FIELD EVALUATION

OF

THE LANE-WELLS ROAD LOGGER

IOWA HIGHWAY RESEARCH BOARD PROJECT HR-113

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MATERIALS DEPARTMENT

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HR-113

Investigation of the Lane-Wells Road Logger

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Abstract

The Lane-Wells Road Logger was utilized primarily to determine the feasibility of employing such a device for moisture and density control in Iowa highway construction. A secondary objective was the use of the Road Logger to obtain information concerning moisture content and density during and after construction.

Correlation studies with conventional test results required a small portion of the lease period. Practically all phases of construction and most materials utilized in base and surface courses were surveyed. Results of this study were good, in general, with the Road Logger indicating dry density slightly higher and the moisture content slightly lower than conventional results in most instances.

Economic feasibility seemed to pose the greatest problem for the acceptance of the Road Logger as a standard compaction control device. It would appear from the findings of this study that probably only large projects, or several smaller contracts tested simultaneously, could justify the expense of the Logger.

A total of about 128 miles were surveyed with the Logger during the lease period. Approximately 16 days of downtime due to minor breakdowns were recorded. Inclement weather forcing construction delays resulted in several idle days in which the Logger's full capabilities were not realized.

Introduction and Description of Road Logger

Moisture and density are two of the more important properties which must be determined of the subgrade, subbase, and base layers of most roadways constructed today. In the asphalt highways the density of the surface course is also of prime consideration. The Lane-Wells device, designated Road Logger, is a machine which is capable of measuring these properties in a continuous strip and recording the results in graph form, in ink on a semi-transparent sheet which can be used as a permanent record or easily be reproduced.

On March 17, 1965, the Iowa Highway Commission approved research project HR-113, Investigation of the Lane-Wells Road Logger, including the proposed budget which totaled $31,350. Basic responsibility for the operation of the Logger rested with the Special Problems Section of the Materials Department. It was necessary, also, to have the assistance of the Research Department and the cooperation of the Construction Department and of the Commission personnel in the districts.

The Road Logger consists, primarily, of a conventional 3/4 ton pickup and a two wheel trailer which have been modified to carry two nuclear sources, shielding, recorder, and the other associated electronic devices and equipment which are needed to carry out logging operations. The gross weight of the truck was about 8000 pounds and the trailer about 1400 pounds.

The Road Logger's moisture measuring system is comprised of a 5 curie Plutonium-Beryllium neutron source which is shielded with paraffin for safety and a neutron detector composed of four Barium Tri-flouride (BF_3) tubes. This entire assembly is mounted on a small two wheel carriage which is lowered hydraulically for logging operations. When the system has been lowered to the logging position, it rides more or less independently of the main vehicle thus minimizing the effects of surface roughness. An air gap of one inch is maintained between the bottom of the carriage and the surface of the material being tested.

According to literature supplied by the manufacturer, the strip of material tested is approximately twelve inches wide and six to eight inches deep. The amount of weight given to moisture in the material varies exponentially from the top to the bottom, with the upper-most moisture receiving the greatest weight. In traversing the roadway each point on the chart represents a volume of twelve inches by six inches by six feet, approximately, or about three cubic feet. The six foot dimension can be varied by changing the speed of the vehicle or by changing the time-constant of integration of the count rate meter. These factors can be varied easily by the operator to suit different requirements, but generally the six foot measurement is found most satisfactory.

The count rate from the detection tubes is relayed to the recorder in the cab of the pick-up. This rate is very nearly linearly related to moisture content in pounds per cubic foot. The portion of the chart which is concerned with moisture is calibrated accordingly with the count rate, from 0 to 25 pounds per cubic foot. Variations as small as 1/2 pounds per cubic foot can be detected from the chart.

The density measuring system is composed of a gamma ray source of 430 millicuries of Cobalt 60 surrounded by a tungsten-lead-steel collimating shield. The assembly is carried in the trailer and, as with the moisture system, is mounted on a two wheel carriage which can be raised and lowered hydraulically. Radiation emerges principally downward penetrating the material being tested. A scintillation detector is used to detect the returning gamma radiation. The volume of material represented by one point on the chart is very nearly the same as described for the moisture unit, and as before, the six foot dimension can be altered if it is desirable. The density portion of the chart is graduated from 90 to 165 pounds per cubic foot.

The manufacturer indicated that the ability of both the moisture and density units to produce accurate results is substantially independent of the composition and degree of compaction of the material normally used in highway construction.

Although both radiation sources used in this operation are fairly large, the hazard to personnel working with the equipment is negligible due to the shielding incorporated in the design and to the distances normally kept by the operator.

The Road Logger is designed to be operated by one man and is quite maneuverable, with a turning radius of about 17 feet. The logging operation is generally performed at 150 feet per minute or about 1-1/2 miles per hour. Travel to and from job locations may be done at normal highway speeds.

Calibration of Moisture and Density Units

At the beginning of operation on almost every project, a calibration was made of the Logger's equipment. This type of calibration was quite simple and could be made in a few minutes by the operator. To make this calibration both units were raised and the calibration blocks were moved hydraulically under the units. The blocks were composed of limestone of known density for the density unit and polyethylene plastic of known hydrogen content for the moisture unit. With the units in this position, the readings on the chart for moisture and density should have been 15.0 lb/ft.^{3} and 136.5 lb/ft.^{3}, respectively. If results different from these were obtained, the readings could be changed by the manipulation of the output circuit of the rate meter in the panel in the back of the cab. A sample calibration of this type is contained in this report on Figure 1.

To insure against the recording of chemical sensitivity by the density unit, all signals below 150,000 volts were rejected or discriminated. In order to find the setting of the amplifier-discriminator at which all low-energy signals were rejected a calibration known as a "Cesium peak" was made. This type of calibration required more time and skill to perform than the one previously described. A Cesium source of known radiation intensity was used to perform this operation. A sample Cesium peak calibration is shown on Figure 2. This type of calibration was performed only a few times a week.

When both of these calibrations were performed at the prescribed intervals, representative results were usually assured.

Evaluation of Road Logger Data as a Means of Compaction Control

The interpretation and use of Road Logger data for compaction control of embankment and subgrade construction could prove to be a problem of some magnitude if similar procedures to those presently in use were to be followed. Presently, density samples are taken from compacted material and compared with maximum impact, AASHO Designation T-99, or Proctor densities which have been determined for soil from the same site. The percent moisture in the sample is compared with the percent of moisture required to attain the Proctor density, or the Optimum Moisture Content.

It is possible to evaluate a section of compacted material from the Logger's chart by comparing the densities obtained to a percent of the Proctor Density. This operation has been carried out on several charts which are included in the Appendix, on Figures 6 through 10. A dry density line was computed and plotted on these charts, together with an optimum moisture line and a line representing minimum acceptable densities which was 95% of Proctor in most cases. This was done for illustrative purposes only, and in the field such a detailed observation as this would neither be needed nor necessary. Only areas of apparent low density where the dry density fell below the minimum density line would have to be checked. With this method, however, Proctor Densities would still have to be prepared whenever a different soil type would be encountered. Also, if a strip of material was evaluated in which more than one Proctor Density was involved, different minimum densities would have to be calculated and applied.

