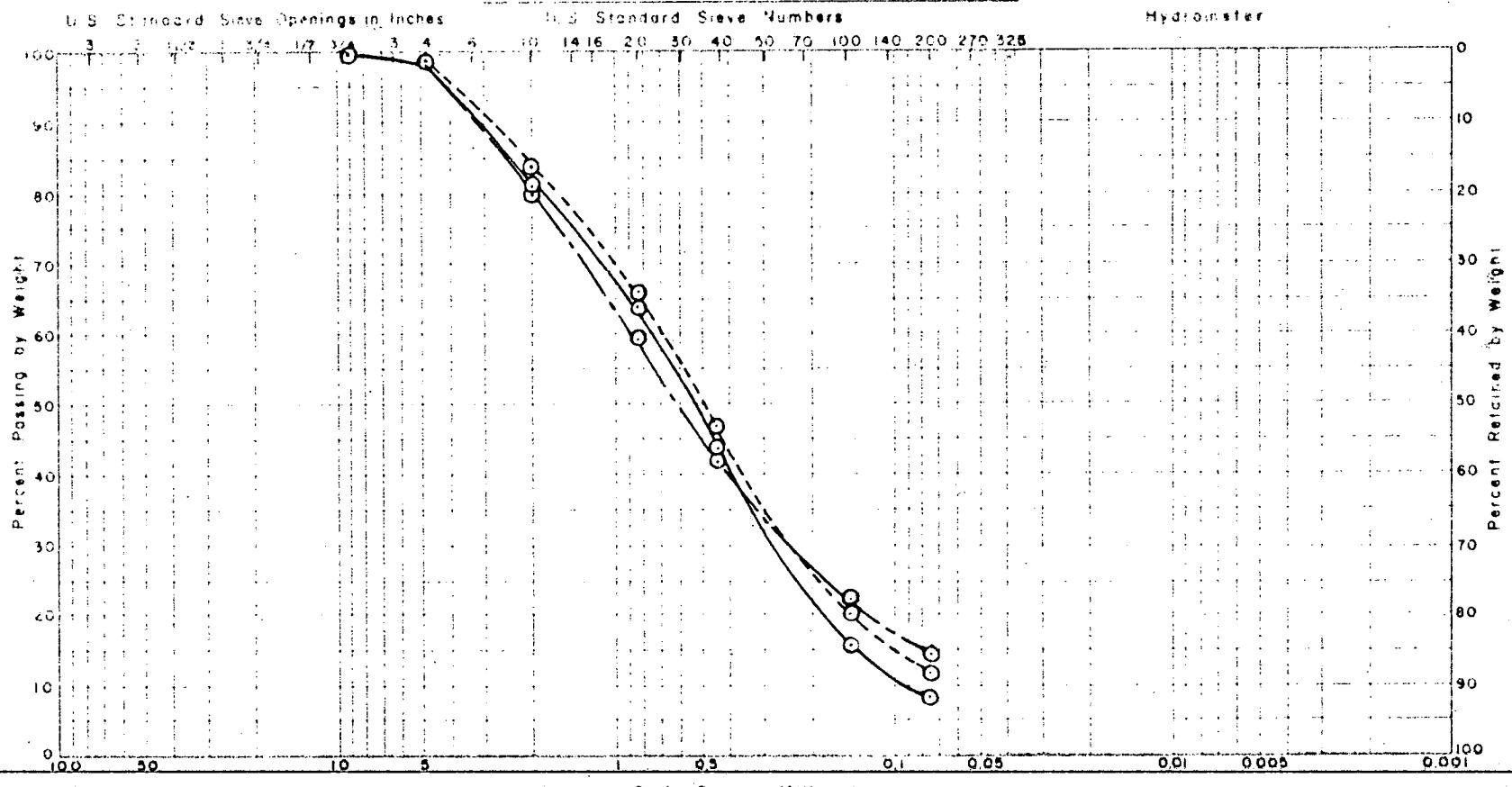
DENSITY VS LOG PRESSURE CURVE

THE ZIA COMPANY
Los Alamos, N.M.
Job No. 59-154
Sample No. 6734

Concrete sand
S.G. - 2.615

LEGEND
Height = 1" ————————
Height = 2" - - - - - - - - - - - -
Height = 3" —·—·—·—

MECHANICAL ANALYSIS CHART



THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab. No. 6784

LEGEND

——— After 10,000 psi Vertical Pressure 3" High Sample
- - - - - After 15,000 psi Vertical Pressure 2" High Sample
—— - —— After 20,000 psi Vertical Pressure 1" High Sample

SOIL MECHANICS INCORPORATED

SUMMARY OF LAB TESTS ON SAND SAMPLE 6785

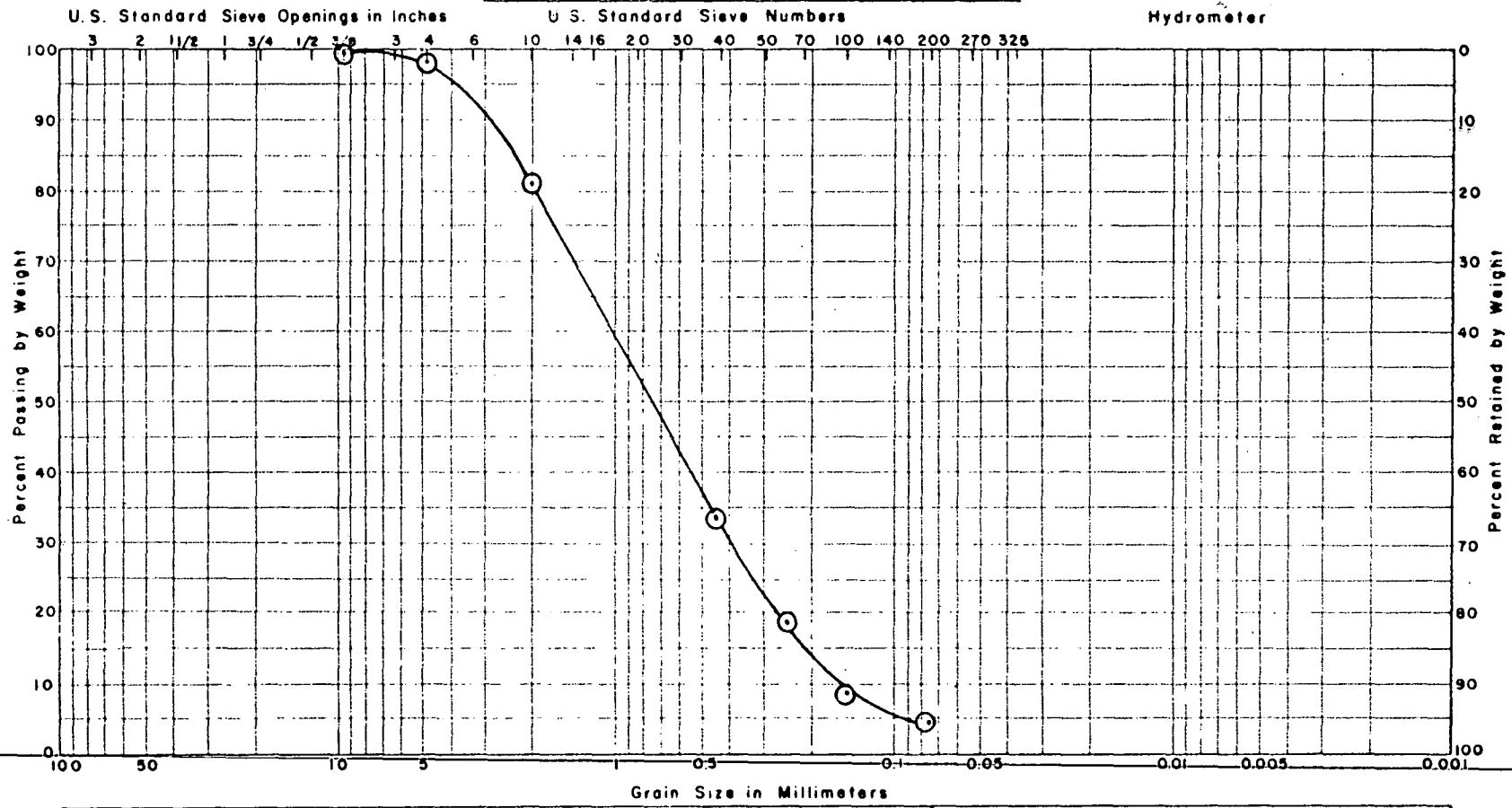
1.	Natural Moisture Content	4.6
2.	Specific Gravity - Absolute	2.615
	- Apparent	2.615
3.	Minimum Dry Density - Dry	97.5 pcf
		98.2 pcf
4.	Maximum Dry Density - Dry	120.5 pcf
		119.1 pcf
5.	Minimum Dry Density - Saturated	108.6 pcf
	- Moisture	15.5 %
	- Saturated	106.1 pcf
	- Moisture	15.5 %
6.	Maximum Dry Density - Saturated	120.1 pcf
	- Moisture	10.9 %
	- Saturated	118.8 pcf
	- Moisture	10.9 %
7.	Retention Moisture (humid atmosphere - drained)	17.2 %
8.	Air Permeability (pack density, 105.1 pcf)	24.97 darcys

9. Thermal Conductivity: 0.77 BTU/Hr-sq ft-°F/ft at an average temperature of 107.6° F., a dry density of 109 lb/cu ft, and a moisture content of 9.5% of dry weight.

10. Specific Heat: 0.261 BTU/lb- °F between the temperature limits of 76.7 and 212° F. and at a moisture content of 8% of dry weight for loose soil as received.

11.	Grain size curve	attached
12.	Porosity vs Density Curve	attached
13.	Mohr Diagrams (low lateral pressure)	attached
14.	Mohr Diagrams (high lateral pressures)	attached
15.	Grain size curve (after high pressure tests)	attached
16.	Direct shear Tests	attached

MECHANICAL ANALYSIS CHART

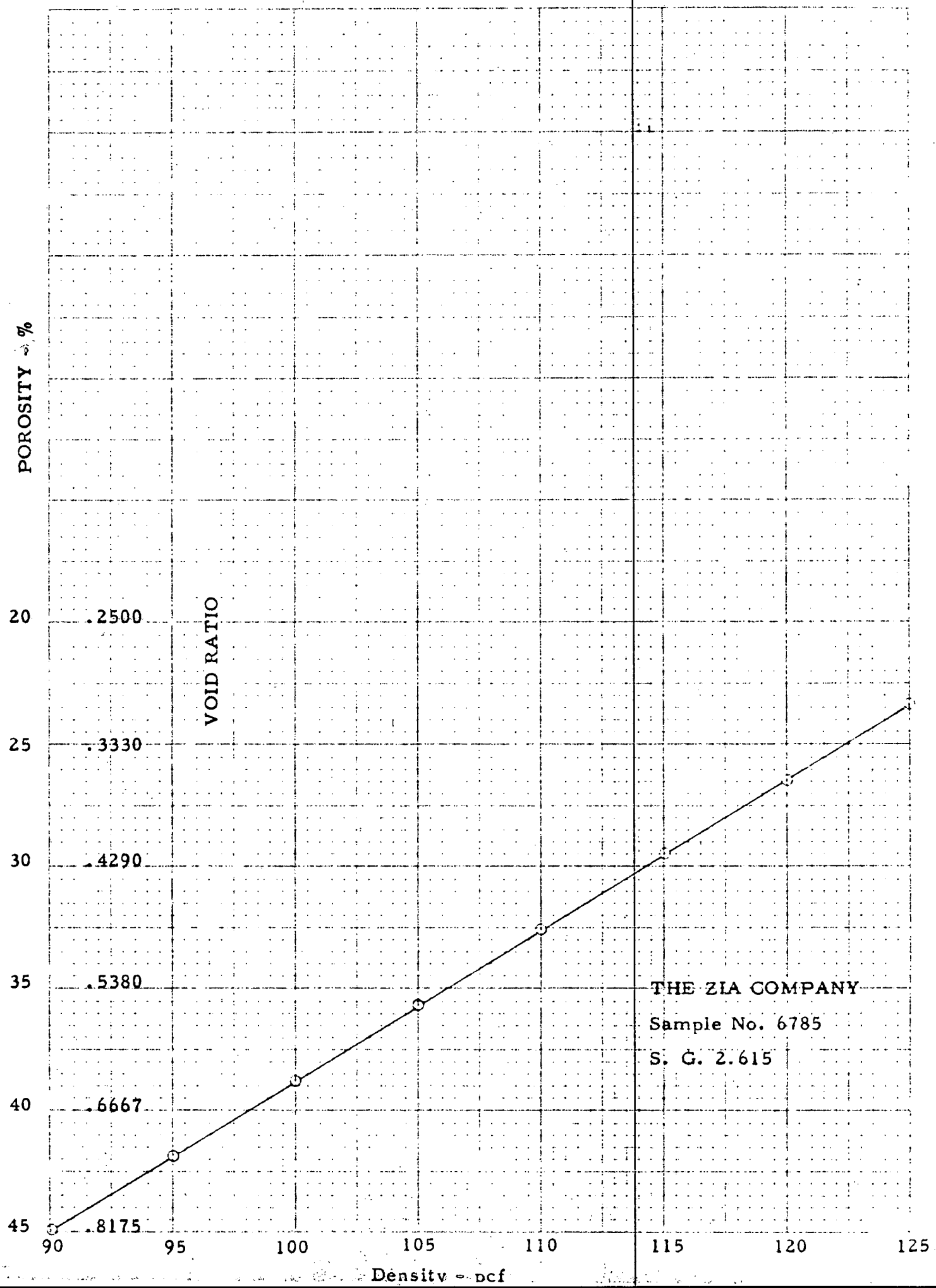


GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY

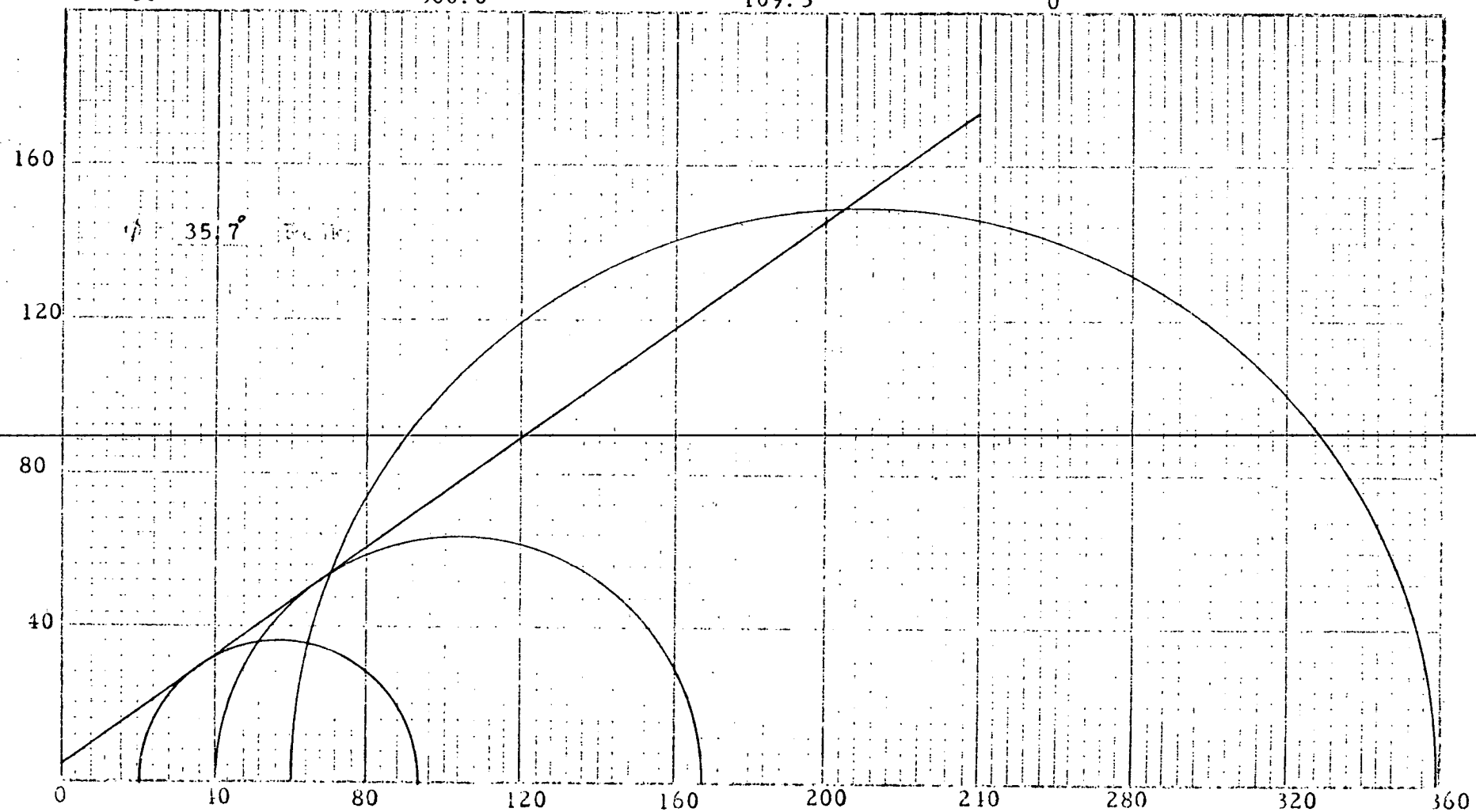
Sample No. 6785


POROSITY - %
VOID RATIO
20
25
30
35
40
45
.2500
.3330
.4290
.5380
.6667
.8175
90
95
100
105
110
115
120
125
Density - pcf
THE ZIA COMPANY
Sample No. 6785
S. G. 2.615

SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6785

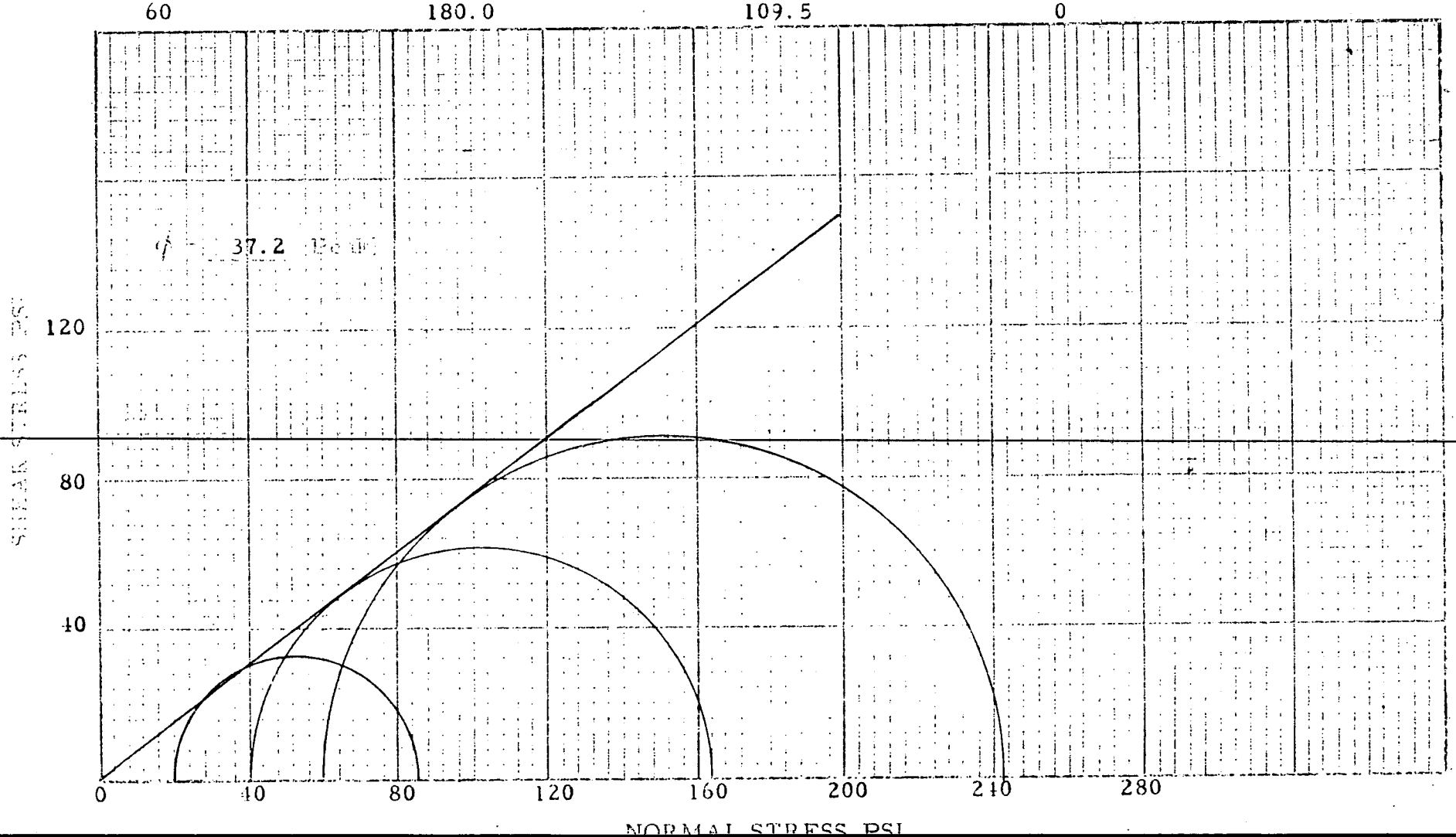
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ pcf	Moisture content, %	Remarks:
20	73.2	109.5	0	
40	128.0	106.5	0	
60	300.0	109.5	0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6785