The State of California, Division of Highways, in it's "Field Evaluation of the Lane-Wells Road Logger" has suggested another method whereby the Logger might be used for compaction control, which might be well to describe here. According to studies made by the California Division of Highways, the Road Logger would duplicate the range and distribution of field densities as indicated by sand volume tests on a strip of similar material. A similar distribution would probably be obtained with any conventional test employed. Maximum impact test data for the same material was also presented. It was found that these densities follow the same pattern as the Logger and conventional tests but at a higher density. Three main observations were made from this study. The first was that the range of field densities was greater than the range of associated maximum densities. The second was that there was always a field density below which all tests failed. This finding suggested that a method could be devised whereby field densities could be controlled by a minimum permissible density. Finally it was discovered that the distribution of field or laboratory densities from a similar material is essentially a normal distribution. The method thus suggested was based on the fact that statistically a contractor could not compact an area such that the lowest density would pass the required minimum density without having all the densities pass the same required minimum, providing that the material was reasonably homogeneous. This method would then require that each soil type would have a range of maximum impact densities determined before field testing was commenced. Several curves would have to be prepared for each material. Then these maximum impact densities would be plotted on probability paper in the form of cumulative percent versus wet density. The State of Louisiana has prepared several sets of such curves and presented the data in Research Project No. 61-11S. The data used was taken from files. In order to compute the minimum density the lower ten percent cumulative maximum impact density was found from the plot. This density would then be multiplied by the specified relative compactive factor to be used. The computation would yield the minimum permissible density.

Some advantages of this method would be the simplicity and ease of application in the field. In the laboratory, once the initial standard for a specific material had been established, no additional testing would be required except to verify that the control used is currently applicable. With this method, however, it would be possible for a contractor who is working with a mixed material of high and low density to concentrate his efforts on the low density material thus not properly compacting the higher density materials. A special provision would have to be written to insure against this.

Economic Evaluation

The lease fee for the Road Logger was $3500 per month. Subgrade operations required two men and an additional vehicle for efficient work. Assuming that the salaries and expenses of the two men were about $1500 per month and that the operating expenses of the two vehicles were $1000, this would bring the total cost for Logger operations to about $6000 per month.

The cost of conventional testing was a difficult item to assess, since the inspectors have many duties other than conducting moisture and density tests. However, if the salaries of the inspectors involved and the cost of the equipment used was estimated to be $1000 per month, and assuming that the Logger could handle two or three projects simultaneously, this would mean that the Logger would have to replace approximately five or six men in order to be economically feasible. It is quite doubtful if the Logger could replace this number. An interesting fact was learned when the cost of testing per mile for the two methods were compared. Using the prorated costs per month and the comparative times required to test a mile of prepared subgrade, assuming that five conventional tests per mile at one half hour each, it was found that, theoretically, the cost for the Logger would be about $12 and $9 for conventional testing. This is due to the much greater speed of testing capabilities of the Logger. It should also be noted that sections are seldom prepared in lengths as great as a mile.

Of considerable importance here, it must be noted that the Logger presents data from an almost infinite number of samples as compared to conventional testing. Certainly this alone must be worth a certain amount in a monetary sense. Use of the Road Logger would enable an inspector to evaluate a strip of prepared subgrade by the density and moisture content at every point along that strip instead of passing or failing the section on the merits of one or two conventional tests. Many sections surveyed with the Logger have been observed to have areas of low density within them. When tested by conventional means, the section would have a good possibility of being passed if the sample was not taken in the low density area. The Logger's results would enable the inspector to outline these areas immediately without additional testing. Thus, further work by the contractor could be performed as required with a minimum of time lost.

It would appear that the Logger's speed of testing would be a valuable advantage in cases when the amount of subgrade being prepared by the contractor overtaxes the inspection personnel and their equipment. The Logger can make one pass over a 1500 foot section in about 10 minutes, thus matching several contractors simultaneous rates of production in all but isolated instances. A single conventional test for moisture and density would require approximately 1/2 hour to perform.

By utilizing the total number of miles logged and the cost of the Logger during the lease period, it was possible to compute the approximate costs per mile and per cubic foot of Logger surveys. Since a total of about 128 miles was logged, the cost per mile would be approximately $280. The Logger surveys a strip of about 12 inches wide by 7 inches deep. The cost per cubic foot thus computed was $0.11. It will be noted that these figures are many times higher than the theoretical ones previously presented.

All of these factors must be considered when making an economic evaluation of the Road Logger.

Dependability of the Logger

Some problems arose during the course of the six month lease period. The moisture unit proved to be the most troublesome single component of the Logger. Condensation of moisture from the air formed within the moisture unit causing the malfunction of components. This problem could be averted by the incorporation of an air-tight moisture unit for use in future Loggers.

Due to the position of the exhaust pipe, directly in front of the right rear tire, a problem was encountered with blowouts due to overheating. Both of these problems are being considered by Lane-wells at this time, according to representatives of the company, and corrections are being made.

The light construction of the trailer resulted in a breakdown when one of the wheels tore loose from the frame. Since aluminum construction is incorporated in the framework to lower the weight of the trailer riveted fasteners were used in place of welding.

Under rugged use this type of breakdown could probably be expected again unless a design change is made.

Some such breakdowns were expected, however, due to the fact that the Logger was new equipment. Probably most of the causes of these breakdowns will be rectified in later models.

It would appear that the Road Logger has a distinct disadvantage in that the dry density results are dependent on the moisture results. If, for any reason, doubt arises as to the validity of the moisture readings, the dry density results must be questioned also, since these results are obtained by subtracting the moisture readings from the wet density values at that same point. The dependability of the Logger would be greatly increased if dry density readings could be obtained by some other means, but this does not appear feasible at the present time.

Special Requirements for Logger Testing

For efficient use of the Road Logger and for reliable test results it was found that many areas required some type of preparation prior to logging. A minimum of one pass with a motorized blade was required in most areas where the tamping or sheepsfoot roller was utilized as the primary compacting device. The nature of this particular type of compaction is to leave one to three inches of uncompacted material on the surface. In order to obtain a representative log of the underlying compacted soil, this loose material had to be removed. This operation was performed quite easily with a blade. The use of a blade in such situations also assured that the required air gap would be maintained, which was quite essential to obtaining a representative log of the area. Also, it was observed that if the loose material was not removed prior to logging, there was a possibility that the sensor opening on the density unit would become clogged with soil, thus producing erroneous results. Other types of compaction, rubber-tired rollers, etc., produced a surface which in most cases did not require blading prior to logging.

The Road Logger was found to be fairly mobile in some areas which would prohibit travel with other vehicles, such as empty pick-ups or travelalls, due to the added traction gained by the Logger's weight. Only in a few isolated cases did the Road Logger become stuck. This made travel to and from the test sites possible on the grade itself.

All of the above observations were made on grading projects. On subbase and base projects where the Road Logger was used, no problems involving mobility were ever encountered.

Efficient Scheduling of Logger Operations

In order to insure efficient scheduling on grading projects, a two-way radio was installed in the Road Logger and in a pick-up which was used in conjunction with the Logger in test operations. The operator of the pick-up would visit each of the three grading projects involved at certain intervals and radio back to the operator of the Road Logger information regarding sections ready for testing. This operation proved to be quite satisfactory, as it eliminated unnecessary moving of the Logger itself and insured much faster testing of an area once it had been completed. In this way the Road Logger was able to test three grading projects simultaneously with only a minimum of delay in most instances.

Contractor Reaction

In almost all cases contracting personnel were quite receptive to Logger operations. The required surface preparation was usually obtained with very little problem or delay and resulted in no known hardship or ill feeling on the part of the contractor. Immediate availability of results, speed of testing, and freedom from operator bias all seemed to benefit the almost unanimous acceptance of the Logger. Due to the newness and uniqueness of the Logger, much of this interest shown could be expected.

Adaptability of the Logger

In most phases of highway construction the Logger appeared to be quite adaptable. Testing of surface courses posed no problems at all, except for, perhaps, safety considerations on open highways due to traffic, which are the same as experienced by all road crews. Base and subbase courses also proved to be comparatively non-troublesome for Logger operations. These three components actually presented several advantages favoring the Road Logger. A non-varying air-gap and the comparatively smooth surface conditions assured that a representative log would be obtained. Another important consideration was that these courses were usually prepared in relatively long segments. This permits continuous operation in which the Logger's speed over conventional testing was increased. The main disadvantage of the Logger in these situations is its weight. Subbase construction of Interstate shoulders, for example, did not appear to be able to support the Logger.

Subgrade construction usually required surface preparation prior to logging operations. Sections which were subject to moisture and density control were seldom prepared in long segments, thus increasing the time required to log an entire project. In some instances mobility also proved to be a problem. Despite these disadvantages the Logger was able to perform quite well in almost all cases.

On sections not subject to moisture and density control the Logger did not perform too well. This, again, was due to the fact that the surface conditions were of such a rough nature as to prevent the obtaining of a representative log since the required one inch air gap was impossible to maintain.

Comparison of Road Logger Results with Conventional Test Results

The majority of testing with the Road Logger was conducted on subgrade construction, much of which was subject to moisture and density control. The predominate soil type was A-7-6 although some A-6 soil was encountered in certain locations as noted below. Several stationary or static logger tests were performed in Pottawattamie County. The readings of both moisture and density were obtained and compared with conventional test results by means of graphs on Figures 11 through 15. In general, the density results of the Logger were higher than those determined by conventional testing. However, it should be noted that most of these tests follow a more or less straight line, meaning that correlation is good in most cases. The fact that the Logger readings are high could easily be alleviated by calibration changes. The moisture comparisons for the stationary tests are quite good.

The density plot of the running log versus conventional density determinations yielded similar results to those obtained in the stationary tests. Logger results varied from two to four points higher than conventional test results. The Logger's moisture readings were all lower than the conventional results. If the moisture readings would have been calibrated two pounds higher, this would have assured that both the moisture and density readings would have agreed much better with the conventional results, since increasing moisture readings will decrease dry density reading of the Logger.

The Logger results from the Mills County project showed little correlation from either stationary or running tests made with the Logger and with conventional results. Little or no explanation can be presented for this. The subgrade surveyed was composed to a great extent of loess. This material, for no known reason at this time, apparently affects the Logger's equipment in some manner so as to prevent any correlation with conventional results. Lane-Wells Company is aware of this problem and is, at this time, searching for a solution. It was observed by the operator that when moisture tests are performed on loess samples, the top layer of dust is discarded and not used in the test. This layer may be as much as 1/2 inch thick. The Logger's moisture sensor, of course, takes its reading from the entire sample. This would tend to make the Logger's moisture results lower and dry density results higher than conventional test results as is observed in the plots. However, this does not account for the high variability of the results obtained. These comparisons are on Figures 16 through 19.

A good deal of work was also done on granular subbase material, in Interstate construction. The results of the test comparisons, on Figures 20 through 24 were, in general, quite good. It will be observed that the Logger's moisture readings again are slightly high. However, especially on the Polk County job, the points exhibit very little scatter. Dry densities on both the Story County and Polk County projects show a good deal of scatter. This could be due to the fact that inexperienced personnel were used to perform the oil density determinations. The fact that moisture results correlate quite well and dry densities do not would seem that probably some erroneous conventional results were obtained. The density results of the work done on the Cass County project show good correlation with Logger results, but here as in Story County more tests should have been made.

A limited amount of testing was also performed on asphalt treated bases, asphalt resurfacings, and on portland cement concrete highways. Only two asphalt treated base projects were tested, one in Jasper County and the other in Story County. The Jasper County project yielded results which exhibited very little scatter considering the fact that only running tests were made. Once again, however, the density unit seemed to be calibrated a bit too high. The Story County job showed quite a bit of variation but only four cores were taken for comparison; therefore no conclusions can be made here. On the Jasper County project an attempt was made to correlate moisture reading from the Logger to asphalt content by extraction of the cores. Figure 26 shows that a correlation of this type might be possible but more study would surely be required.

Two asphaltic concrete resurfacing projects were logged also. Only five cores were taken from the Hardin County project. The Logger density readings at the respective stations where these cores were taken were quite high indicating a low calibration once again. Project FN-72 in Story County, however, yielded very good results. These results were taken from a running log also, and even better agreement with conventional results might be expected from stationary tests.

Several highways constructed of portland cement concrete were tested with the Logger. An attempt was made to correlate Logger density with the percent of air in the cores as indicated by the High Pressure Air Meter. Two such plots are included for the north bound lane and the south bound lane of Interstate 35 in Polk County. Once again it appeared that such a correlation might be possible, especially on slabs of less than eight inches of thickness, as shown on Figures 32 and 33. Even though this pavement was ten inches thick, the correlation, especially on the south bound lane was surprisingly good. The results are far from conclusive. Laboratory displacement tests were employed to determine the density of these cores taken from this project. These data were plotted versus Logger density. Excellent correlation was obtained for the cores taken for the south bound lane. The data from the north bound lane exibited good correlation, but the calibration seemed to be two or three pounds per cubic foot low.

Portions of several other projects were logged in addition to these discussed. Included were a soil-cement subbase, an asphaltic concrete highway, and several bridge decks. Lack of sufficient conventional test data prohibited the making of an intelligible comparison.

In general, several conclusions can be drawn from the aforementioned results. One of the most important is the necessity of making a representative calibration of the equipment before logging operations are undertaken. If the moisture or density readings had been changed by only two or three pounds, excellent correlation with conventional test results would have been attained in most cases. Samples taken for conventional testing were many times several feet from the area tested by the Logger. This fact would tend to create deviations in results obtained by the two methods especially in a variable material such as subgrade soil. In support of this, it will be noted that stationary test results made with the Logger correlated well with conventional results in most instances.

On soils composed of loess evidently the Logger had yielded erroneous results. Little can be proposed in this area until Lane-Wells Company proposes a solution. Also, some of the plots in this report present too little information to be of much use. Probably only the plots where more than six to eight data points are shown should be used for analysis of correlation results.

District Comments

The evaluation of the Road Logger as a compaction control device was carried out almost entirely on several Interstate 80 grading projects in District 4. Personnel from this district, including Bruce C. Claggett, Resident Construction Engineer and Dick Dueland, gave their reactions to the Road Logger program in an interview held after the completion of operations.

The remarks made are as follows:

1. The Road Logger would probably replace only one man on moisture and density control, and on some jobs this man could be used for other tasks, such as, on roller operations.

2. The requirement of a smooth surface for surveys would probably not pose too great a problem, since in almost all cases a blade is used to smooth the areas.

3. The generally receptive mood of contracting personnel to Logger operations this year might have been due to the newness of the equipment and could possibly change in the future.

4. Road Logger operations would probably not have a reducing effect on bid prices, despite the greater testing speed. However, a better compacting job could perhaps be attained by Logger testing due to its ability to secure more information, thus pointing out deficient areas which might be missed by conventional testing.

5. Proctor densities for each soil would still have to be determined for Logger use.

6. No particular problems were encountered when the subbase under the pavement was tested. The thinner subbase in the shoulder construction failed to carry the heavy Logger, however. Revised standards now show a uniform 3 inch granular subbase under the shoulders, thus, perhaps making Logger testing possible.

7. Road Logger operations would prove most beneficial to the State on long projects or on those with continuity regarding construction under moisture and density specifications due to the speed of testing capabilities.

Conclusions

The significant results of the Road Logger evaluation program are as follows:

1. The measurements with the Logger correlated satisfactorily with conventional results on almost all materials surveyed with the exception of loess soils.

2. Several limitations in the Road Logger were observed. Many of these, such as the susceptibility to failure of the moisture sensing system in humid weather, or otherwise wet conditions, should be rectified in future models. However, the requirement of a smooth testing surface and weight disadvantages will probably pose continuing limitations.

3. The data obtained from the Logger would probably require some type of specification modification to ensure compliance in all situations. For example, a decision would have to be made regarding the percentage of sub-standard material, if any, that would be allowed to pass before the entire strip surveyed would be failed.

4. Many advantages evidently would be realized from the use

of the Logger in compaction control. Speed of testing, immediate availability of results, freedom from operator bias, and the much greater amount of information presented are all aspects in favor of Logger testing over the conventional means now employed.

5. Economic feasibility is the important single aspect to be considered in this evaluation. Only projects requiring a good deal of compaction control or several simultaneous projects in fair close proximity of each other, could justify the use of the Logger economically.