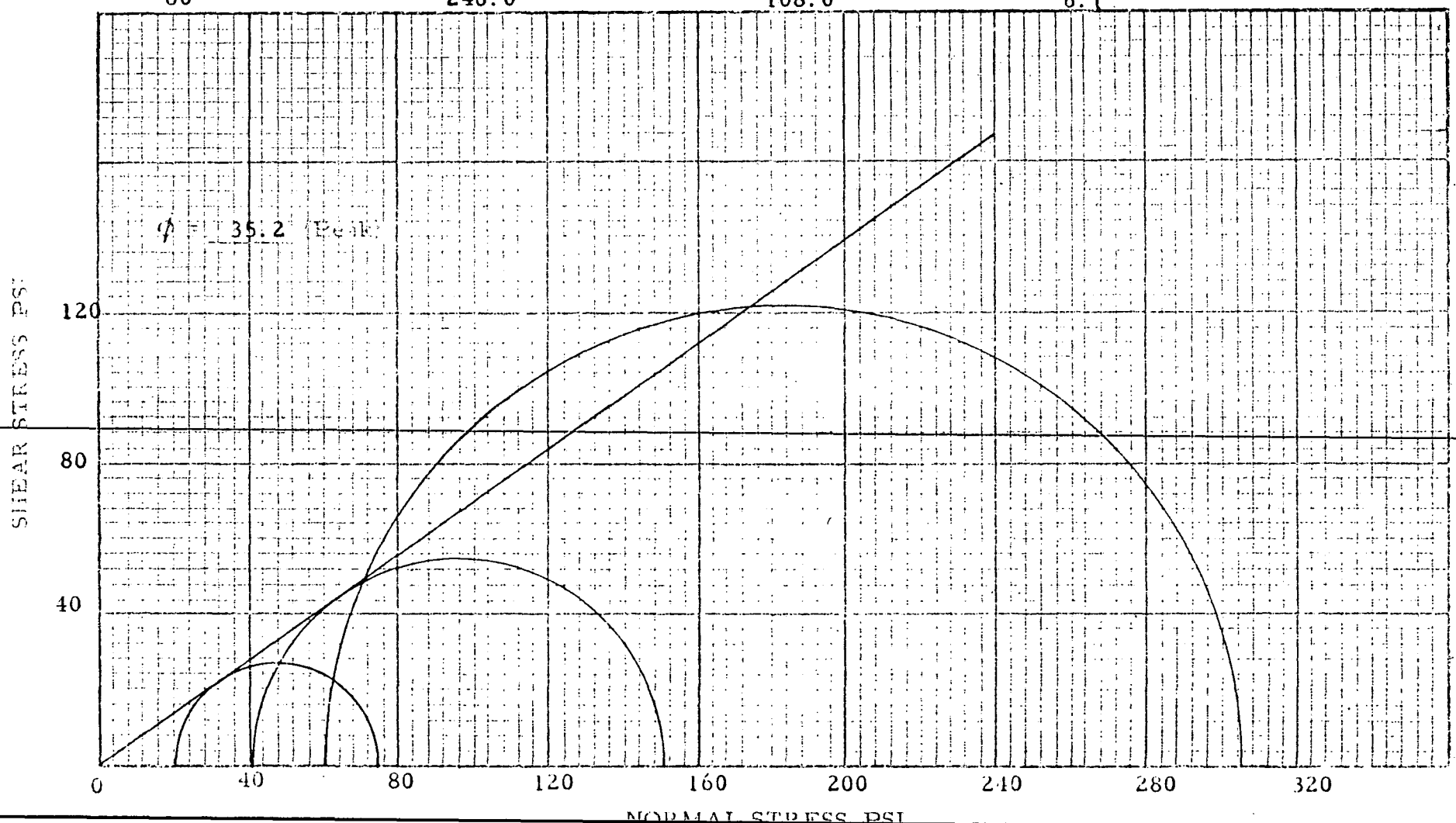
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	63.6	109.5	0	Material Passing
40	124.2	111.0	0	No. 10 Sieve
60	180.0	109.5	0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6785

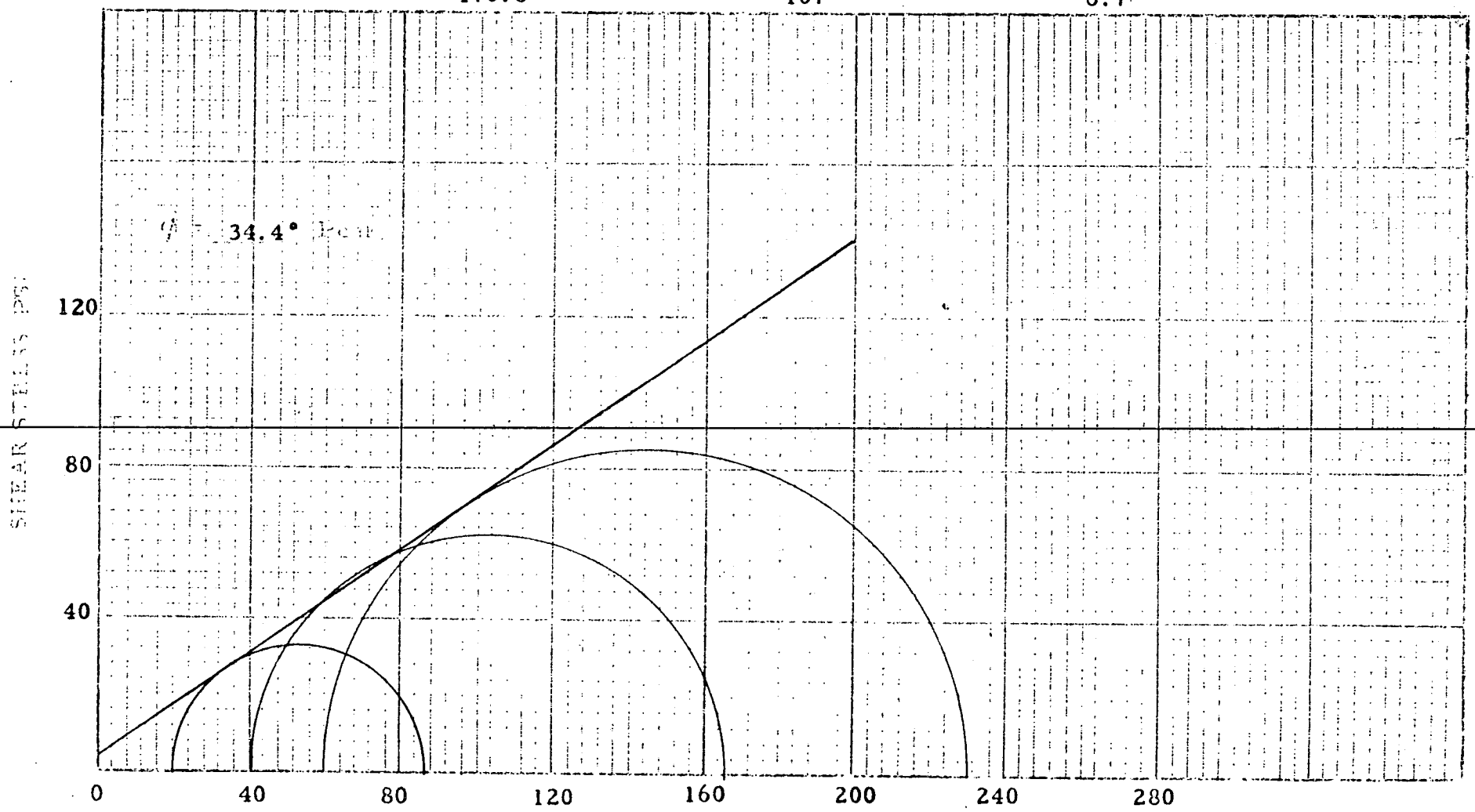
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ pcf	Moisture content, %	Remarks:
20	55.3	104.5	6.4	
40	110.0	109.4	6.3	
60	246.0	108.0	6.1	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6785

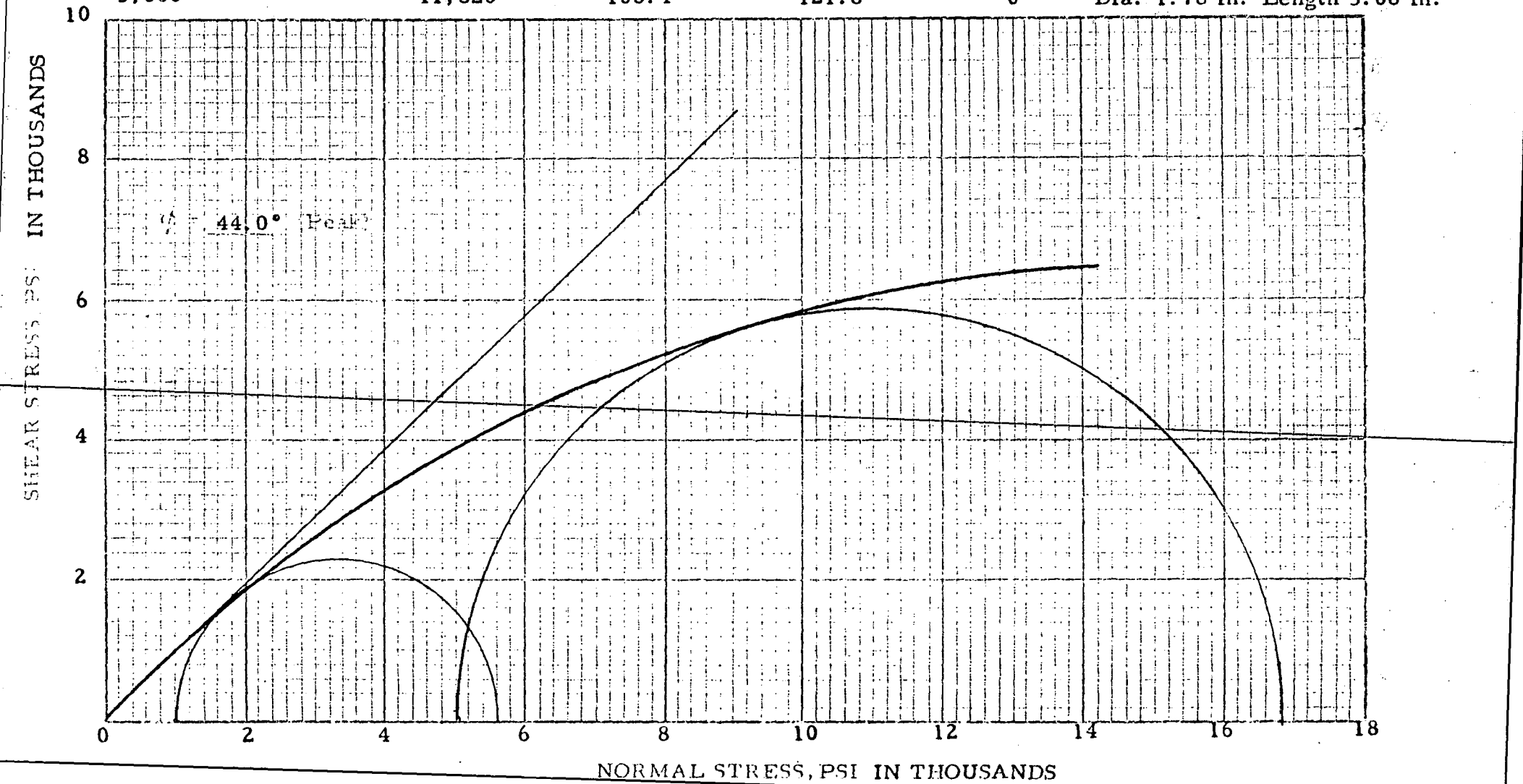
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	66.4	107	7.4	Material Passing
40	125.2	108	6.5	No. 10 Sieve
60	170.6	107	6.7	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6785

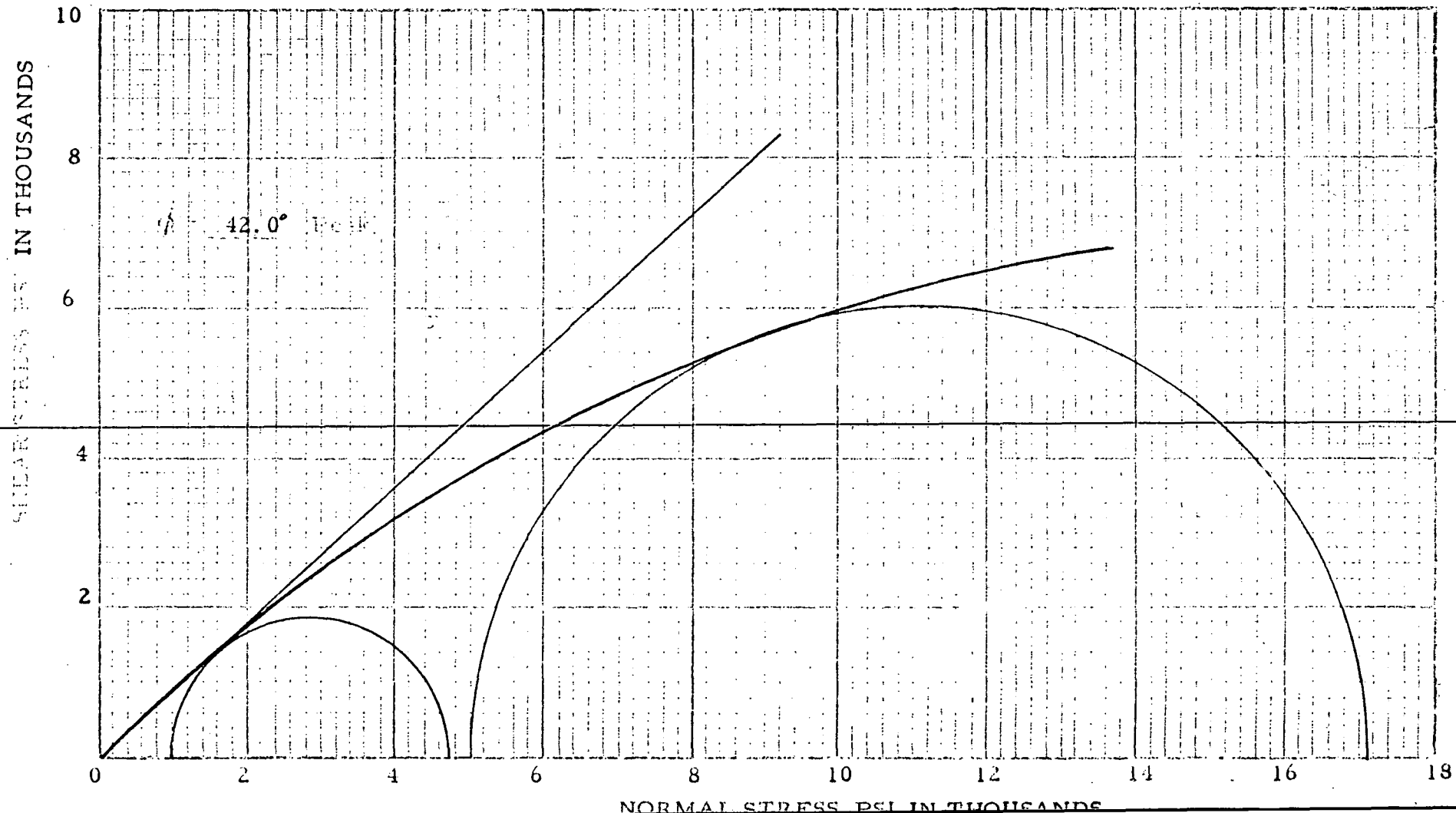
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density Before test, pcf	Dry Density After Applying Lateral Press.	Moisture content, %	Remarks: Before Test
1,000	4,580	107.4	114.1	0	Dia. 1.75 in. Length 3.19 in.
5,000	11,820	108.4	121.8	0	Dia. 1.78 in. Length 3.06 in.



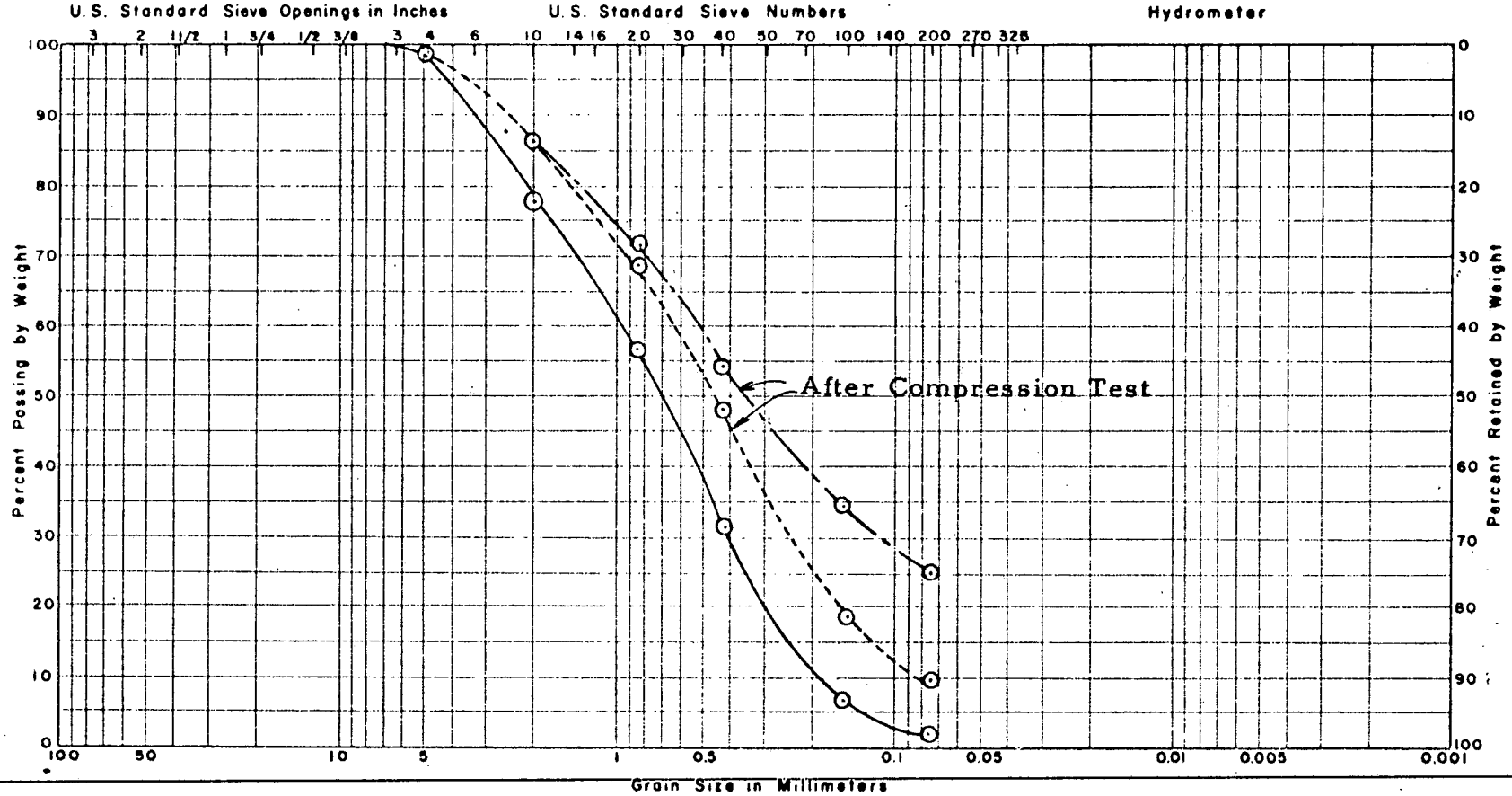
SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6785

Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density Before test, pcf.	Dry Density After Applying Lateral Press.	Moisture content, %	Remarks: Before Test
1,000	3,630	111.0	118.4	6.2	Dia. 1.75 in. Length 3.13 in.
5,000	12,150	111.8	126.4	5.3	Dia. 1.75 in. Length 3.13 in.



MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab. No. 6785

Concrete Sand

LEGEND

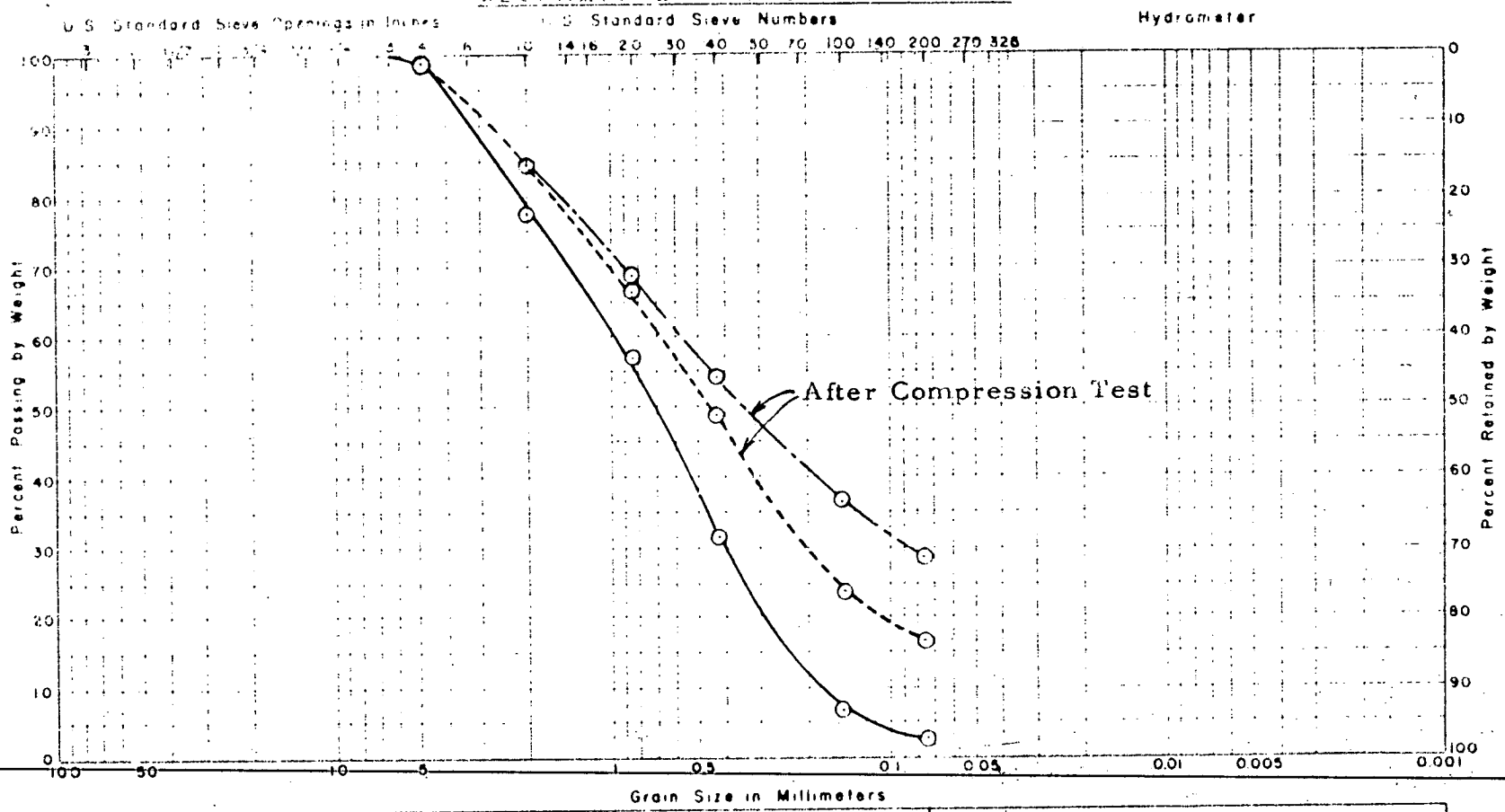
——— Natural Condition
- - - - - - - After 1,000 psi Lateral Pressure
——— - ——— After 5,000 psi Lateral Pressure

MOISTURE CONTENT

0
0

SOIL MECHANICS INCORPORATED

MECHANICAL ANALYSIS CHART

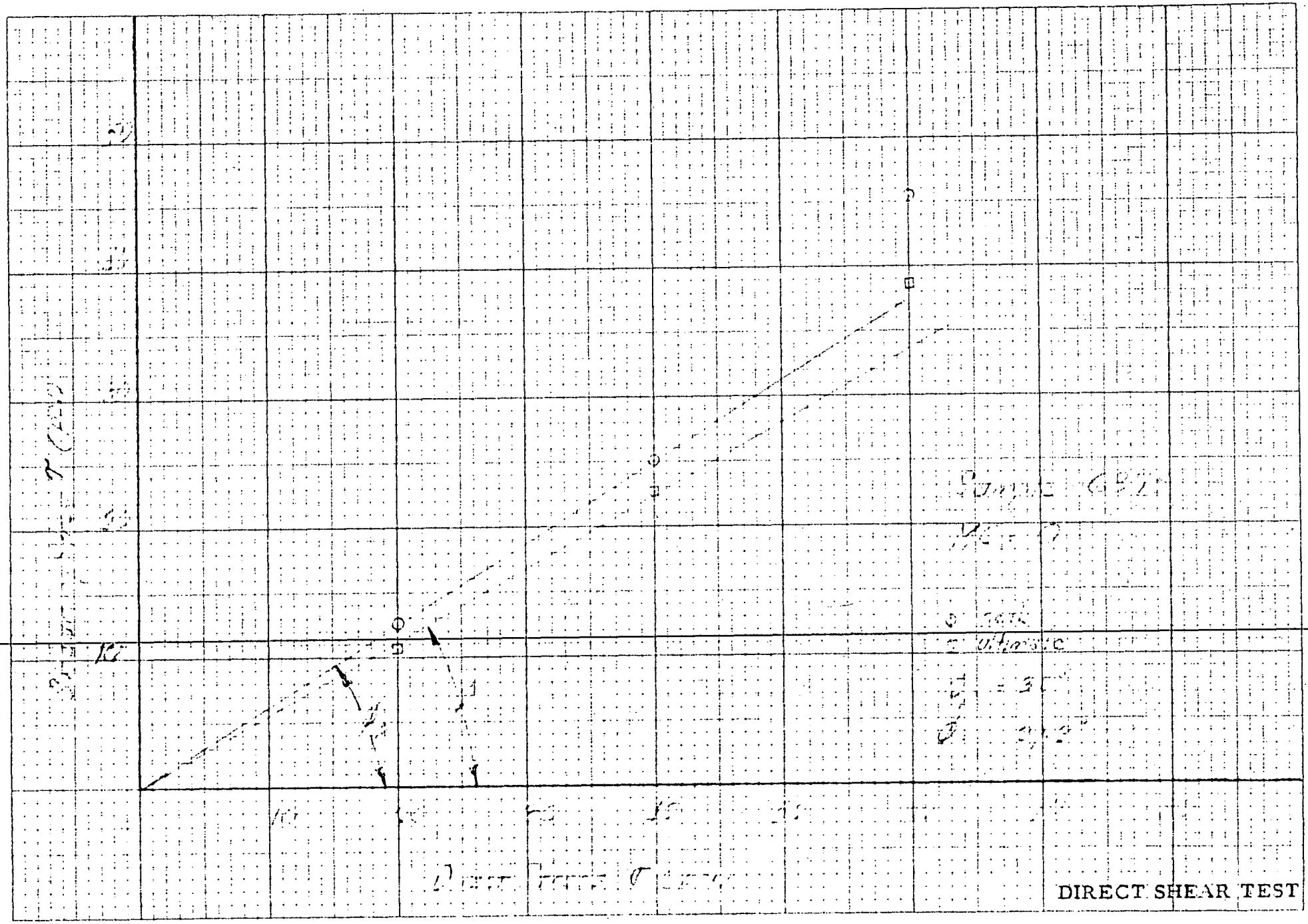


THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab No. 6785

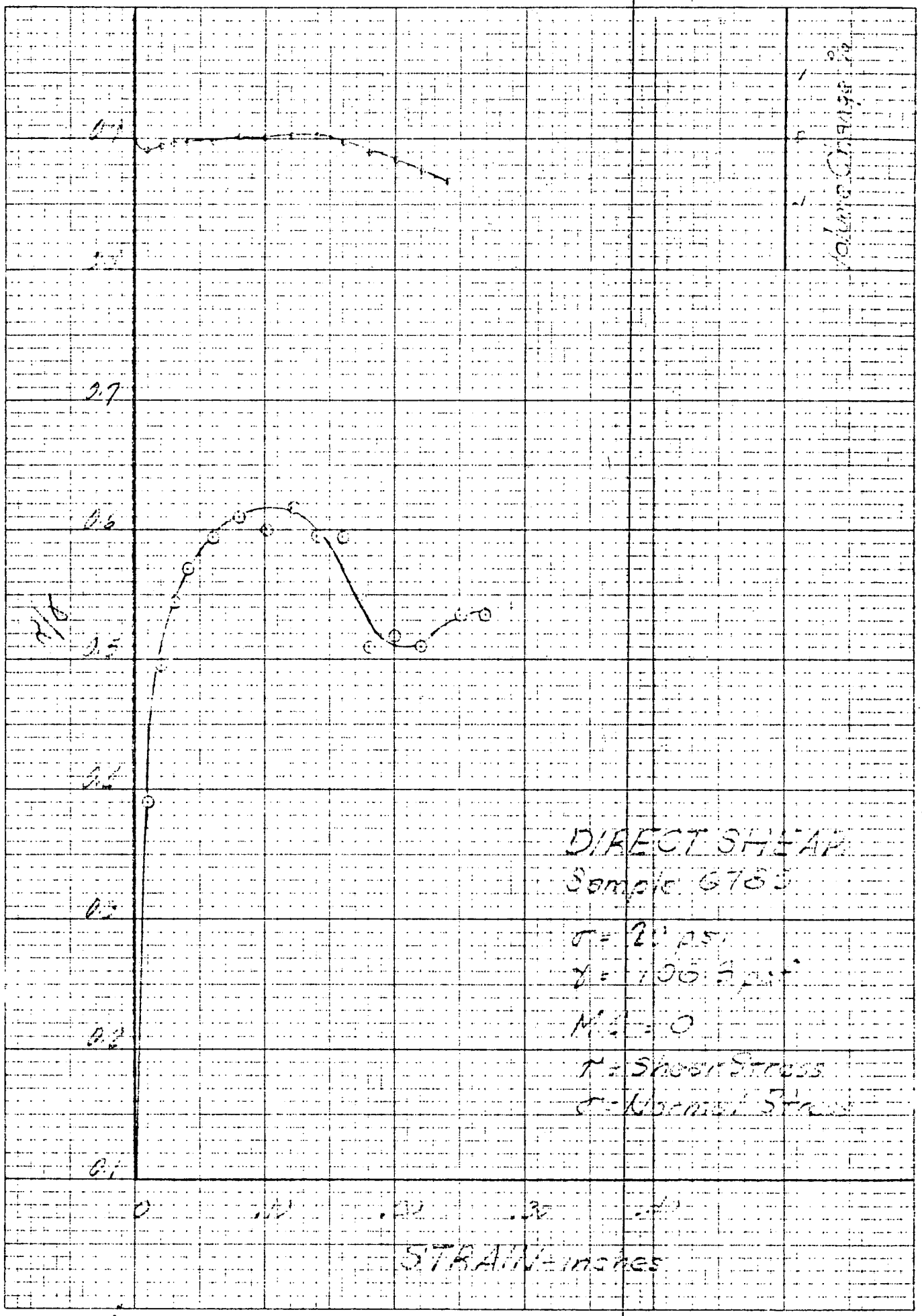
Concrete Sand

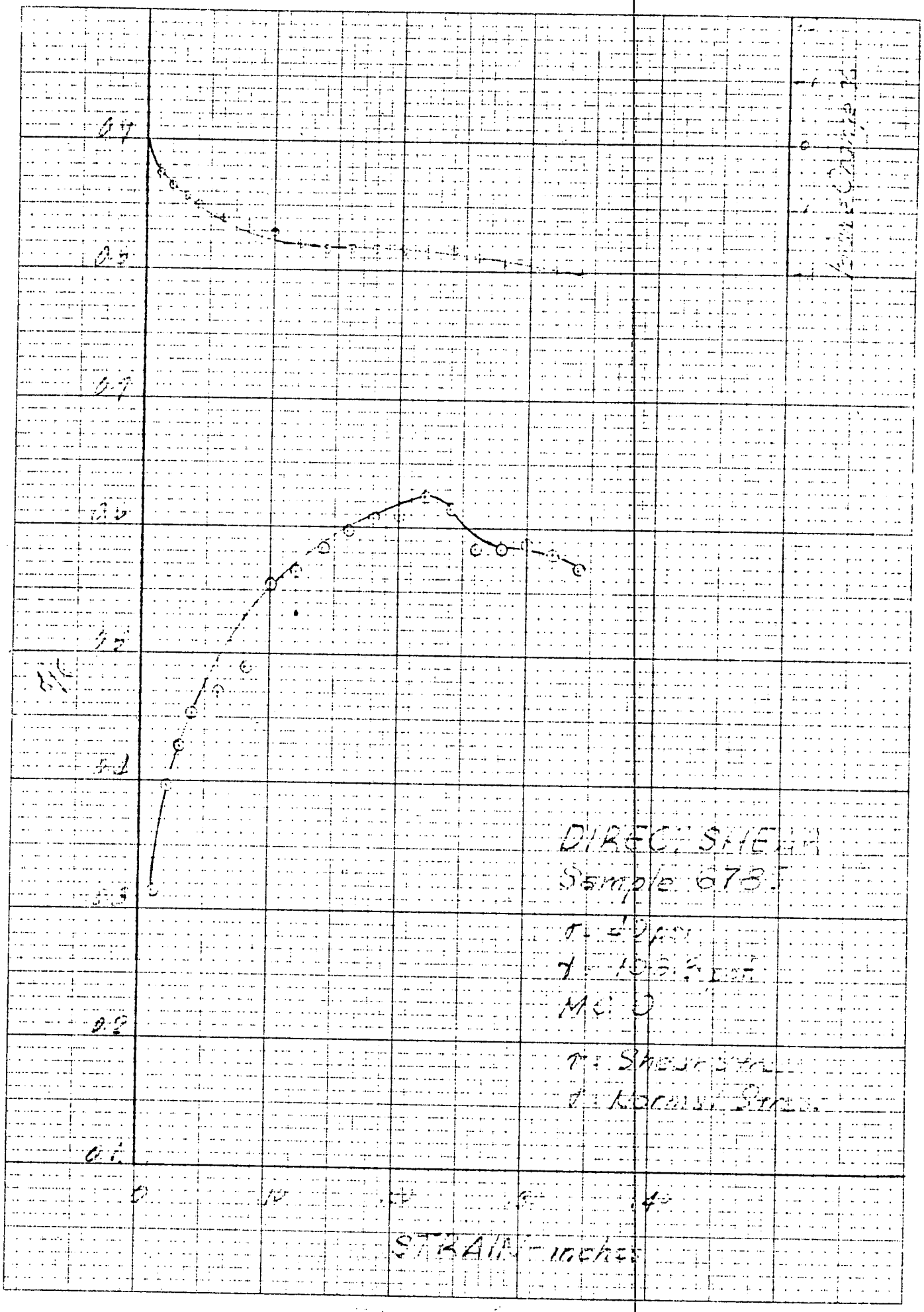
LEGEND	MOISTURE CONTENT
———— Natural Condition	-
- - - - - - - After 1,000 psi Lateral Pressure	6.2
—— - —— After 5,000 psi Lateral Pressure	5.3

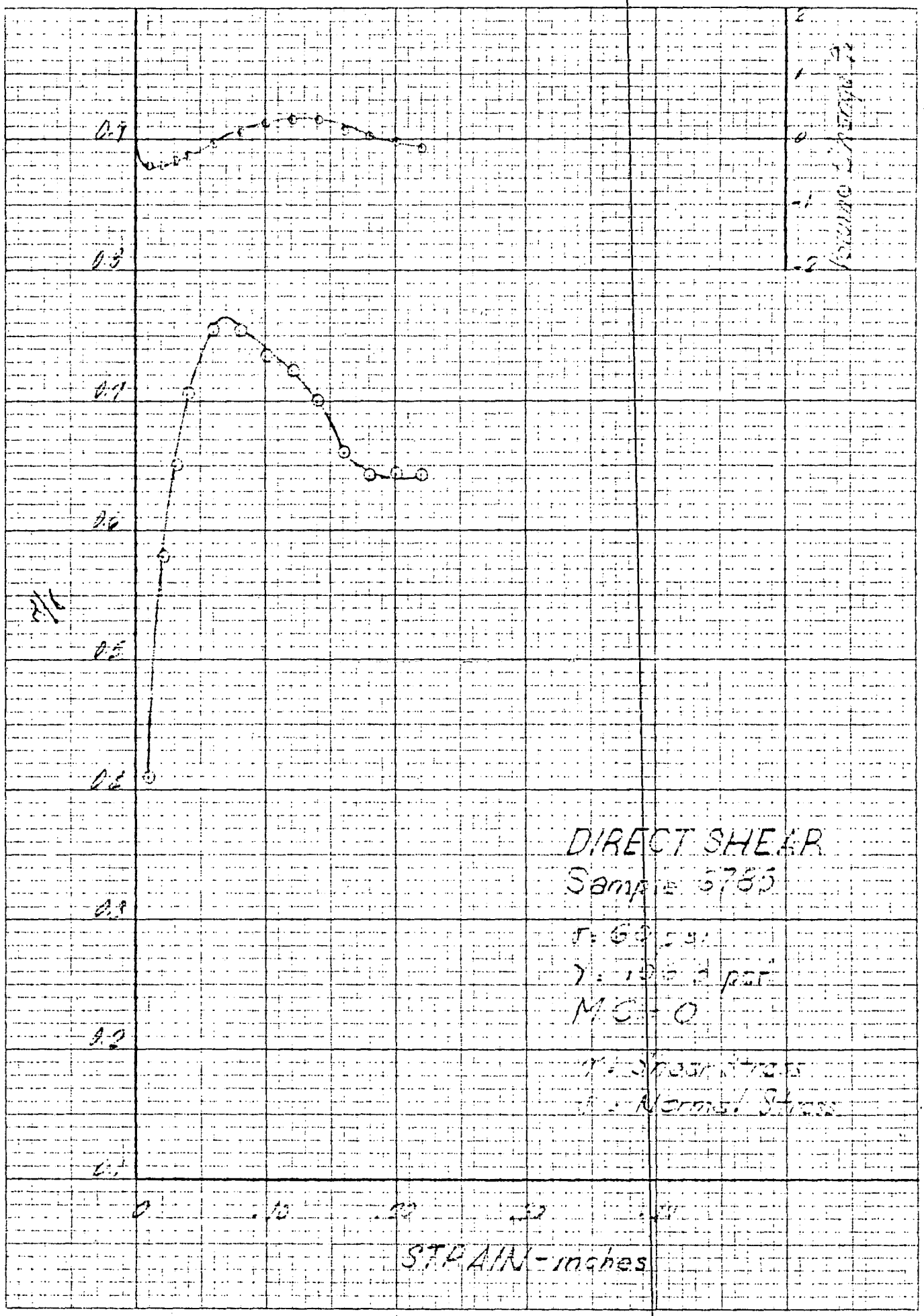
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.

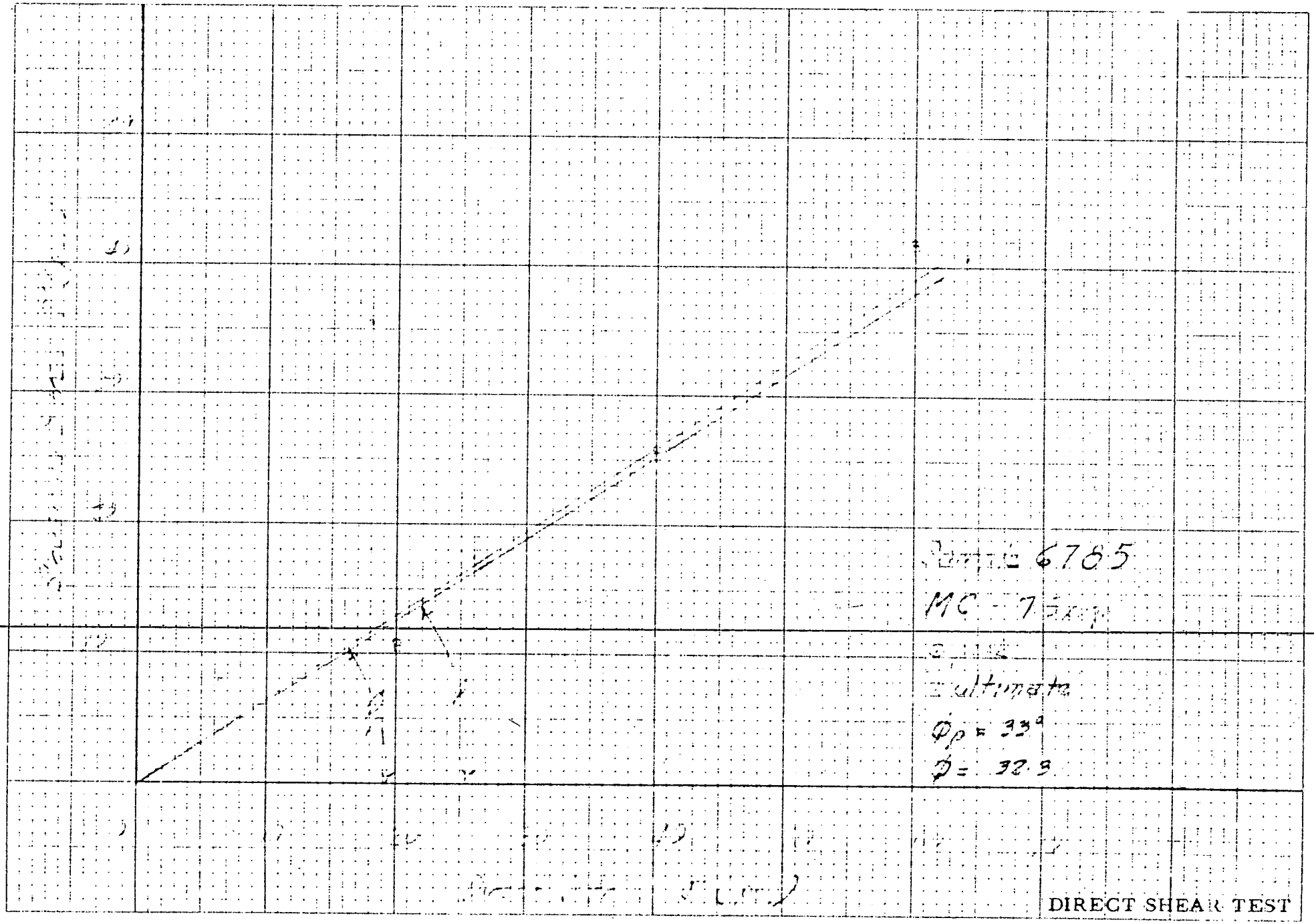


DIRECT SHEAR TEST

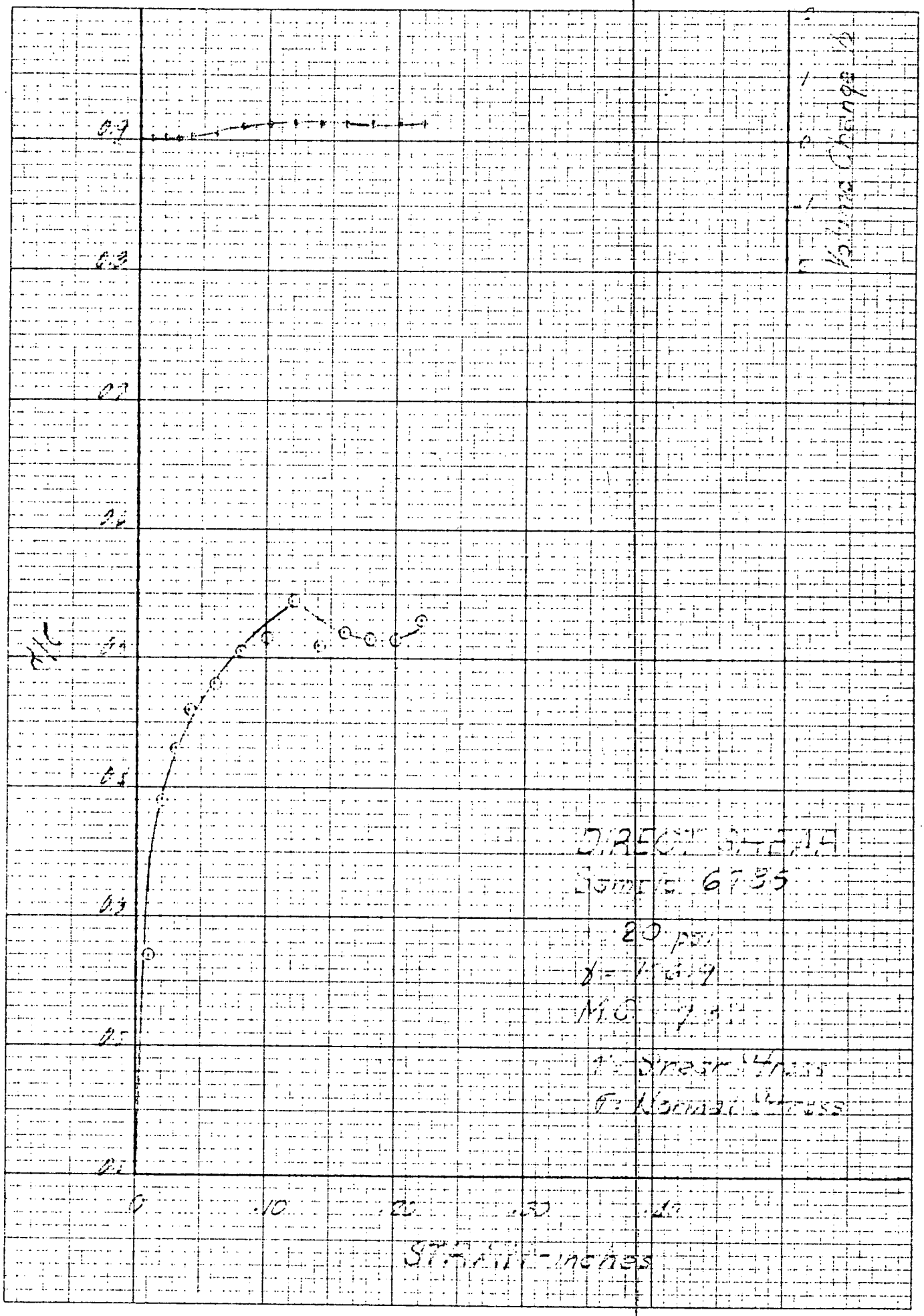

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
.10
.20
.30
.40
τ/σ
STRAIN-inches
DIRECT SHEAR
Sample 6785
σ = 2.0 psi
γ = 100.2 pcf
M.C. = 0
τ = Shear Stress
σ = Normal Stress

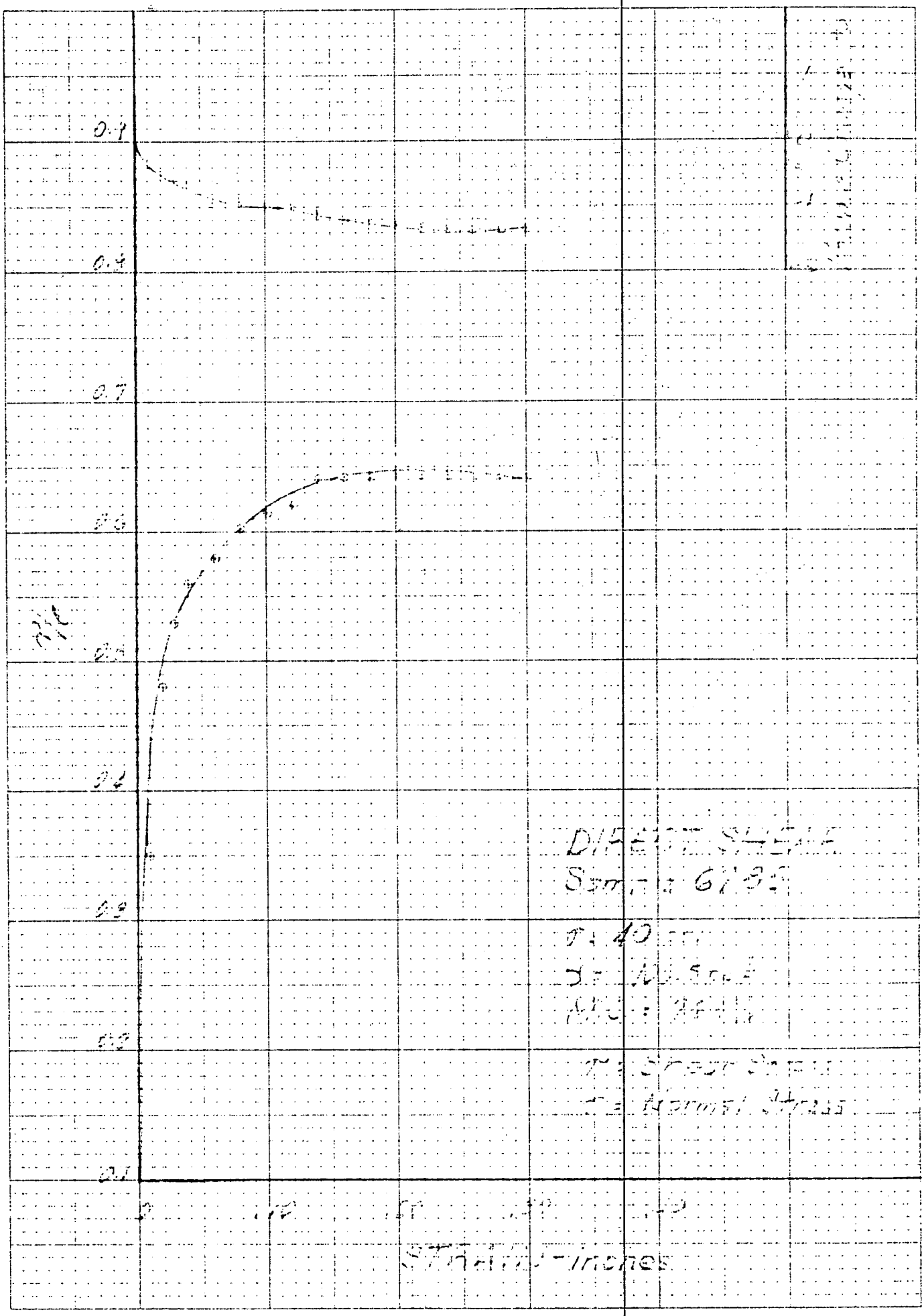

0.7
0.5
0.3
0.1
0.2
0.4
0.6
0.8
0.1
0
10
20
30
40
STRAIN - inches
DIRECT SHEAR
Sample 675
σ = 50 psi
γ = 105 pcf
Mc = 0
τ = Shear Stress
σ = Normal Stress

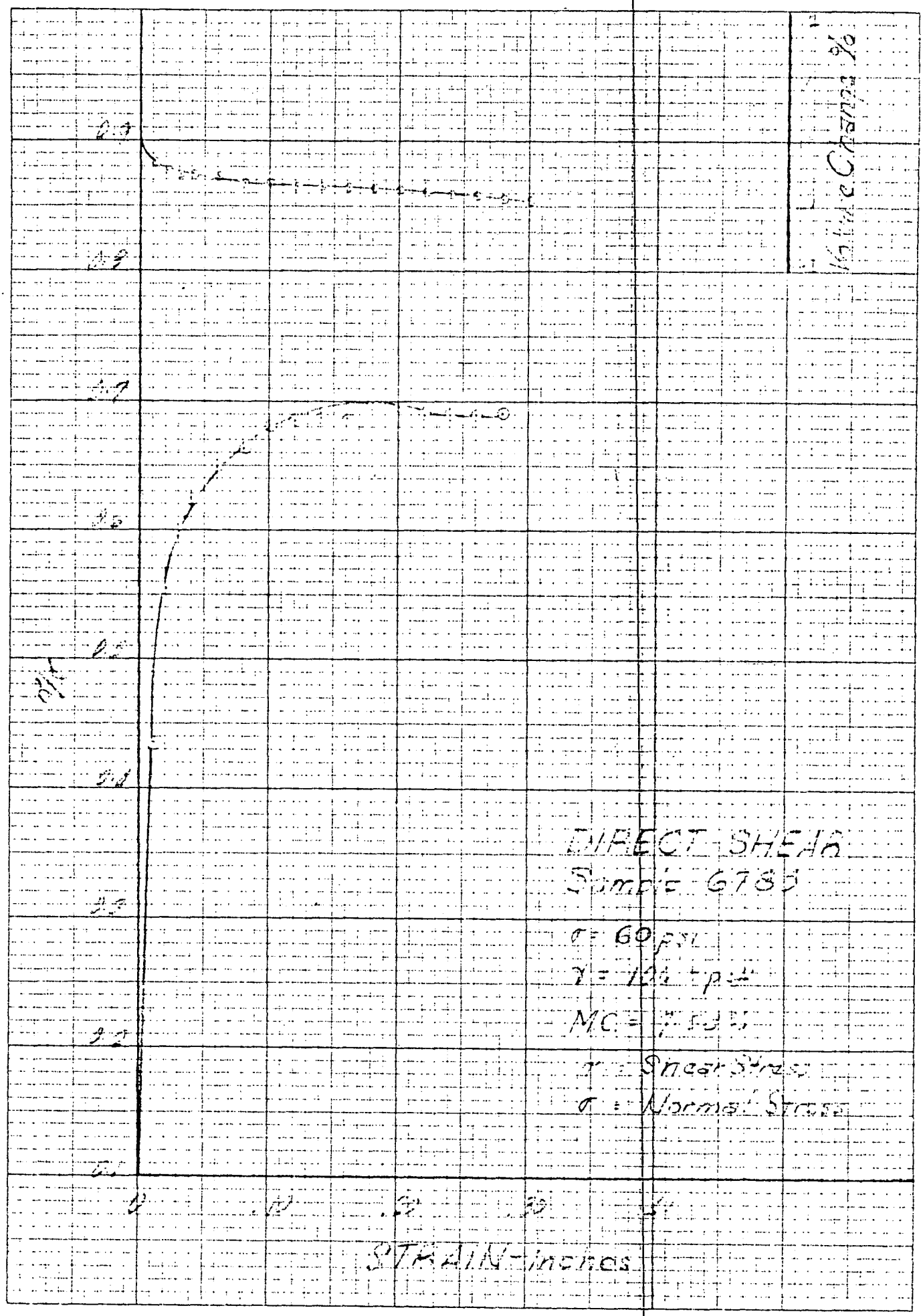

0.7
0.5
0.4
0.3
0.2
0.1
0
.10
.20
.30
.40
STRAIN-inches
DIRECT SHEAR
Sample 5785
MC-0



DIRECT SHEAR TEST


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
.10
.20
.30
.40
STRAIN - inches
DIRECT STRAIN
Lamina 6755
20 psi
MC 7.4
τ = Shear Stress
σ = Normal Stress


0.1
0.4
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
STRAIN - INCHES


% Change in Height
DIRECT SHEAR
Sample 6785
σ = 60 psi
τ = 104 psi
MC = 7.5%
τ = Shear Stress
σ = Normal Stress
STRAIN-inches

SUMMARY OF LAB TESTS ON SAND SAMPLE 6803

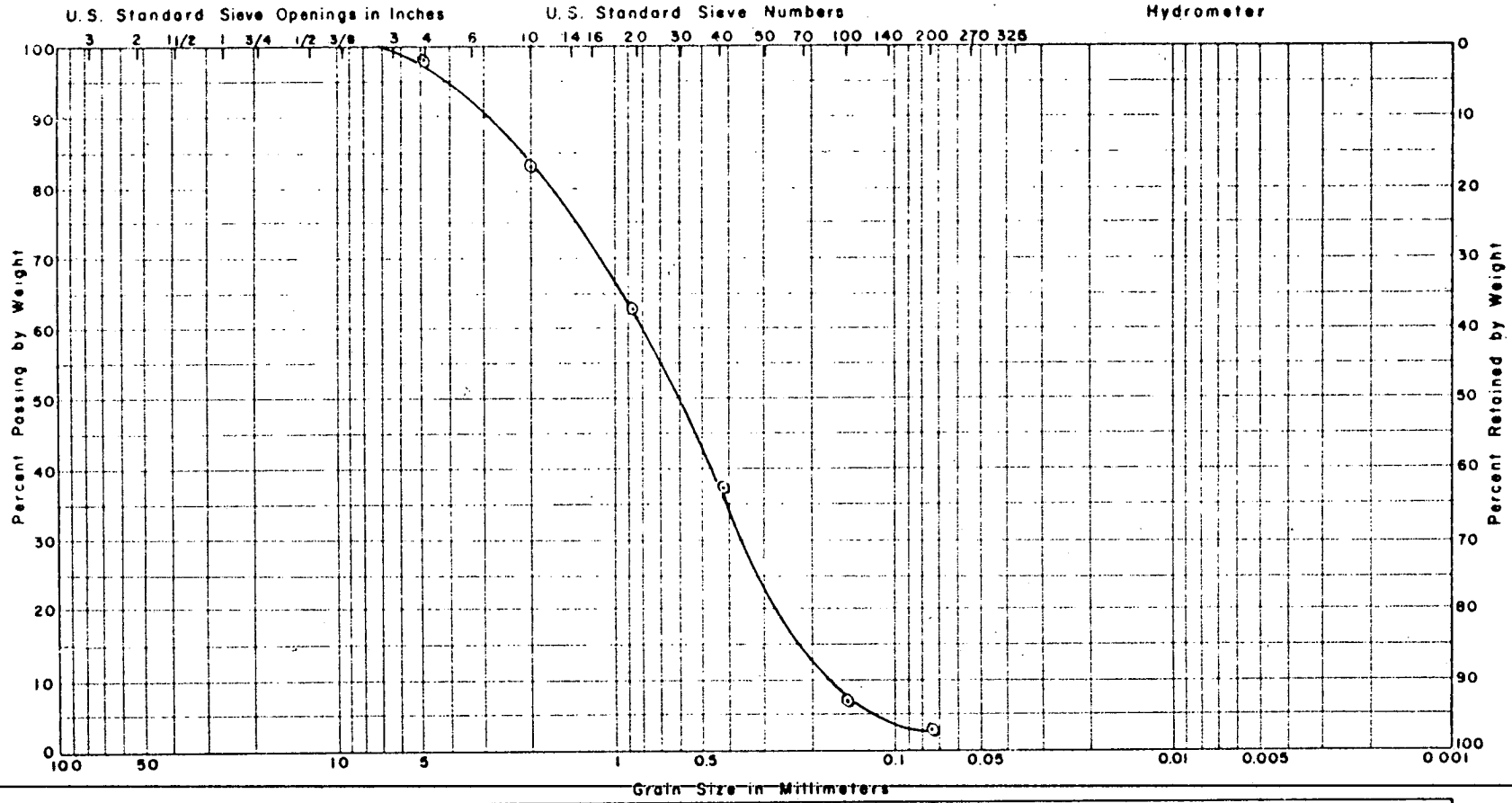
1.	Natural Moisture Content	4.6
2.	Specific Gravity - Absolute	2.580
	- Apparent	2.580
3.	Minimum Dry Density - Dry	97.2 pcf
		97.2 pcf
4.	Maximum Dry Density - Dry	119.5 pcf
		118.5 pcf
5.	Minimum Dry Density - Saturated	111.3 pcf
	- Moisture	11.4 %
	- Saturated	110.0 pcf
	- Moisture	11.4 %
6.	Maximum Dry Density - Saturated	118.9 pcf
	- Moisture	12.6 %
	- Saturated	118.9 pcf
	- Moisture	12.6 %
7.	Air Pearmebility (pack density, 105.3 pcf)	24.58 darcys

8. Thermal Conductivity: 0.81 BTU/Hr-sq ft-°F/ft at an average temperature of 105.4° F., a dry density of 109 lb/cu ft, and a moisture content of 8.7T of dry weight.