6. The introduction of another vehicle with two-way radio communication with the Logger greatly increased the efficiency of operations.

7. Possibilities exist toward the use of the Logger as a control device on density of asphalt mats as well as for asphalt content and for approximate determinations of the percent of entrained air in portland cement concrete construction.

8. Much more information regarding the practicability of the Road Logger could be obtained if the device was designated to be the primary means of compaction control for an entire project or projects.

A listing of projects which were surveyed with the Logger is shown on Table 1. The distance logged and the approximate time consumed are also included. This table is not entirely complete, however, since day by day records, containing this data, were not kept for all projects. The total number of feet surveyed with the Logger was 675,326, or approximately 128 miles, according to the Table. Seventy-four stationary tests were made, and 6,695 minutes, or about 112 hours, were required for logging operations. This last figure stated does not include travel time to and from job-sites, and therefore may be somewhat misleading.

PROJECT	MATERIAL TESTED	DISTANCE LOGGED, (FT)	NUMBER OF STATIONARY TESTS	TIME, MINUTES
I-IG-35-4(10)88	Granular Subbase	13,500	15	360
I-IG-35-4(10)88	Portland Cement Concrete	47,600	-	400
FN-FGN-15(5)	Subgrade	14,100	12	300
S-1799(1)	Portland Cement Concrete	19,200	-	150
S-1284(8)	Portland Cement Concrete	19,500	-	170
S-829(3)	Portland Cement Concrete	32,200	-	220
F-1032(4)	Portland Cement Concrete	40,500	-	350
S-2051(2)	Asphalt Treated Base	40,700	3	485
-IG-35-4(12)103	Granular Subbase	8,400	3	90
-IG-35-4(12)103	Portland Cement Concrete	36,200	-	250
------	Various Bridge Decks	600	-	120

PROJECT	MATERIAL TESTED	DISTANCE LOGGED, (FT)	NUMBER OF STATIONARY TESTS	TIME, MINUTES
U-72(9)	Granular Subbase	1200	-	60
FN-72	Asphalt Overlay	77,200	-	820
FN-79	Asphalt Overlay	12,300	-	90
F-467(10)	Soil Cement	64,400	-	620
F-146(9)	Portland Cement Concrete	30,000	-	200
-80-1(30)55	Granular Subbase	8,450	5	120
-80-1(30)55	Lime Treated Subbase	7,700	1	90
-IG-80-1(33)27	Subgrade			
I-80-1(34)31	"			
I-80-1(20)34	"			
I-80-1(21)40	"			
I-80-1(38)47	"	201,576	35	1,800
Totals		675,326 ft. or about 127.90 miles	74	6,695 min. or about 112 hours

Breakdown of Road Logger Operations

The Road Logger was received on May 17, 1965 and three Highway Commission personnel were selected to receive instruction on the operation of the equipment. The first week, from May 17 to May 21, was consumed in the instruction of operation and the making of practice runs.

On May 24, with a starting mileage of 2088 miles, the Logger was taken to Atlantic, but returned on May 25 because of rain.

On May 26, after a four hour repair, the Logger was taken to Jasper County where testing was done on an Asphalt Treated Base under construction. The project was S-2051(2). This work was continued on May 27.

June 2nd through June 4th were spent logging subgrade construction on Interstate 80 at Walnut and Avoca. The mileage on June 4th was 3035 miles.

June 5 was spent in washing, servicing, and general maintenance of the Logger.

On June 7, the Logger was used on portland cement concrete paving and asphalt resurfacing on FN-79 in Hardin County.

On June 8, more work was done on the asphalt treated base in Jasper County. Approximately one mile was logged on 6 inches of base.

On June 9th, the unit was greased and checked. One half day was spent on Interstate 35, east of Ames.

Six thousand eight hundred feet of log were obtained from the asphalt treated base in Jasper County on June 10.

On June 11, the Logger was taken to Polk County where 3600 feet were logged in the morning and 1400 feet and 6 stationary tests were obtained in the afternoon. The work was done on granular subbase on Interstate 35 construction.

June 14, 15, and 16, were spent in the maintenance and cleaning up of the equipment.

On June 17 and 18, more work was done on the granular subbase on I-35 in Polk County.

On June 21, the Logger was taken to Mills and Montgomery Counties to test subgrade construction on U.S. 34, FN-FGN-15(5). The governor dashpot cracked, making the governor inoperable. June 22nd through 24th more logging was done on this project, however, the moisture system became erratic during some of the operation. On June 25, the Logger was returned to Ames due to rain in Mills County.

June 26, Logger was washed and greased. Amplifiers were removed and cleaned.

On June 28, mileage was 4990 miles. Asphaltic concrete county road was logged in Jasper County, west of Newton.

June 29, oil was changed, air cleaner was cleaned. Portions of U.S. 65 asphaltic concrete resurfacing, south of Colo in Story County were logged.

On June 30, the cover was removed from the moisture box and the connections were checked. The top caps on two of the pickup tubes were loose. These were tightened and all connections were checked again. This seemed to stop the shorting out which had been noticed. The moisture unit was then recalibrated.

On July 1, subgrade construction on I-35 in Story County was logged. Too wet for operations on July 2nd.

On July 5, the trailer was disconnected in order to make repairs on the stop for the moisture doors.

July 6, mileage was 5584. Logger was taken to Atlantic.

July 7th through July 9th were spent logging subgrade construction on I-80 north and west of Minden. Sixteen stationary tests were made during this period. Tire was blown out on return trip to Ames on July 9th.

July 10 was spent on maintenance of the Logger.

On July 12, Logger was taken to Atlantic for subgrade logging on I-80. Another tire was blown out in transit.

Only 230 feet logged on July 13, due to 6 hours of downtime required to repair tire and damaged exhaust pipe. Mileage was 6353 miles.

July 14 through July 16, 300 feet and 17 stationary tests were logged.

July 19, rain canceled work and Logger was returned to Ames on July 20.

No work until July 27, except for small projects, due to adverse weather.

On July 28, mileage was 7848 miles. Sixteen thousand five hundred feet were logged and one stationary test was made on I-80 subgrade.

No work on July 29th.

On July 30, operator slipped in rear of truck and dislocated his back. Returned to Ames after seeing doctor. No work until August 2nd due to this accident.

On August 2, Logger was returned to Atlantic and encountered heavy rain.

August 3rd and 4th, not too much moisture and density work ready, due to rain. Twenty thousand feet of subgrade were logged.

August 5th, 11,700 feet were logged, then Logger was returned to Atlantic to repair density unit's hydraulic system.

On August 6, more work was done on I-80 in Cass and Pottawattamie Counties. Thirteen thousand six hundred feet were logged. Mileage was 8841 miles.

On August 9, 10, and 11, the Logger was used to test three portland cement concrete secondary roads in Boone County. The project numbers were S-1799(1), S-829(3), and S-1284(8).

August 12th and 13th, portions of the completed I-35 in Polk County were logged. The data obtained was used in an attempted correlation between Logger density and indicated air content of cores.

On August 16 through August 18, the Logger was used to survey several concrete bridge decks in the vicinity of I-35 in Polk and Story Counties. In addition to this some of the granular subbase construction on U.S. 69 in Ames, U-72(9), was logged.

More data from I-35 in Polk County was obtained on August 19 and 20.

For the remainder of the month not too much work was scheduled for the Logger since the operator had reinjured his back and was unable to work. However, about 40,500 feet of portland cement concrete on Iowa #21 in Poweshiek County were logged. This was a highway in which the variation in air content was low and it was felt that the Road Logger data would bear this out, which it subsequently did.

On September 1, the mileage was 11,350 miles. The Logger was taken to Des Moines where the Cottage Grove Overpass over the Des Moines Freeway was logged. Thirteen thousand feet of log were obtained here.

On September 3, the Road Logger was equipped with a two-way radio.

On September 8, the Logger was driven to Akron in Plymouth County, where Iowa #9 from Akron to Westfield was logged. This was an asphaltic concrete highway of black base construction and was beginning to show signs of distress. It was felt that perhaps the Logger data might be of use in analyzing the problem. The results were mainly negative, as neither the density nor the moisture data showed any large degree of variation at areas of obvious failure. The work was completed on September 9.

From September 9th through 14th heavy rains forced cancellation of work on I-80 in Pottawattamie County.

September 15, after two hours of downtime due to a wet moisture box, 7550 feet of log were obtained on the subgrade on I-80 near Atlantic. Two stationary tests were also made. There was no survey work for the Logger for the next week due to heavy rains in the Atlantic area.

On September 23, the Logger was taken back to Atlantic but subgrade was still too wet for surveying.

For the remainder of the month, the Logger remained at Atlantic. Twenty-three thousand eight hundred feet of log were obtained from the I-80 subgrade construction.

On October 1, the Logger was returned to Atlantic where the radiator was drained of water and replaced with anti-freeze. Another day lost due to wet weather on October 2.

October 3, still very wet on grade, however, 7000 feet of log were made before moisture unit became wet. One and one half hours of downtime were taken.

On October 4, a routine cesium peak was run. Ten thousand seven hundred feed of subgrade were logged. Only 1000 feet were logged on the following day due to trouble with the moisture unit. Two hours of downtime were lost.

On October 6, another hour of downtime. Nineteen hundred feet were logged and six stationary tests were made in an attempt to improve moisture unit. Lane-Wells man was present to check the operation.

On October 7, 6900 feet were logged before radio truck became stuck and had to be rescued.

The wheels on the density trailer came loose from the frame on October 8. Trailer had to be returned to Ames to await replacement. On October 13, the replacement trailer arrived from Lane-Wells. The next several days were spent in the calibration of the replacement trailer. The Logger itself was serviced and washed. Mileage was 14,198 miles.

On October 26, the Logger was returned to Atlantic but not enough construction was ready to be surveyed. Twenty-one thousand six hundred feet of subgrade on I-80 were logged by the end of the month.

November 1, the Logger was taken back to Atlantic. In the next five days 28,300 feet of subgrade construction were logged before the density unit broke down on November 6. On the next day, the density unit was dismantled, the broken parts removed, and the Lane-Wells representative was contacted for replacement parts.

On November 8, parts were located and installed. The Logger was returned to Atlantic on November 9, to complete repairs.

On November 10, logging operations were resumed on I-80 subgrade construction. Six thousand seven hundred feet were logged before rains canceled work for the remainder of the week. The Logger was returned to Ames.

Wet weather and lack of construction activity prevented extensive Logger operations for the remainder of the lease period. On November 17, however, 3800 feet of subgrade were logged on the I-80 construction. Also some correlation work with a seismic device for density determination was attempted in conjunction with Iowa State University during this period.

On December 3, the Road Logger was returned to Lane-Wells Company in Houston, Texas, by the operator.

Acknowledgements

The investigators wish to thank all Highway Commission and contracting personnel who were involved in this project, especially those of District 4, where complete cooperation made the completion of this evaluation program possible. Special thanks to those listed below:

R. L. Gumbert, P. E., Engineer in charge

B. C. Claggett, P. E., Resident Construction Engineer, Dist. 4

B. C. Brown, P. E., Research Department

R. Smith, Research Department

H. Sharpnack, Operator

Appendix

Figures 1 through 33.