9. Specific Heat: 0.265 BTU/lb-°F between the temperature limits of 73.8°F. and 212° F. and at a moisture content of 8% of dry weight for loose soil as received.

10.	Grain size curve	attached
11.	Porosity vs Density Curve	attached
12.	Mohr Diagrams (low lateral pressure)	attached
13.	Mohr Diagrams (high lateral pressures)	attached
14.	Grain size curve (after high pressure tests)	attached
15.	Direct Shear Tests	attached
16.	Density vs Log Pressure Curve	attached
17.	Grain size Curve (log pressure curve)	attached

MECHANICAL ANALYSIS CHART



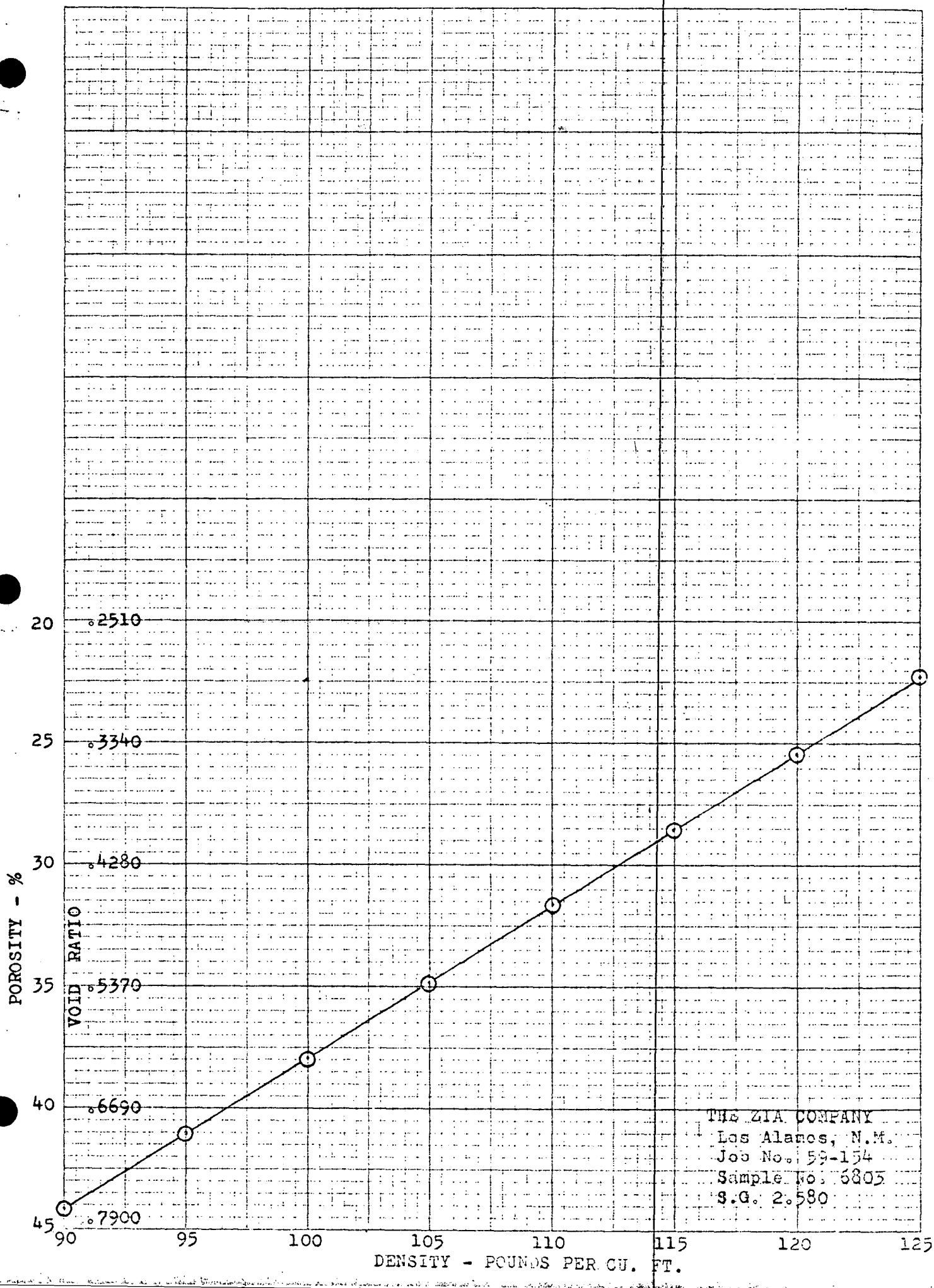
GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, N.M.
Job No. 59-154
Sample No. 6803

Concrete Sand

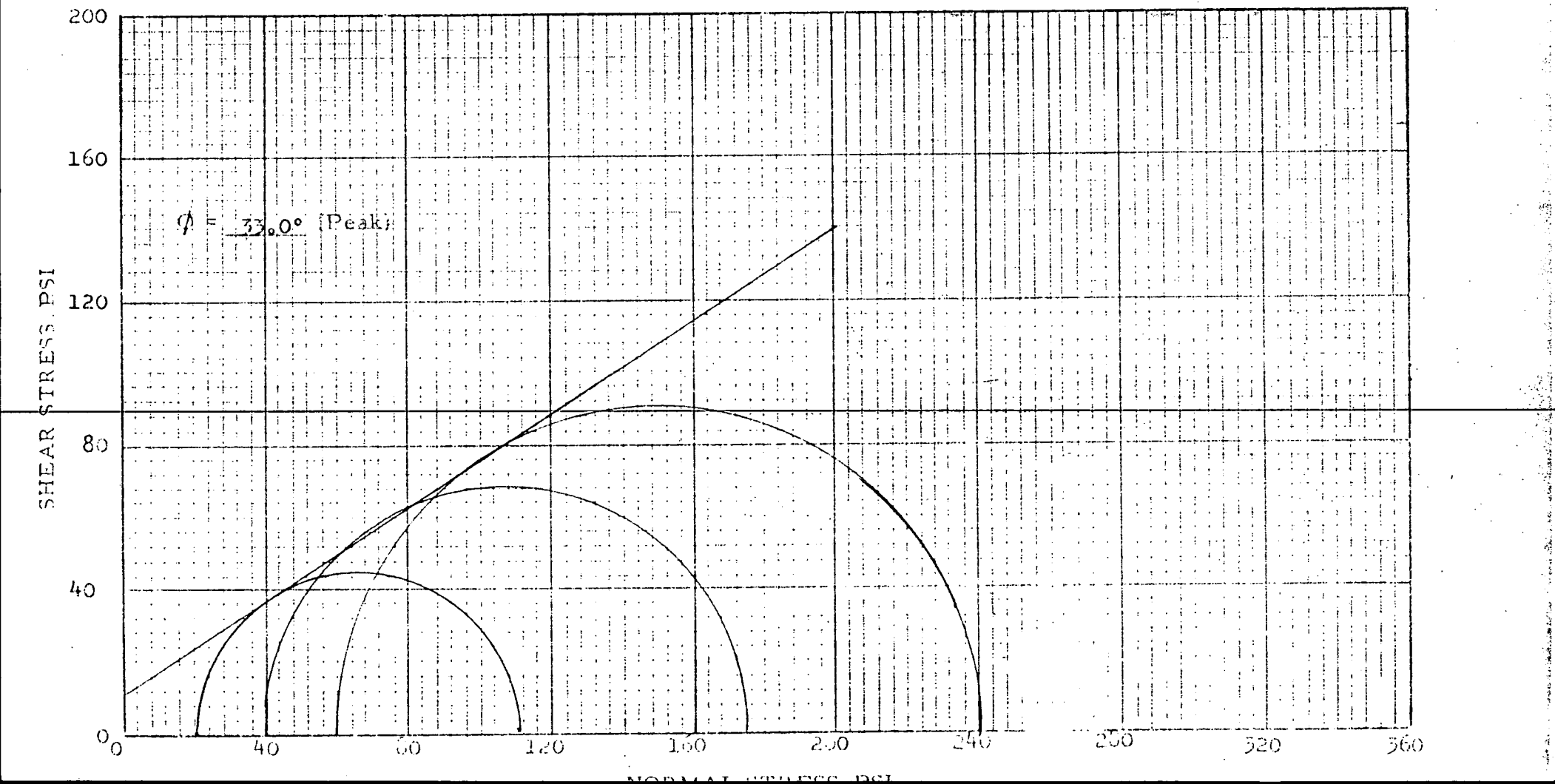
SOIL MECHANICS INCORPORATED


POROSITY - %
VOID RATIO
20
25
30
35
40
45
.2510
.3340
.4280
.5370
.6690
.7900
90
95
100
105
110
115
120
125
DENSITY - POUNDS PER CU. FT.
THE ZIA COMPANY
Los Alamos, N.M.
Job No. 59-154
Sample No. 6805
S.G. 2.580

SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154 Lab No. 6803

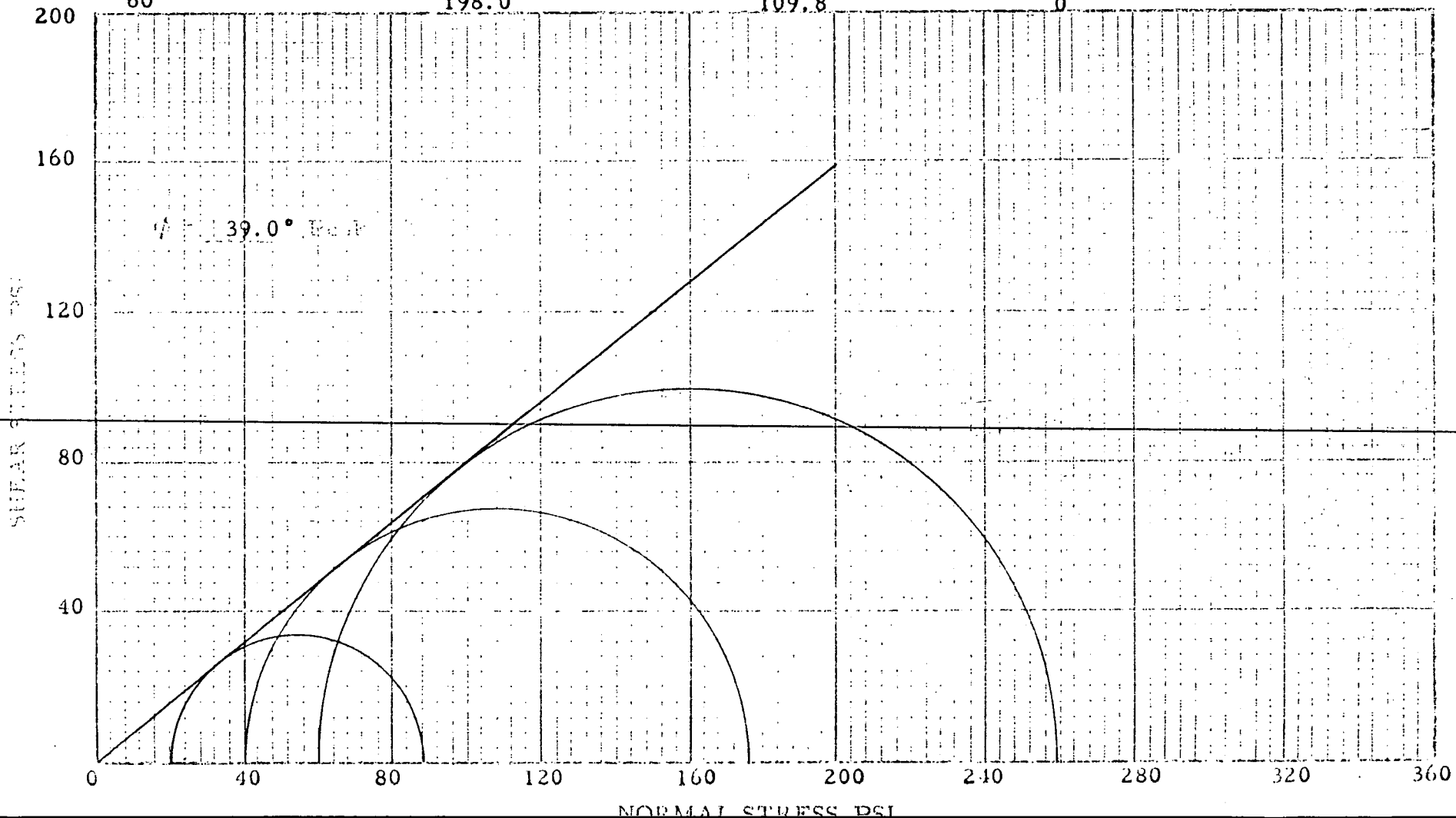
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ pcf	Moisture content, %	Remarks:
20	91.4	108.4	0	
40	135.0	109.6	0	
60	179.4	109.6	0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6803

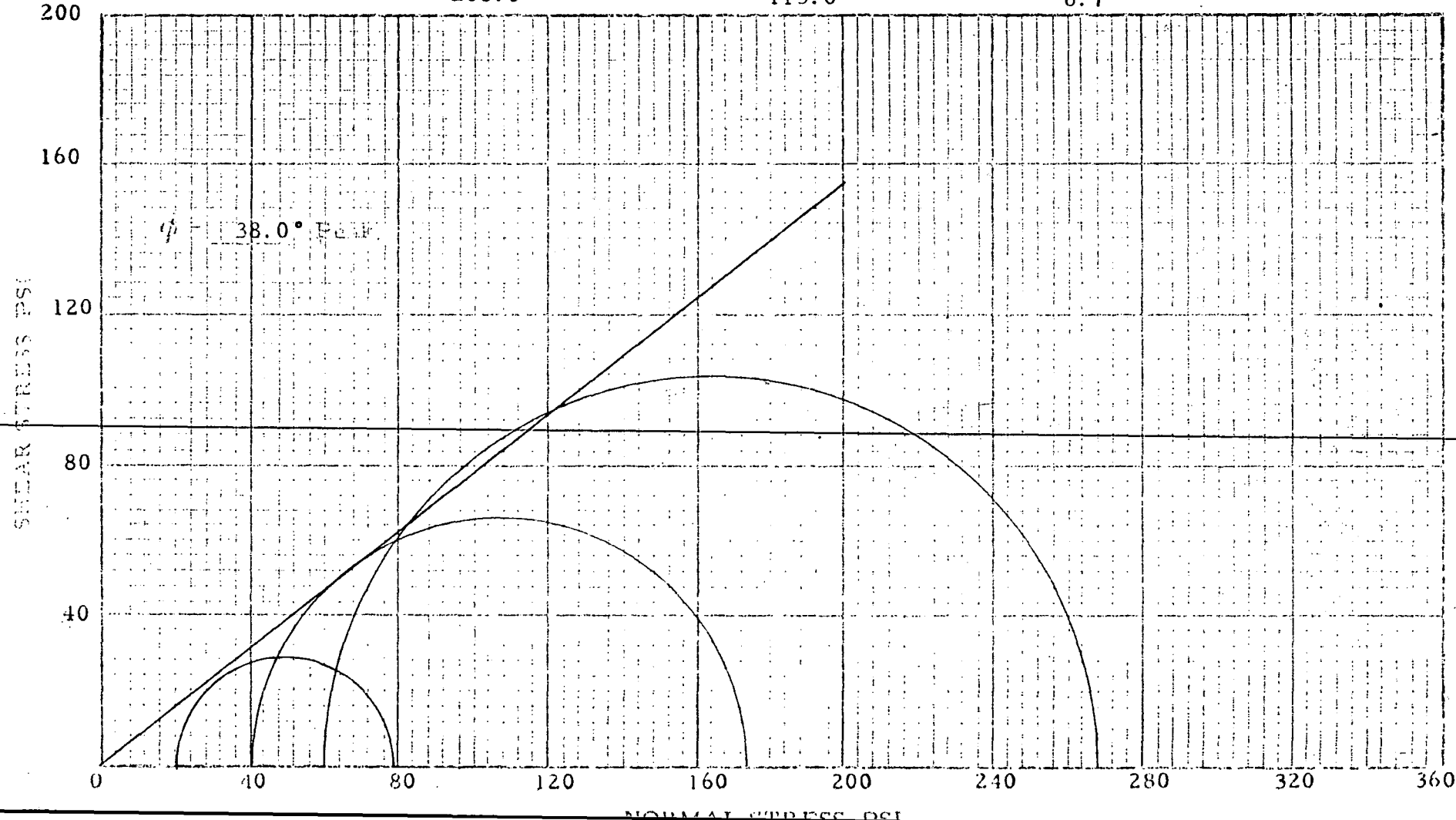
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	68.6	108.6	0	Material Passing No. 10 Sieve
40	135.8	108.6	0	
60	198.0	109.8	0	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6803

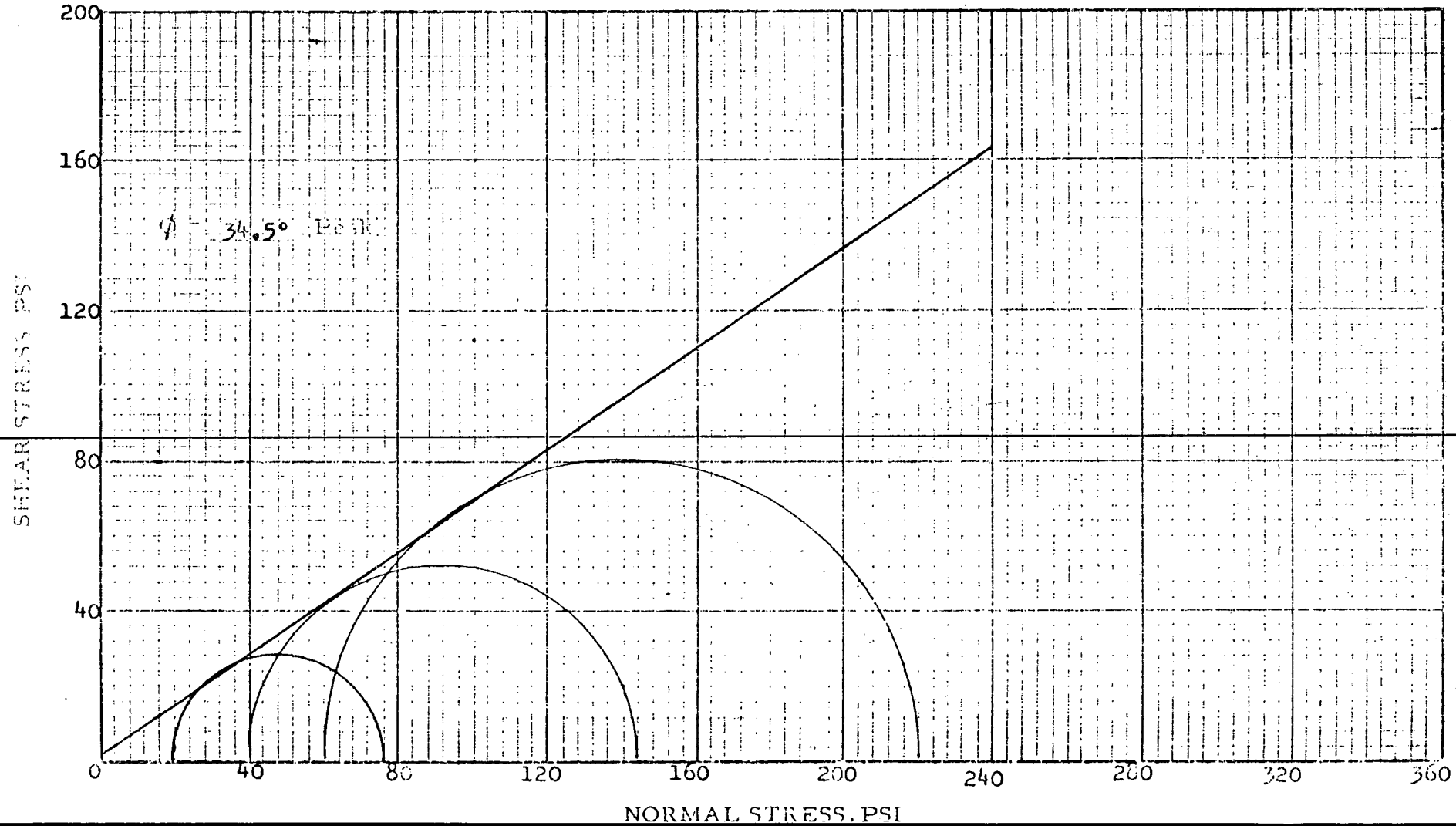
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ, pcf	Moisture content, %	Remarks:
20	57.4	111.0	6.9	
40	133.4	112.6	7.0	
60	208.0	113.0	6.7	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY, Los Alamos, N.M. Job No. 59-154 Lab No. 6803

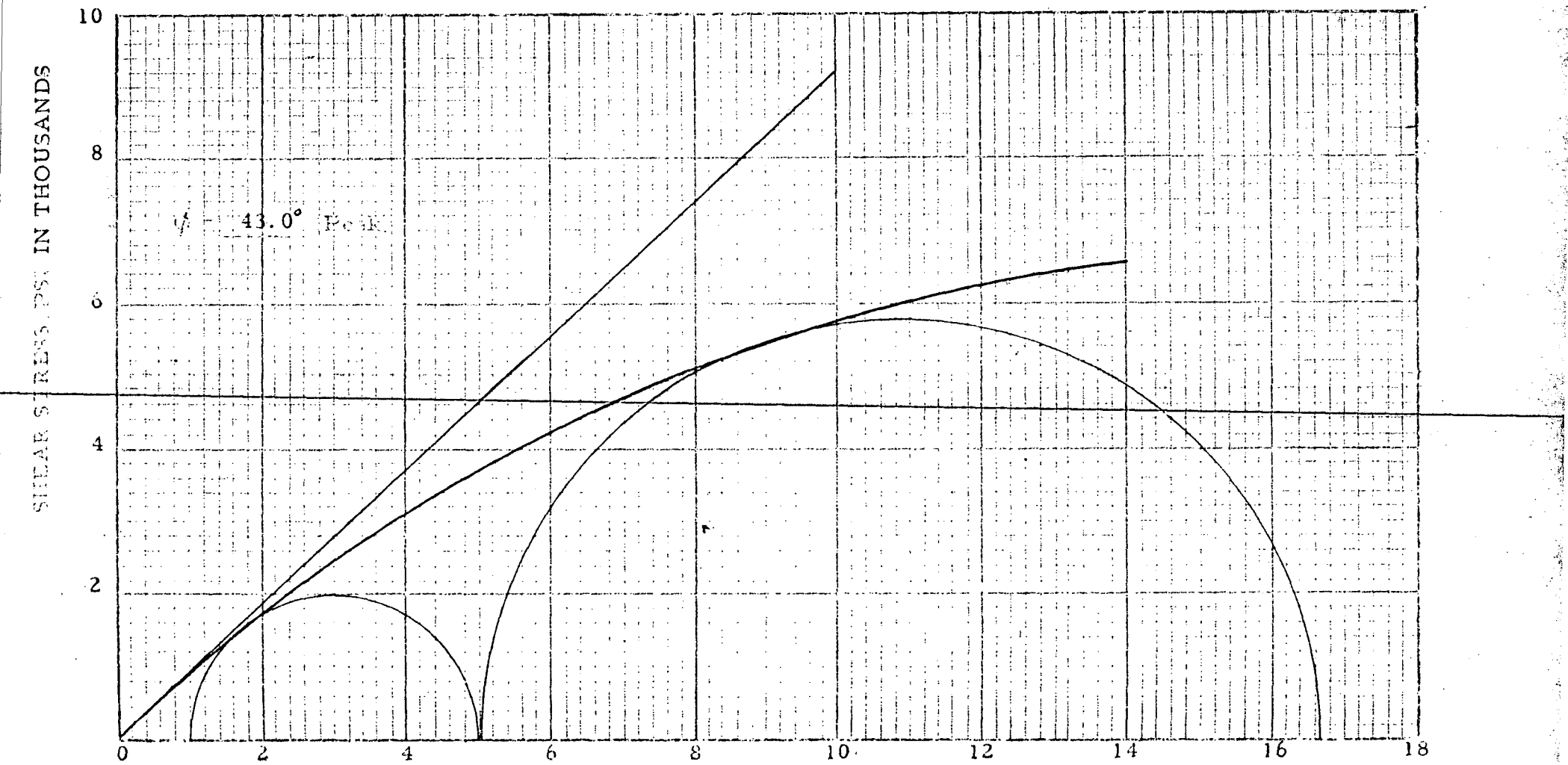
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density γ pcf	Moisture content, %	Remarks:
20	56.0	109.0	7.5	Material passing
40	105.4	106.2	7.4	# 10 sieve
60	159.4	110.8	6.3	



SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6803

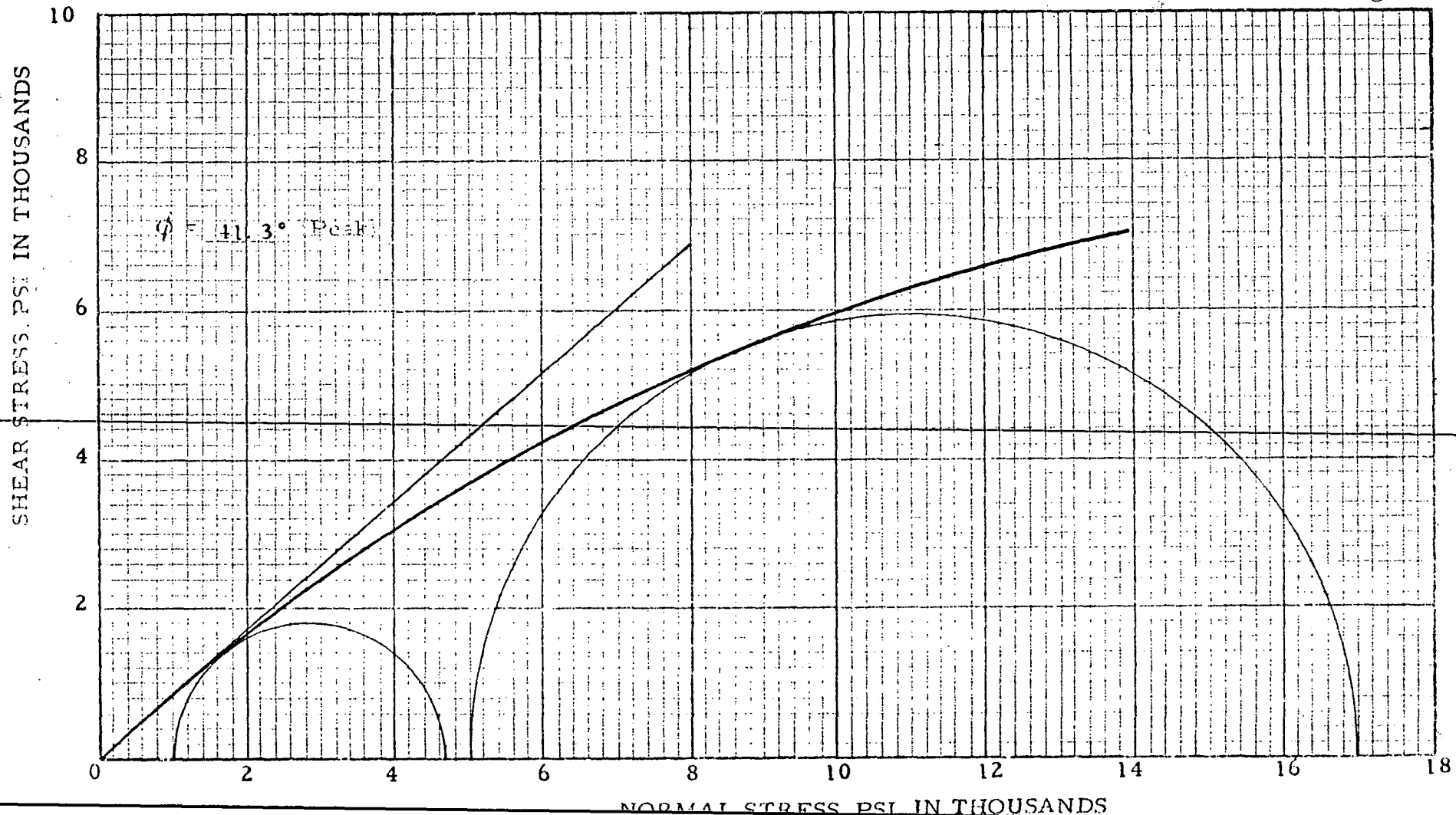
Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density Before test, pcf.	Dry Density After Applying Lateral Press.	Moisture content, %	Remarks: Before Test
1,000	3,980	110.4	117.1	0	Dia. 1.73 in. Length 3.19 in.
5,000	11,640	107.4	121.0	0	Dia. 1.75 in. Length 3.19 in.



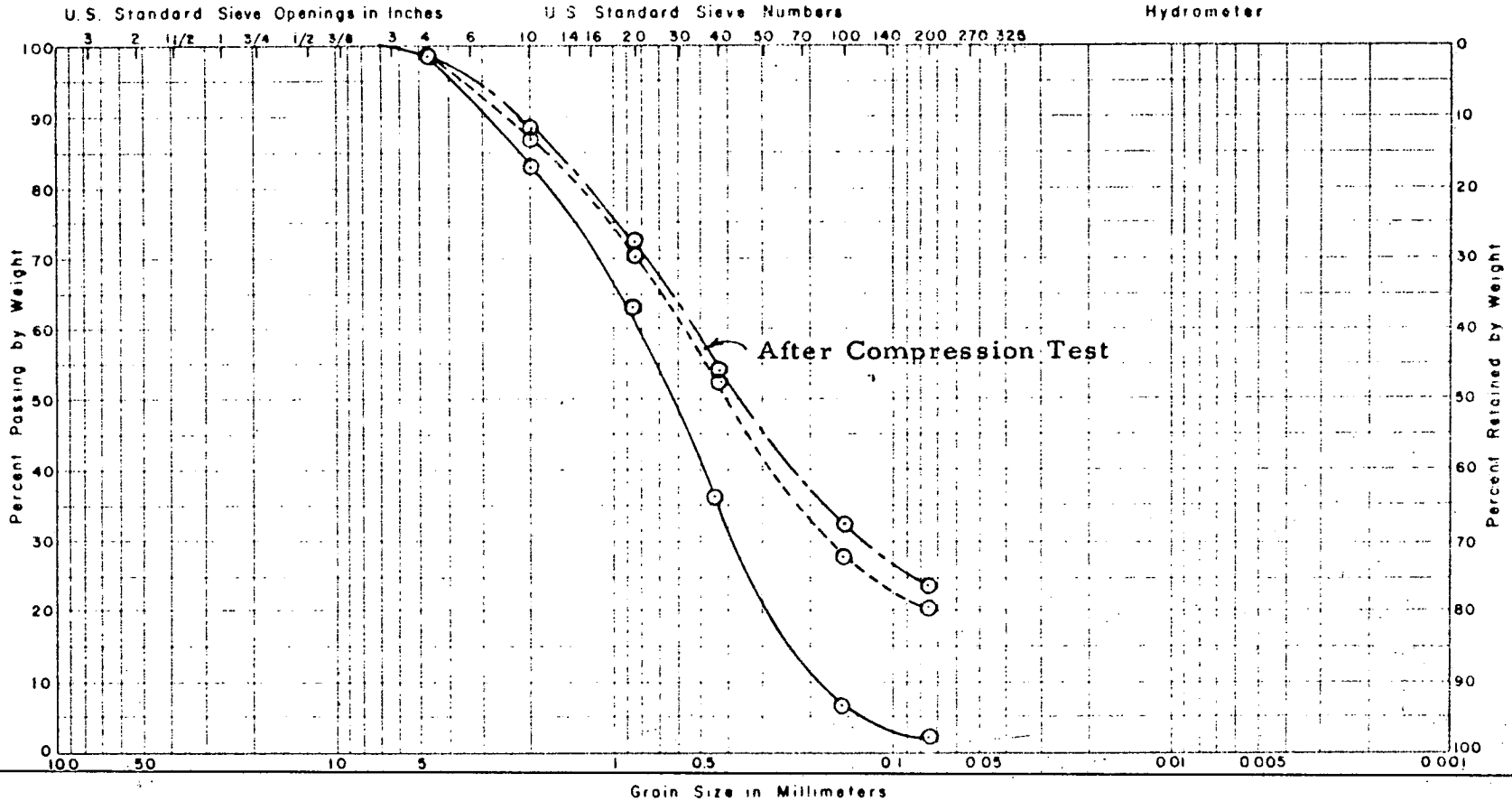
SOIL MECHANICS INCORPORATED
TRIAXIAL COMPRESSION TEST

Project THE ZIA COMPANY Job No. 59-154 Lab No. 6803

Confinement σ_3, psi	Max. Stress $\sigma_1-\sigma_3$, psi	Dry Density Before test, pcf.	Dry Density After Applying Lateral Press.	Moisture content, %	Remarks: Before Test
1,000	3,610	109.4	116.2	7.2	Dia. 1.75in Length 3.15 in.
5,000	11,900	111.5	126.0	5.0	Dia. 1.75 in. Length 3.16 in.



MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

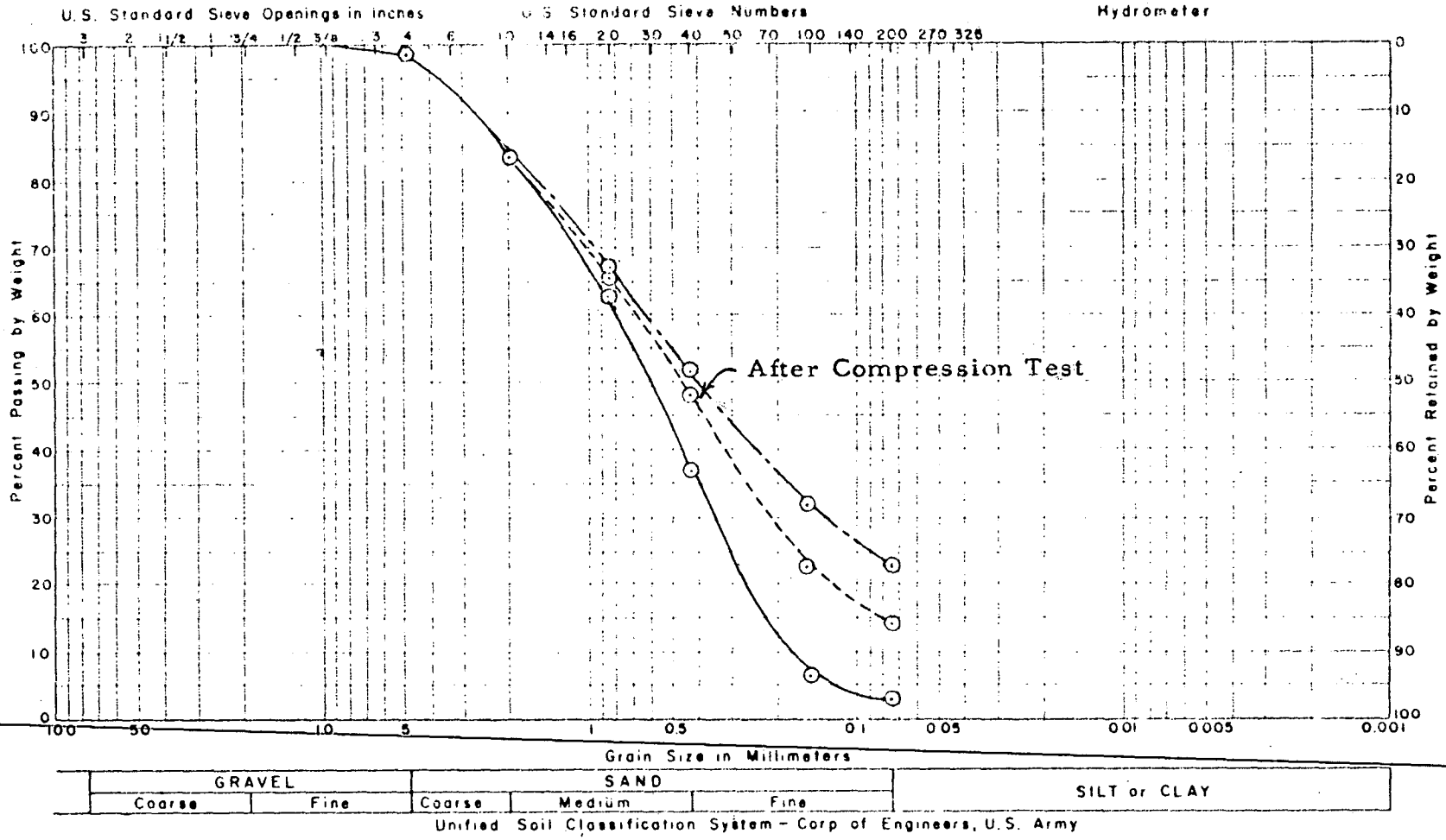
Unified Soil Classification System – Corp of Engineers, U.S. Army

THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab No. 6803

Concrete Sand

LEGEND	MOISTURE CONTENT
———— Natural Condition	-
- - - - - - - After 1,000 psi Lateral Pressure	0
——— - ——— After 5,000 psi Lateral Pressure	0

MECHANICAL ANALYSIS CHART



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System - Corp of Engineers, U.S. Army