Typical Calibration

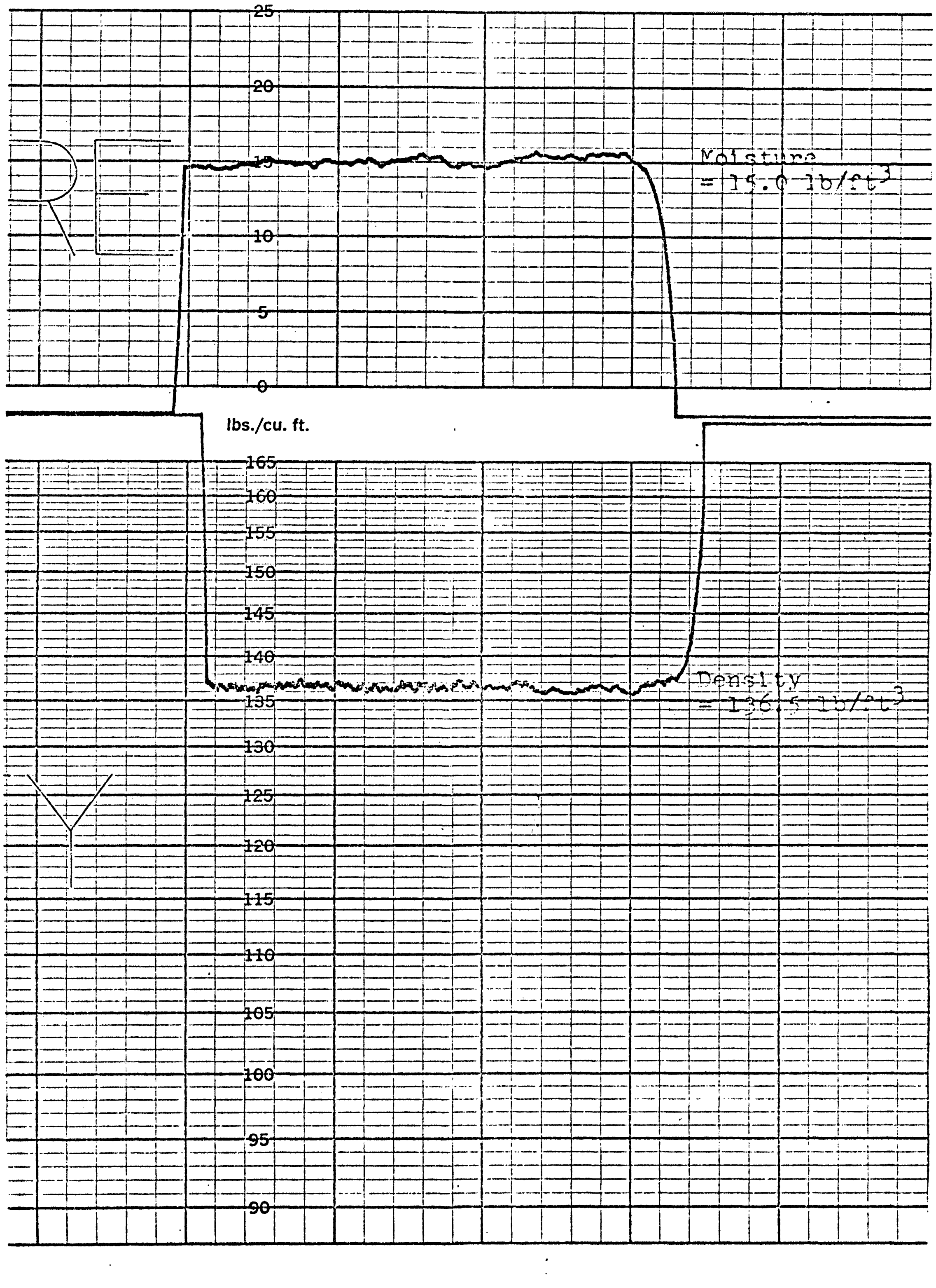


Figure 2

Typical Cesium Peak Calibration

For Density Unit

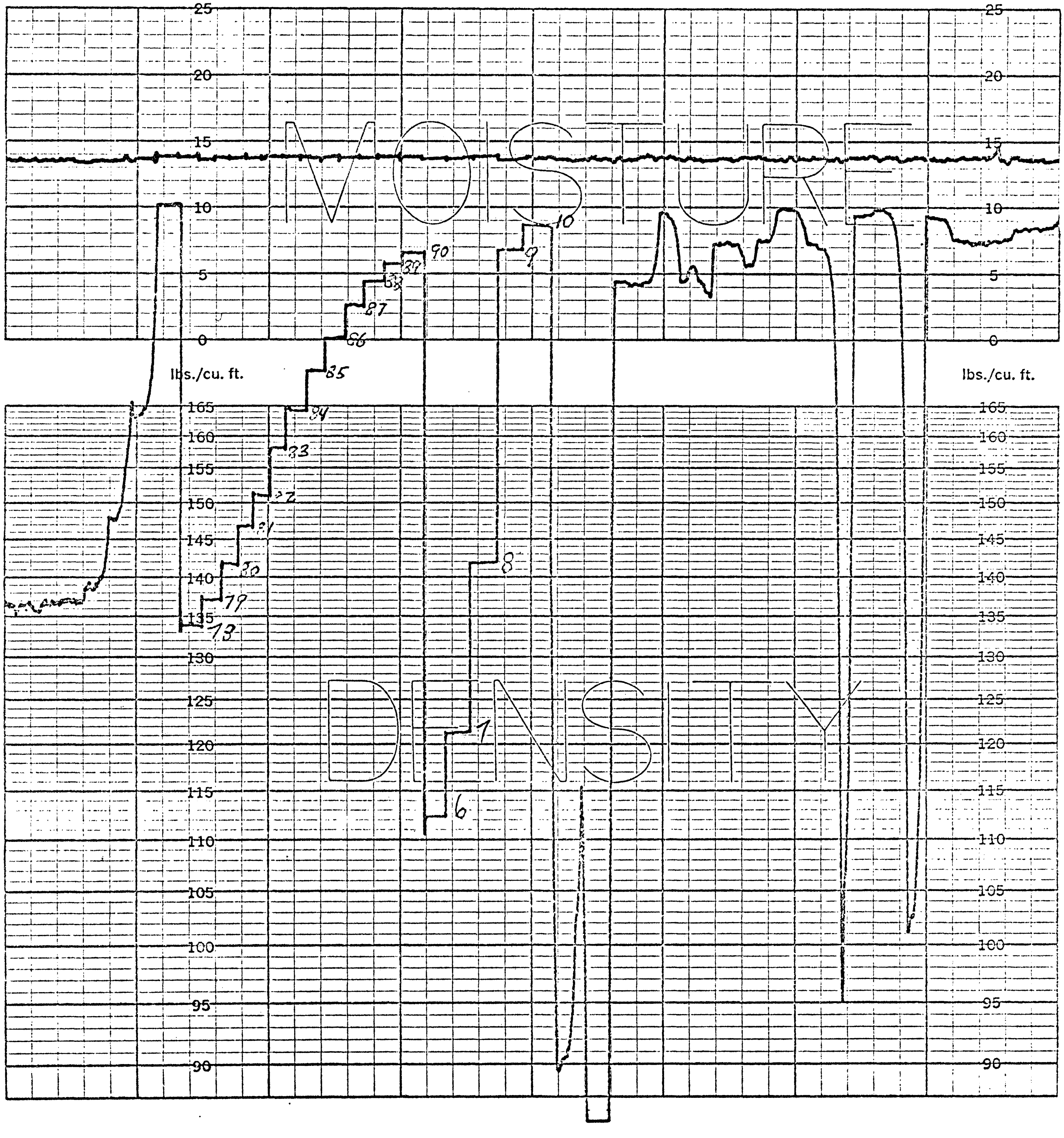


Figure 3

Typical Stationary Test

I-IG-80-1(27)33

Sta. 1090+20

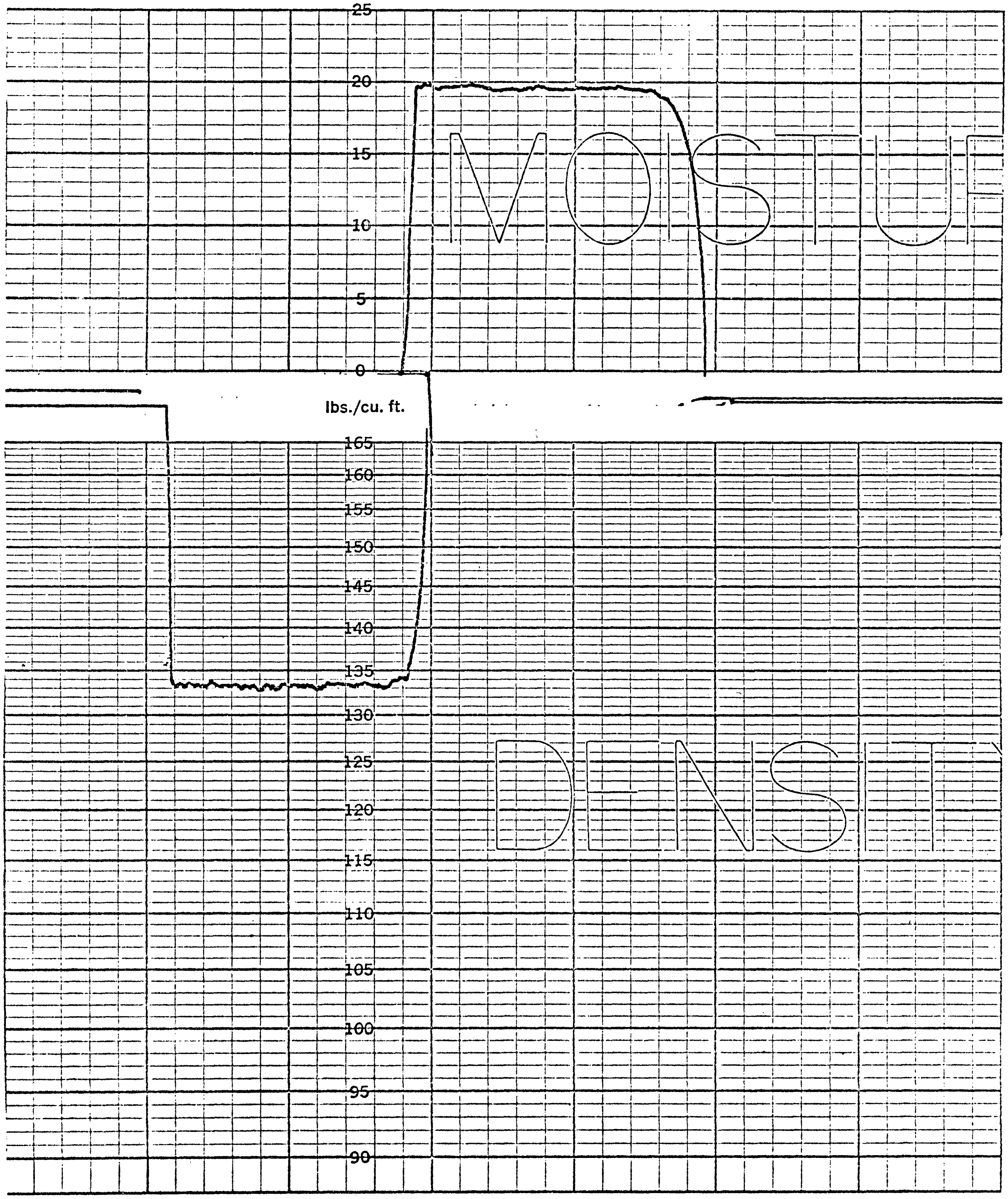


Figure 4