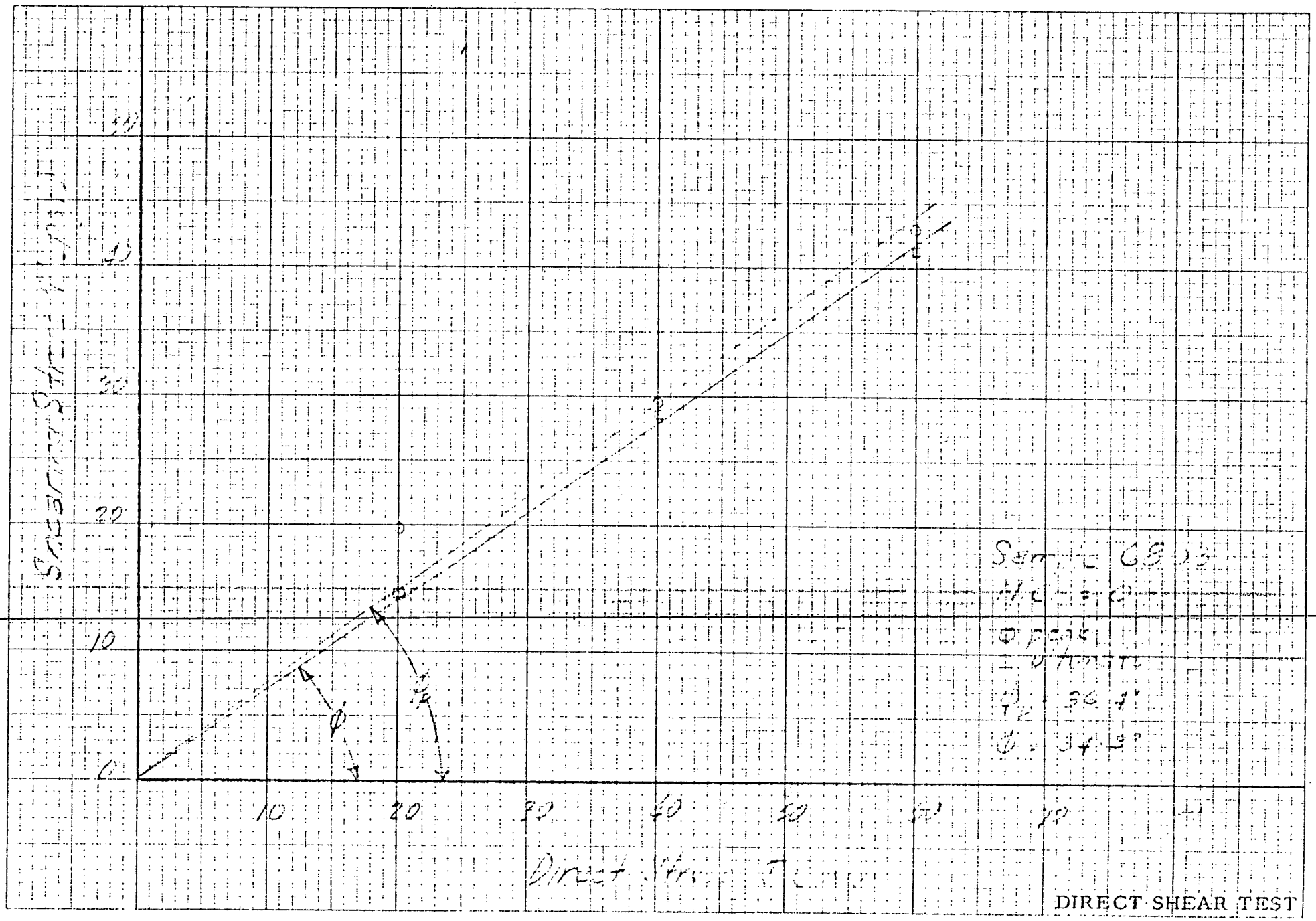
THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab No. 6803

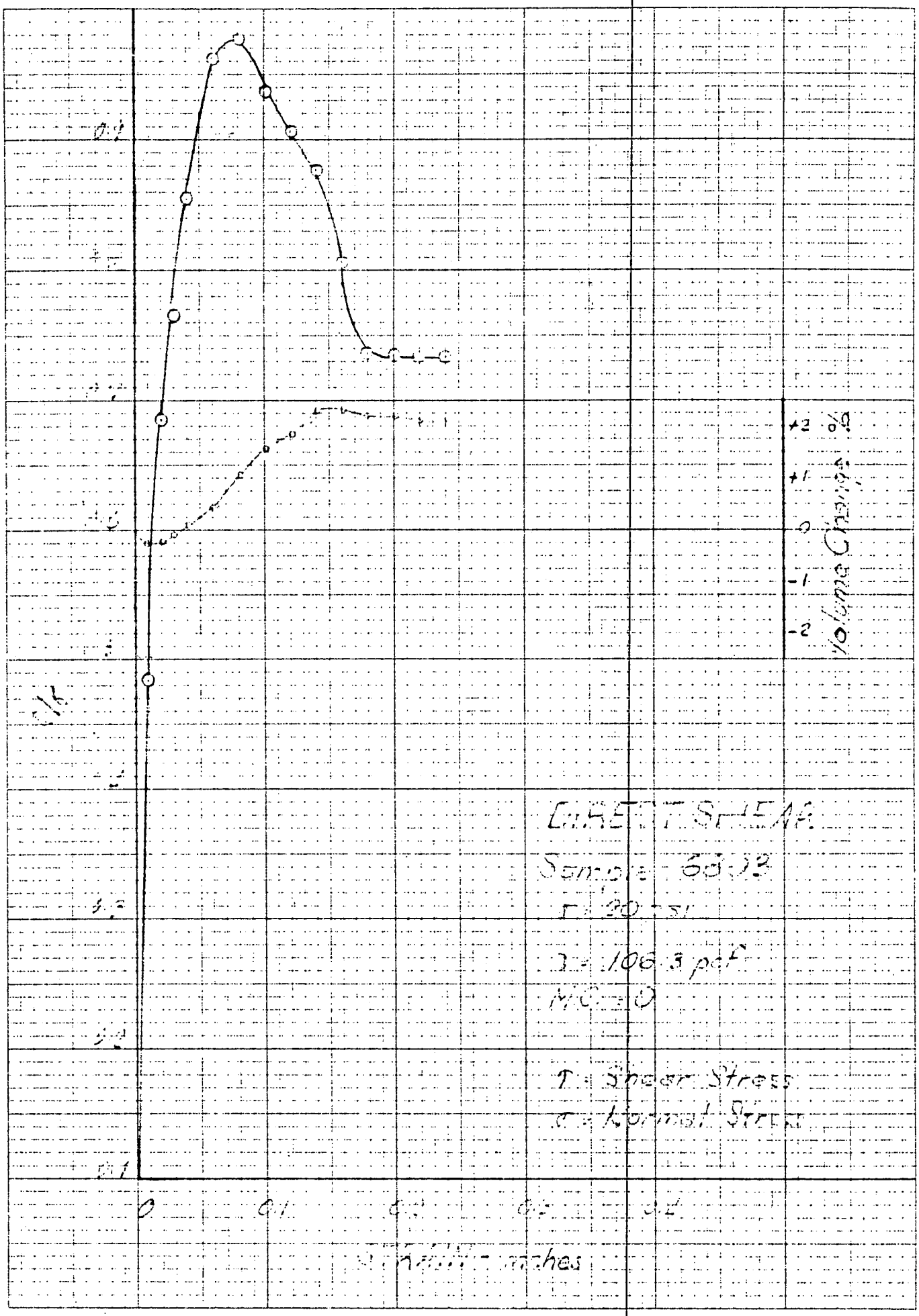
Concrete Sand

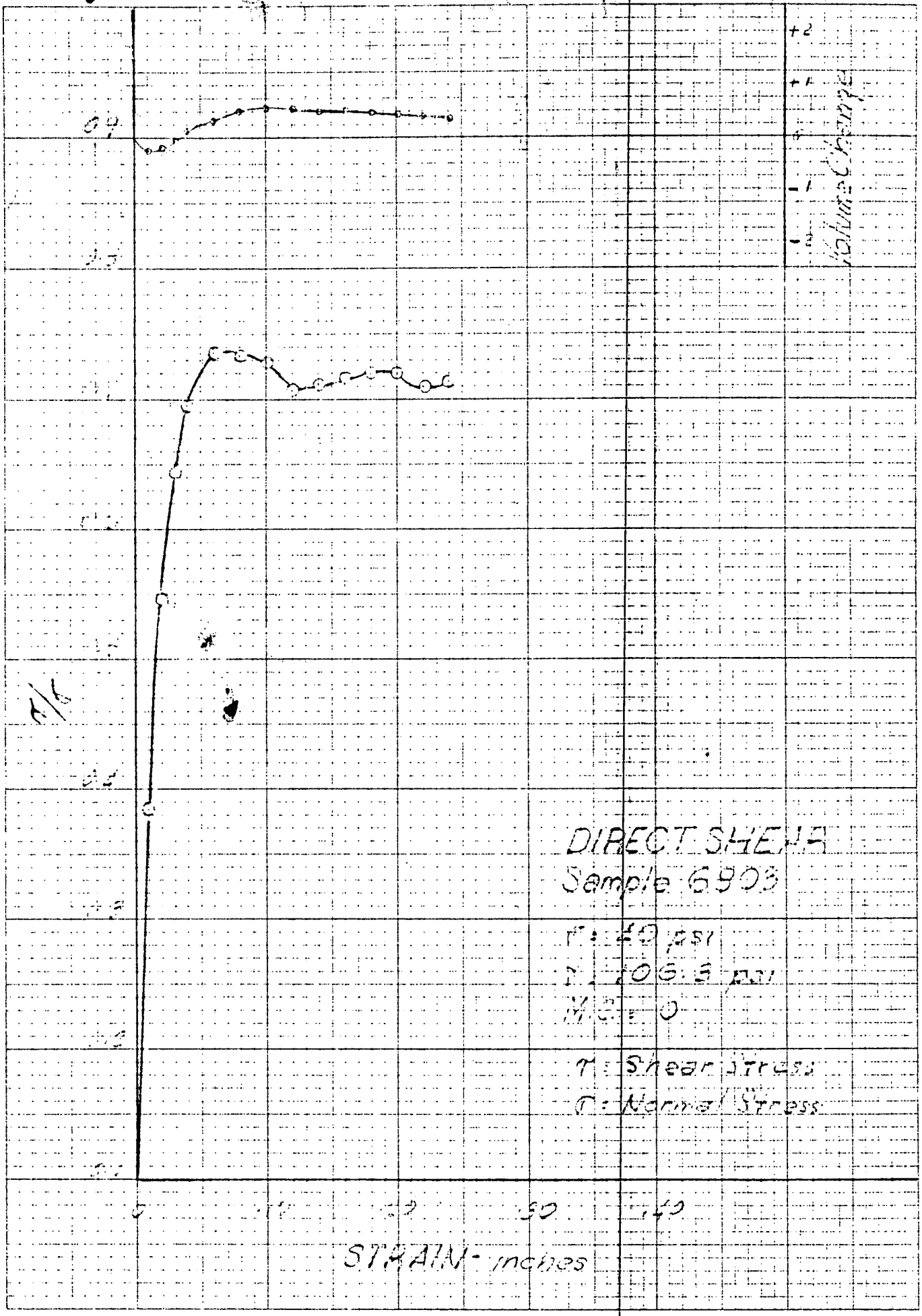
LEGEND	MOISTURE CONTENT
———— Natural Condition	-
- - - - - - After 1,000 psi Lateral Pressure	7.2
—— - —— After 5,000 psi Lateral Pressure	5.0

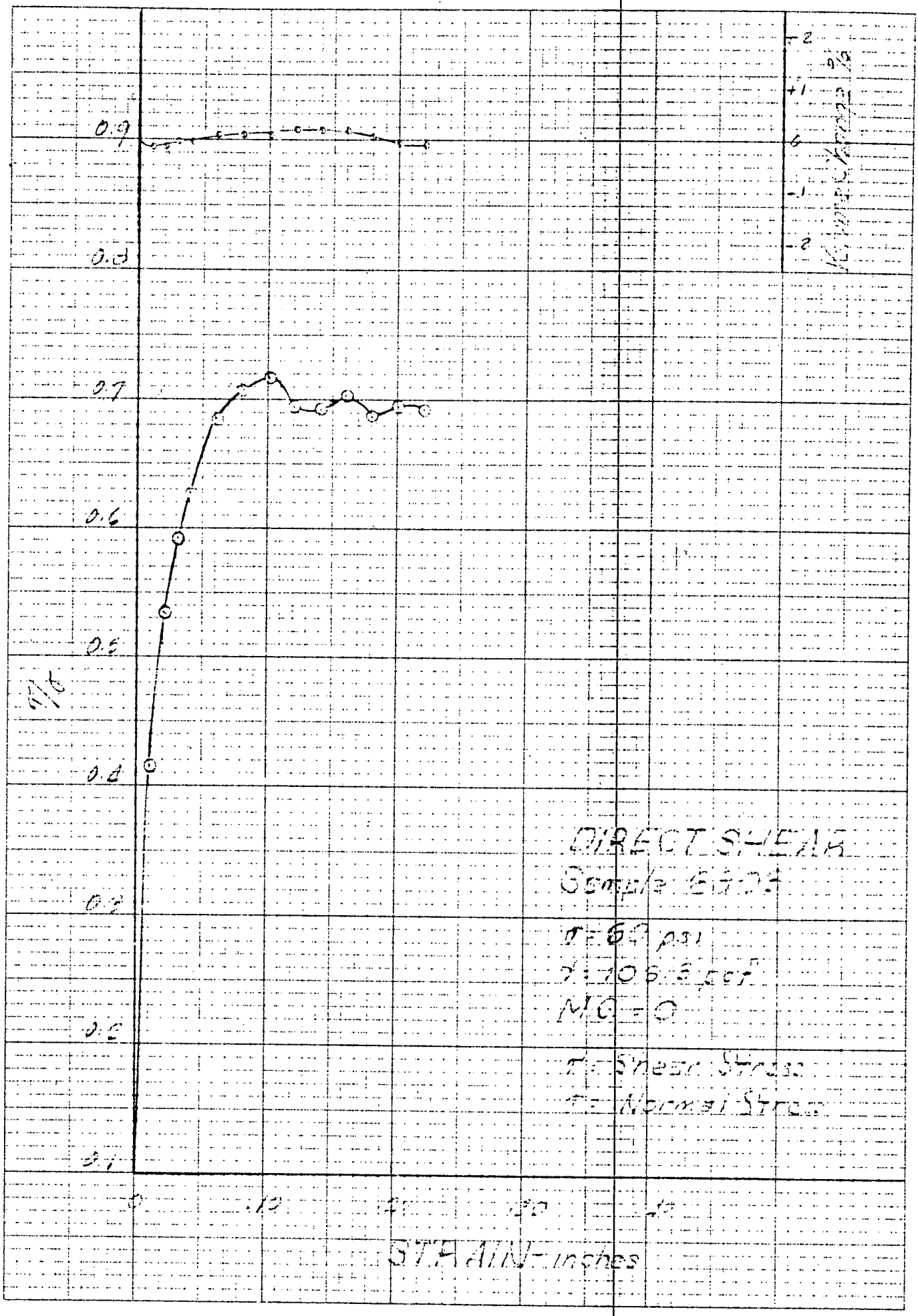
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U.S.A.



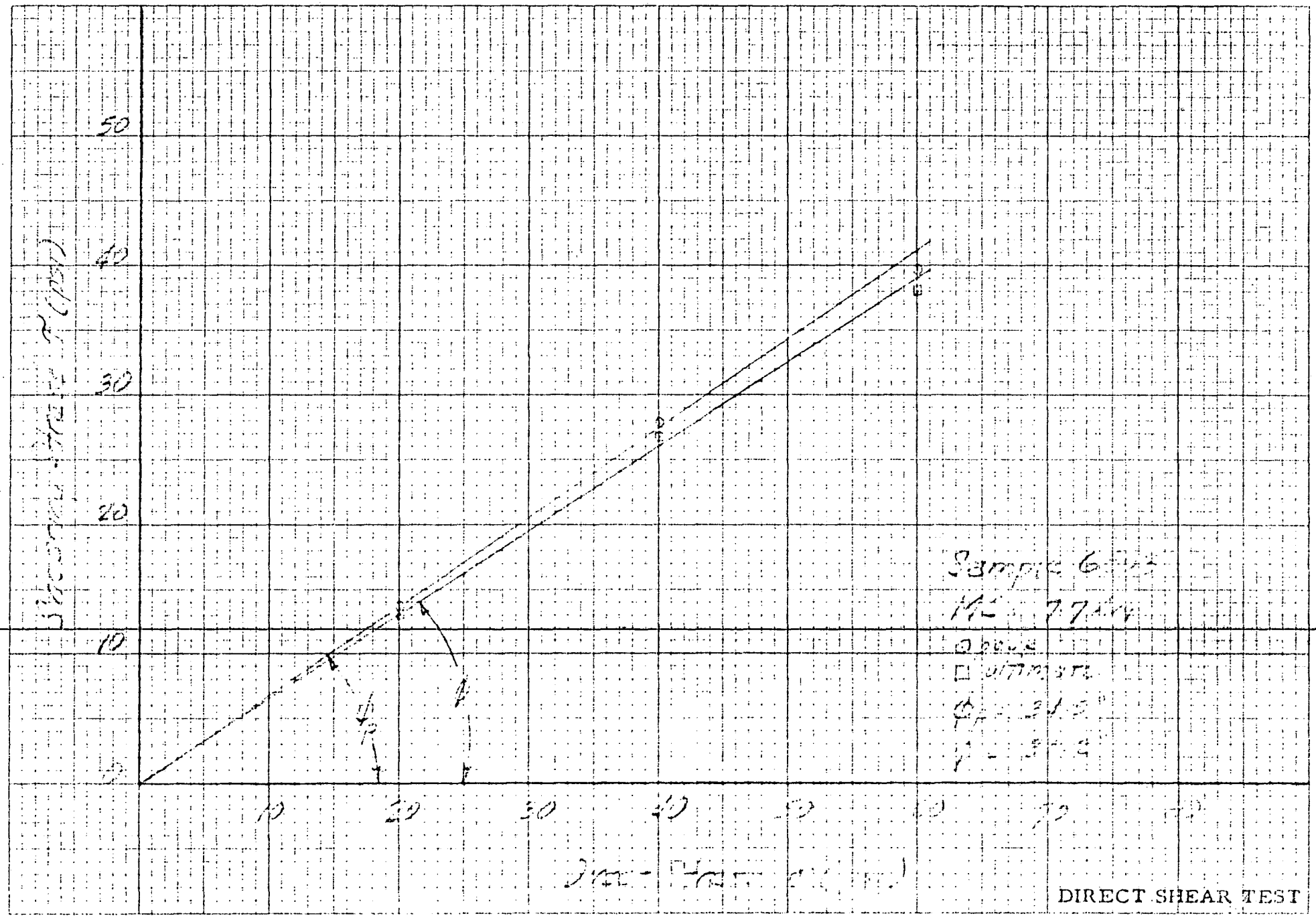

+2 %
+1
0
-1
-2
Volume Change
CHEETT SHEAR
Sample: 6012
σ = 20 - 51
γ = 106.3 pcf
MC = 0
τ = Shear Stress
σ = Normal Stress
0
0.1
0.2
0.3
0.4
Displacement - inches

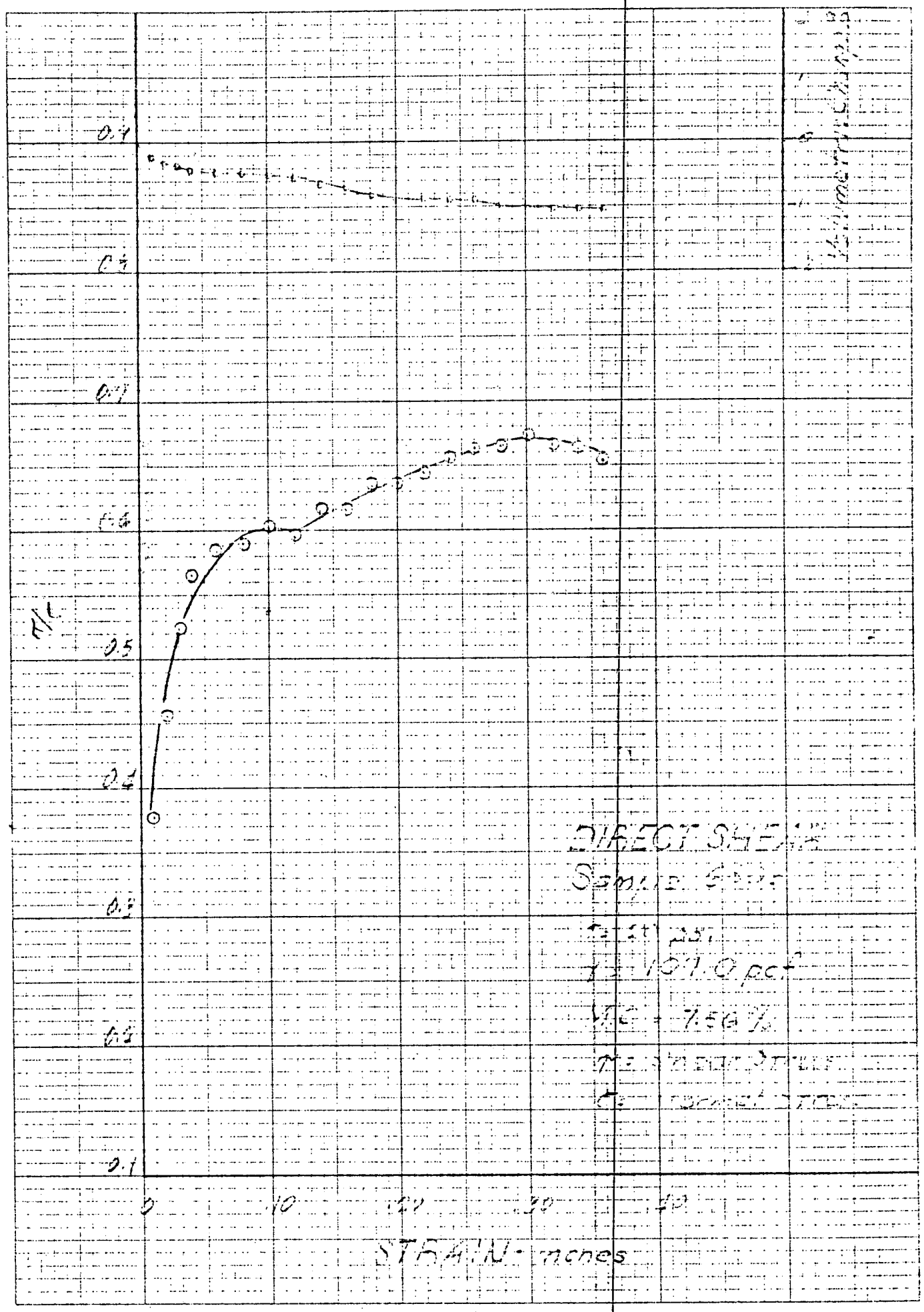

DIRECT SHEAR
Sample 6903
σ: 40 psi
τ: 106.5 psi
MC: 0
τ: Shear Stress
σ: Normal Stress
STRAIN - inches
VOLUME CHANGE


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
τ/σ
+2
+1
0
-1
-2
0
.10
.20
.30
.40
STRAIN-inches
DIRECT SHEAR
Sample 6T04
σ = 69 psi
γ = 106.5 pcf
MC = 0
τ = Shear Stress
σ = Normal Stress

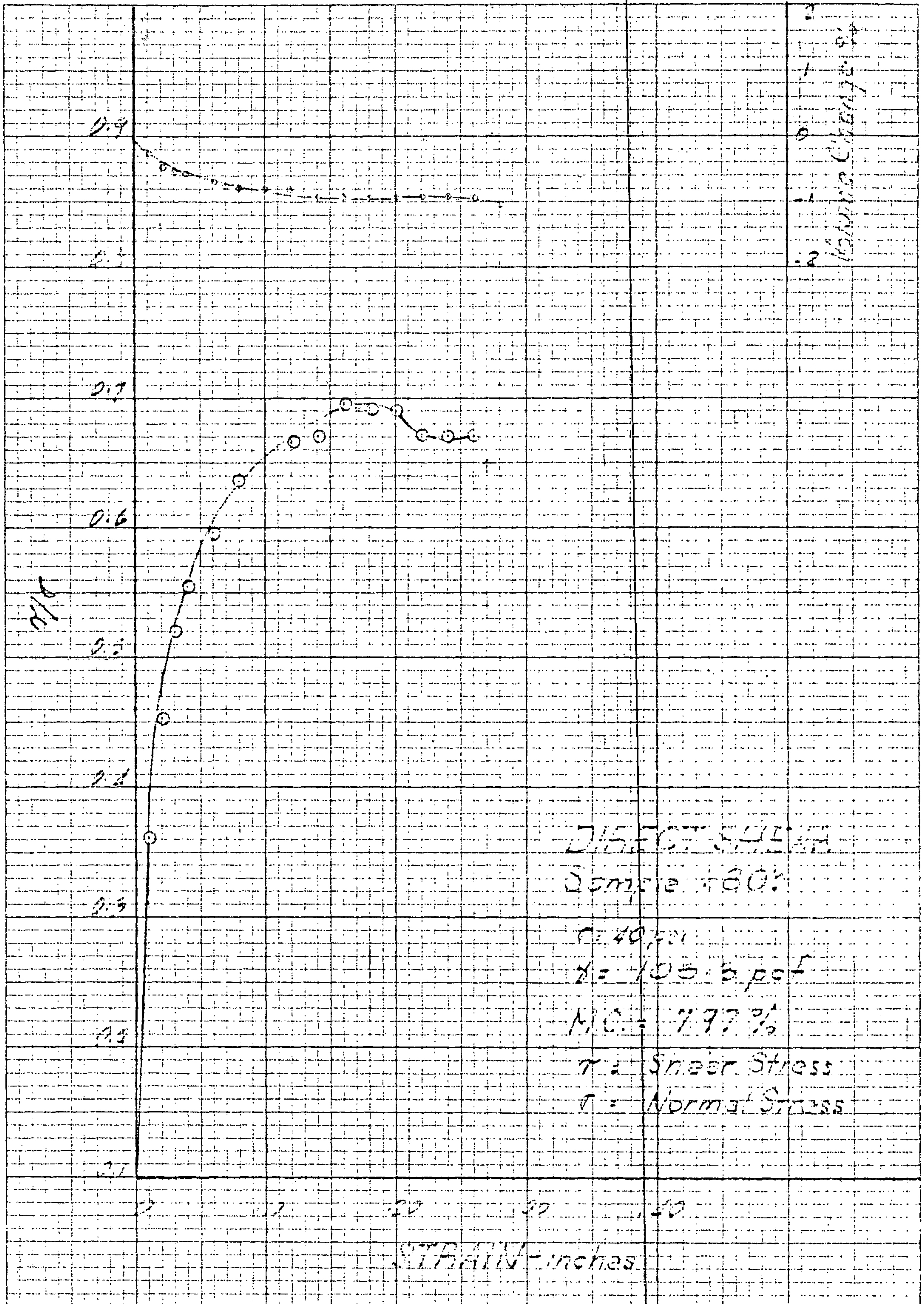
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

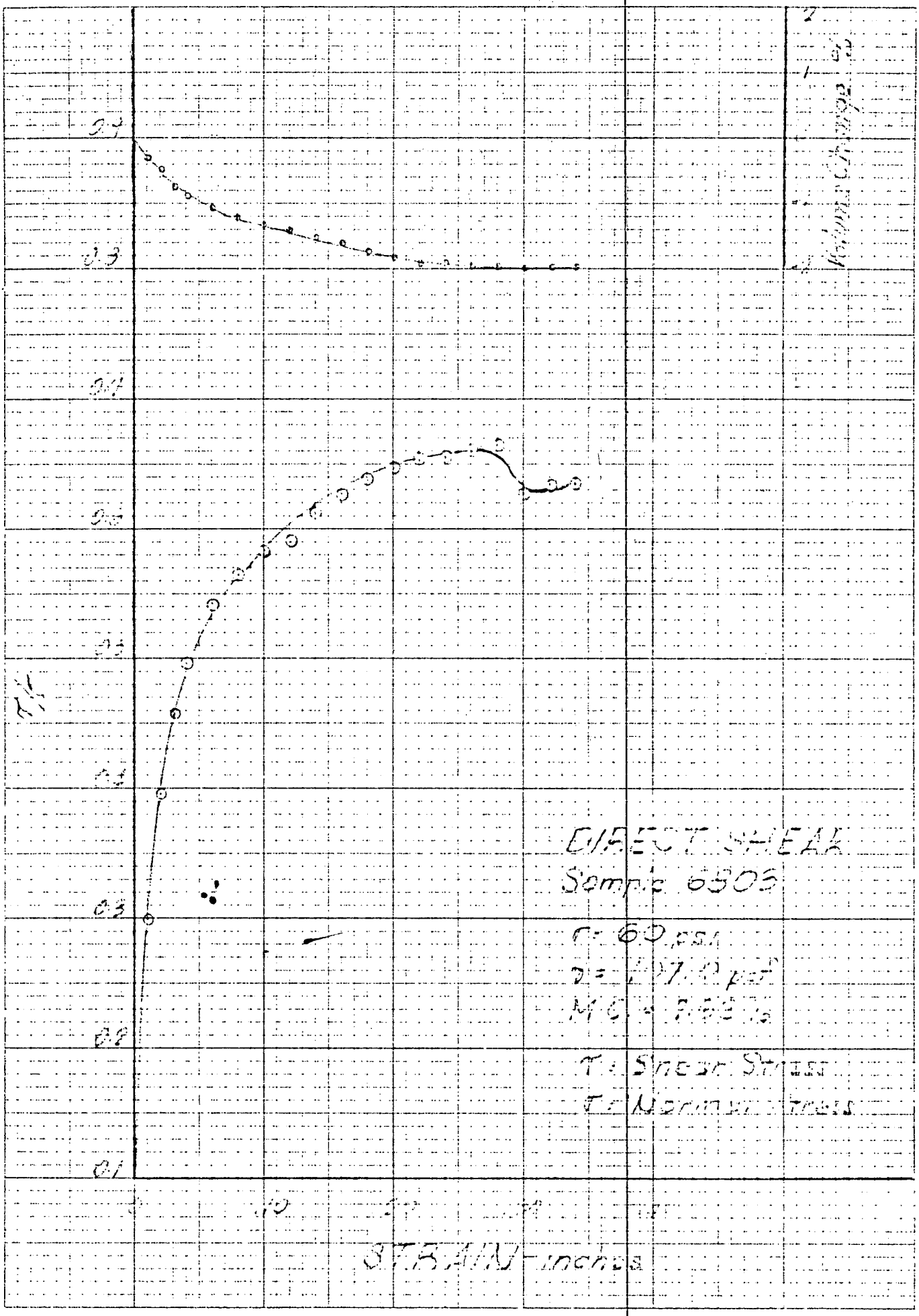
EUGENE DIETZGEN CO.
MADE IN U.S.A.

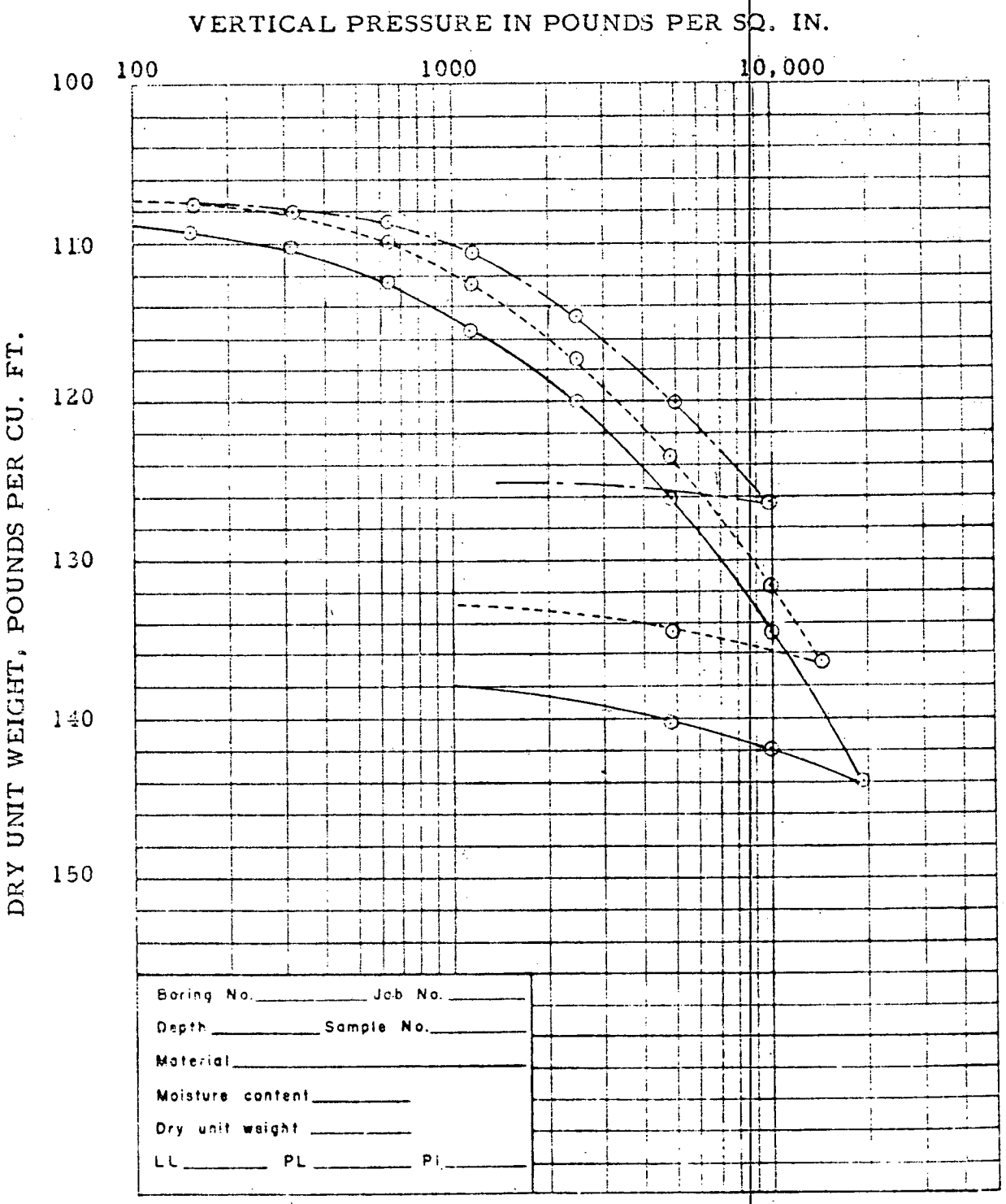



0.7
0.6
0.5
0.4
0.3
0.2
0.1
A/L
0
10
20
30
40
STRAIN - inches
DIRECT SHEAR
Sample 6
γd = 101.0 pcf
MC = 7.5 %

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.




DIRECT SHEAR
Sample 6505
STRAIN - inches



DENSITY VS LOG PRESSURE CURVE

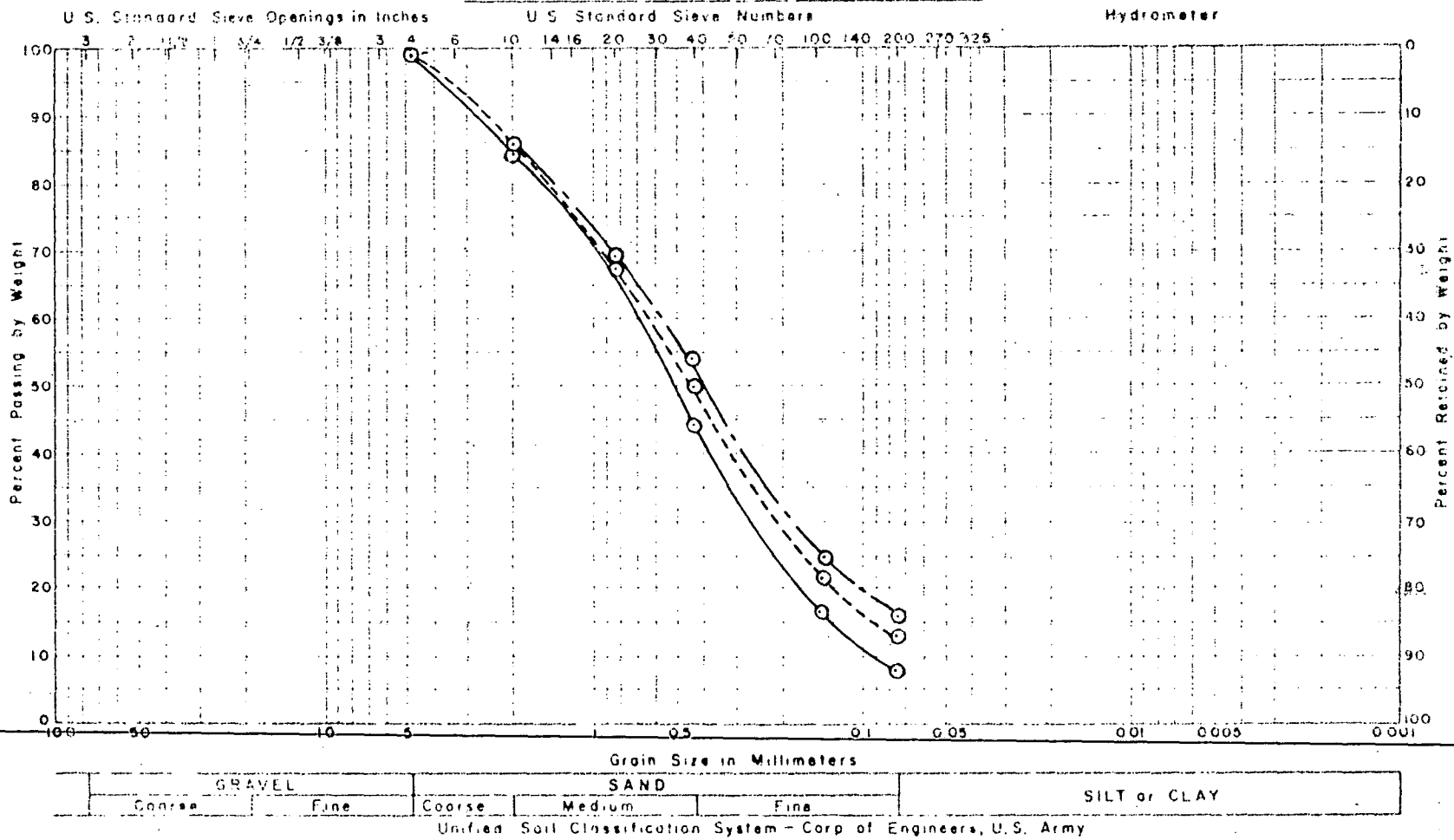
THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Sample No. 6803

Concrete Sand
S. G. 2.580

LEGEND

Height = 1" ————————
Height = 2" - - - - - - - -
Height = 3" —— · —— · ——

MECHANICAL ANALYSIS CHART



THE ZIA COMPANY
Los Alamos, N. M.
Job No. 59-154
Lab. No. 6803

LEGEND

——————— After 10,000 psi Vertical Pressure 3" High Sample
- - - - - - - After 15,000 psi Vertical Pressure 2" High Sample
——— - ——— After 20,000 psi Vertical Pressure 1" High Sample