Typical Section Showing Effect of Varying

Vehicle Velocity and Time Constant

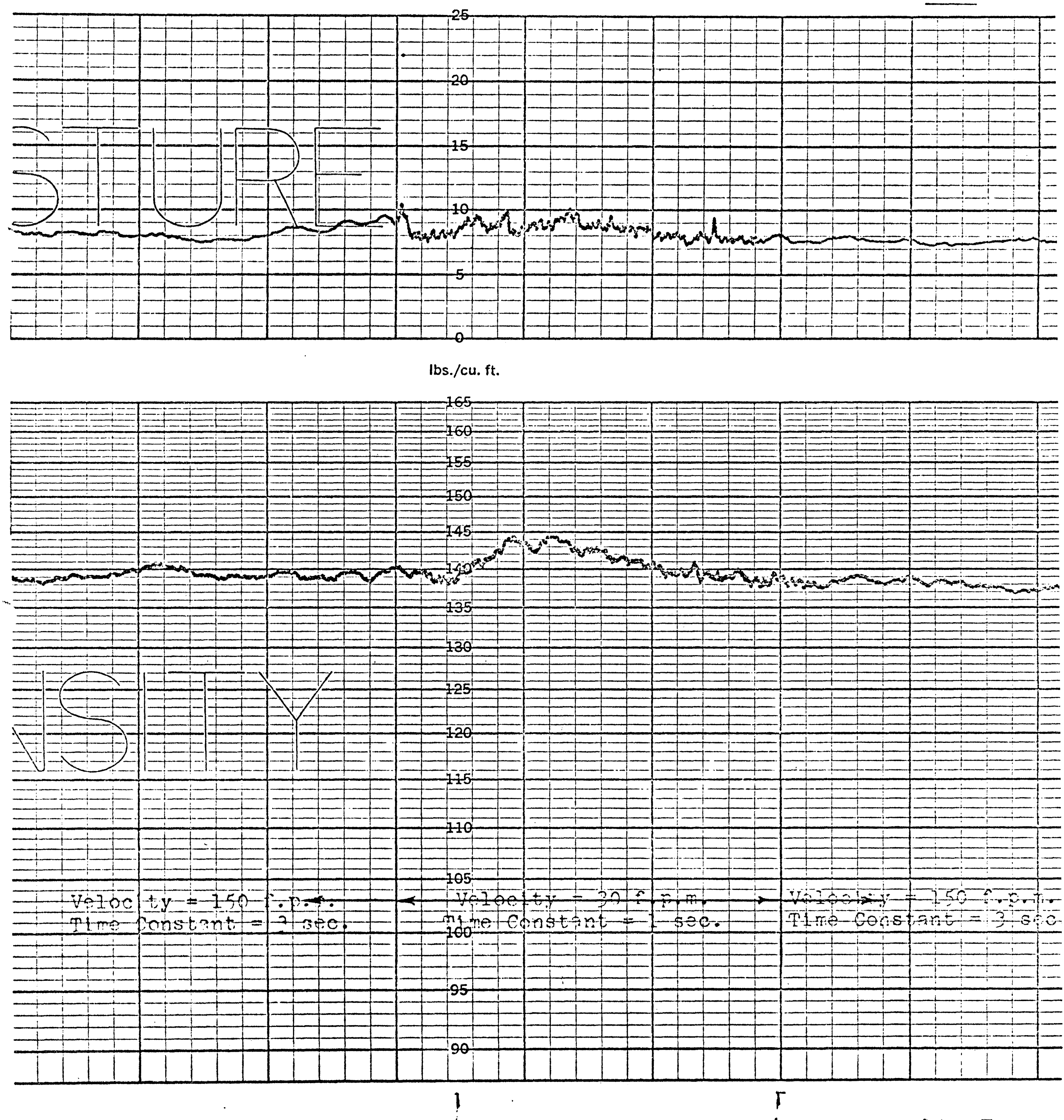


Figure 5

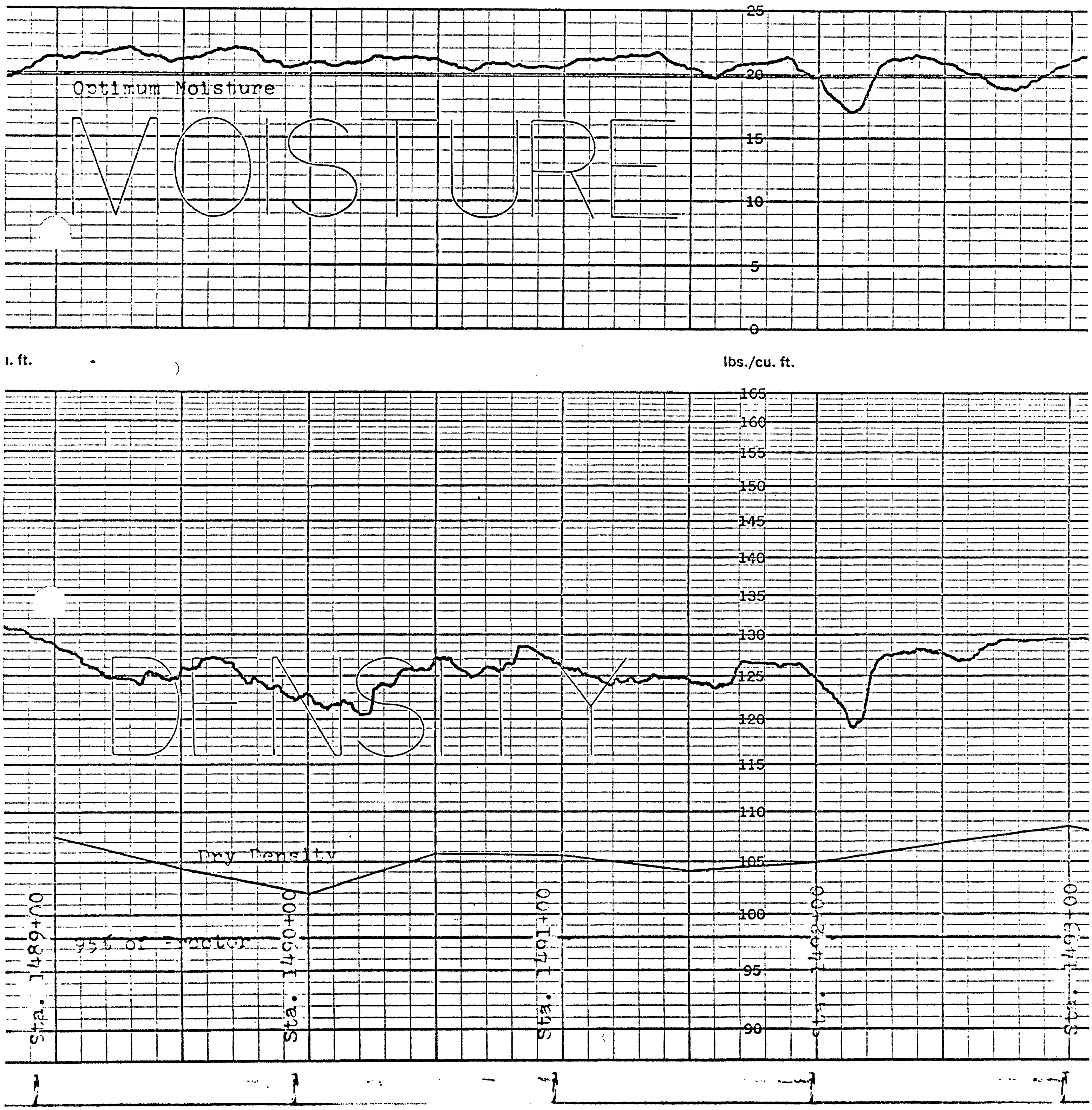
TYPICAL BRIDGE DECK TESTED WITH ROAD LOGGER

OVER I-80-35, NORTH OF DES MOINES, IOWA

Velocity = 30 f.p.m., Time Constant = 1 sec.

Figure 6

Pottawattamie County
I-80-1(20)-34
Subgrade
Optimum Moisture = 19.9 lb/cu. ft.
Proctor Density = 103.1 lb/cu. ft.
Required 95% of Proctor

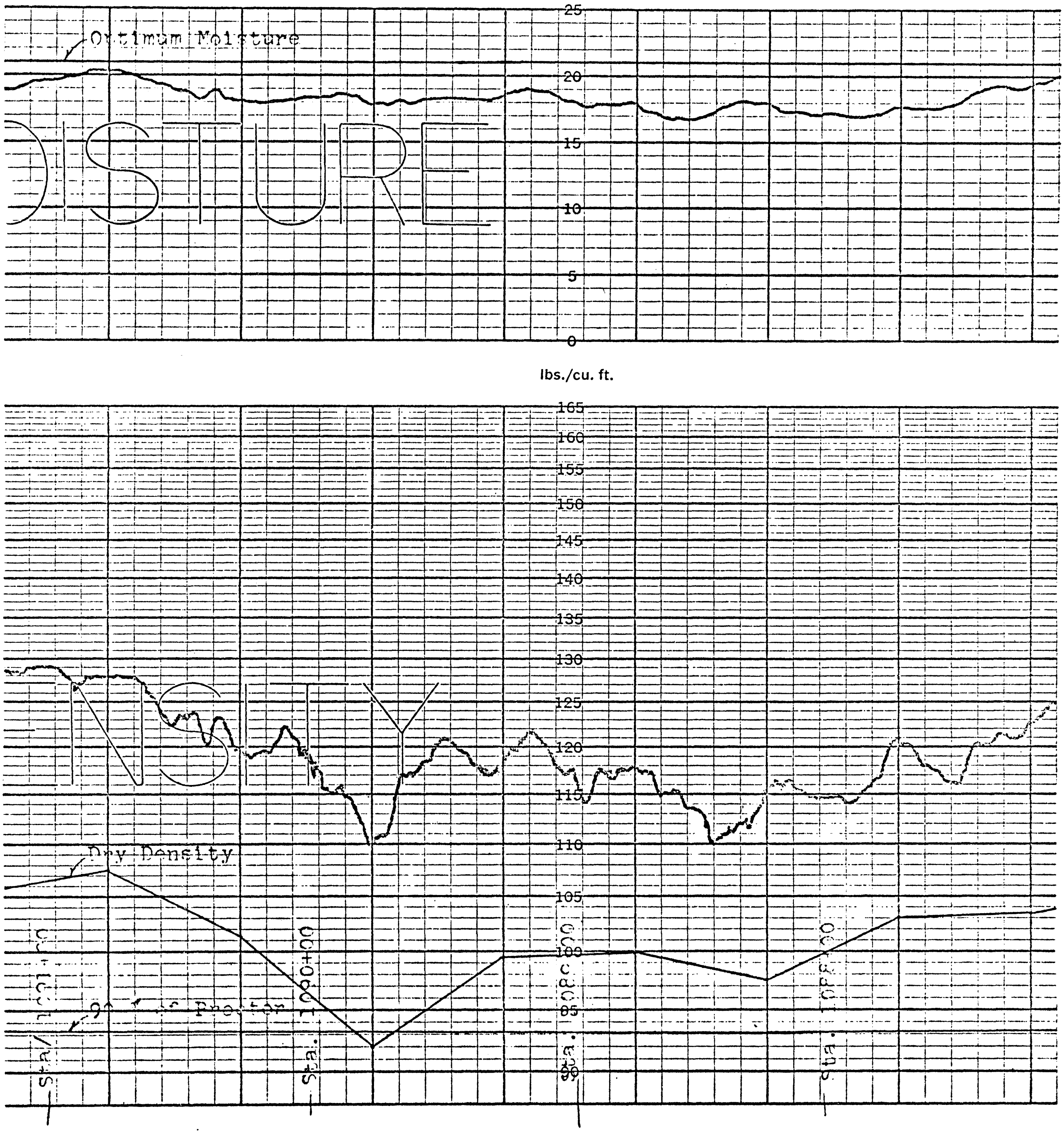


Pottawattamie County
I-80-1(34)31
Subgrade
Optimum Moisture = 19.5 lb/cu. ft.
Proctor Density = 103.1 lb/cu. ft.
Required 95% of Proctor

Figure 7

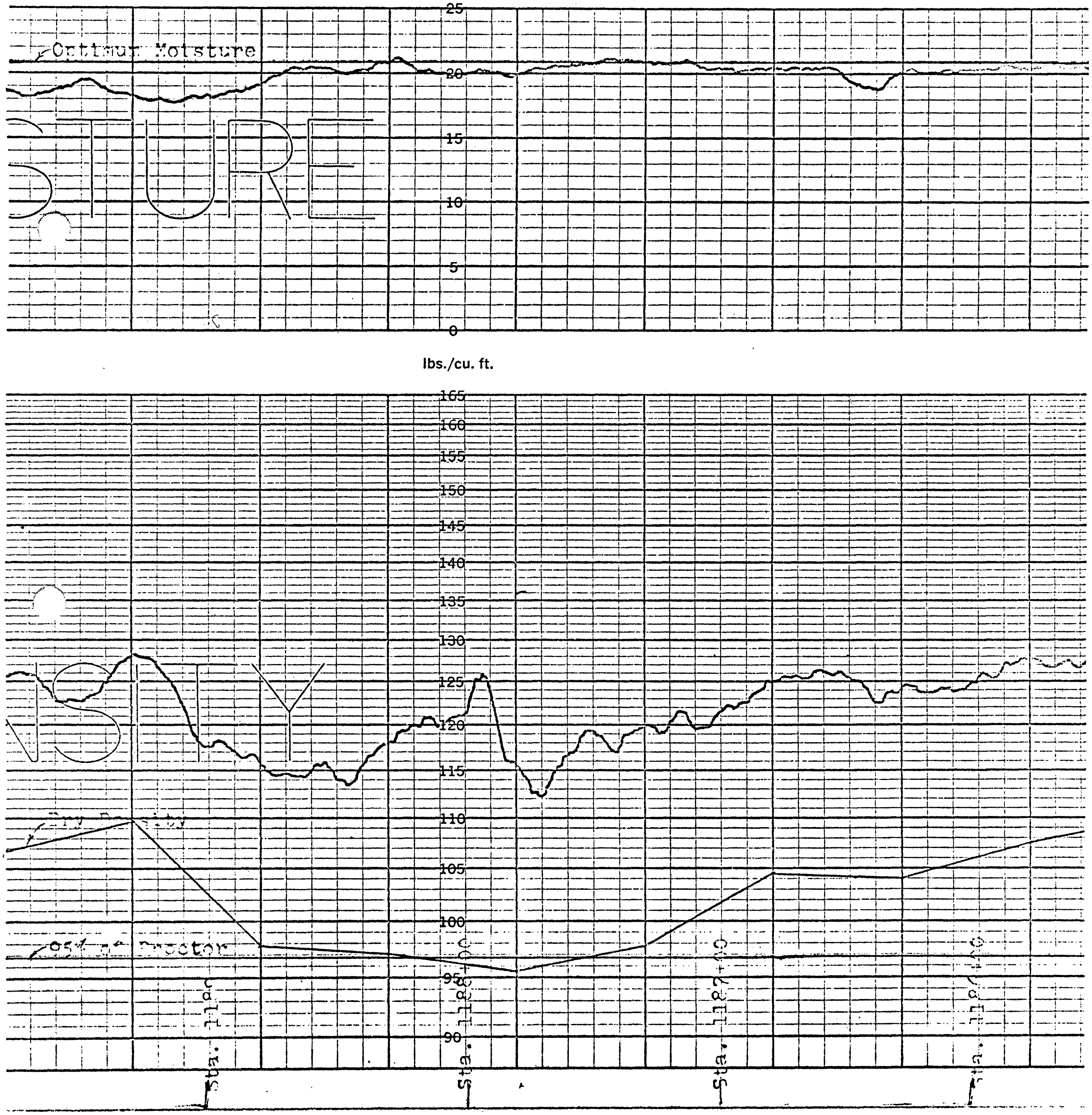
Pottawattamie County
I-IG-80-1(33)27
Subgrade
Optimum Moisture = 20.9 lb/cu. ft.
Proctor Density = 103.6 lb/cu. ft.
Required 90% of Proctor

Figure 8



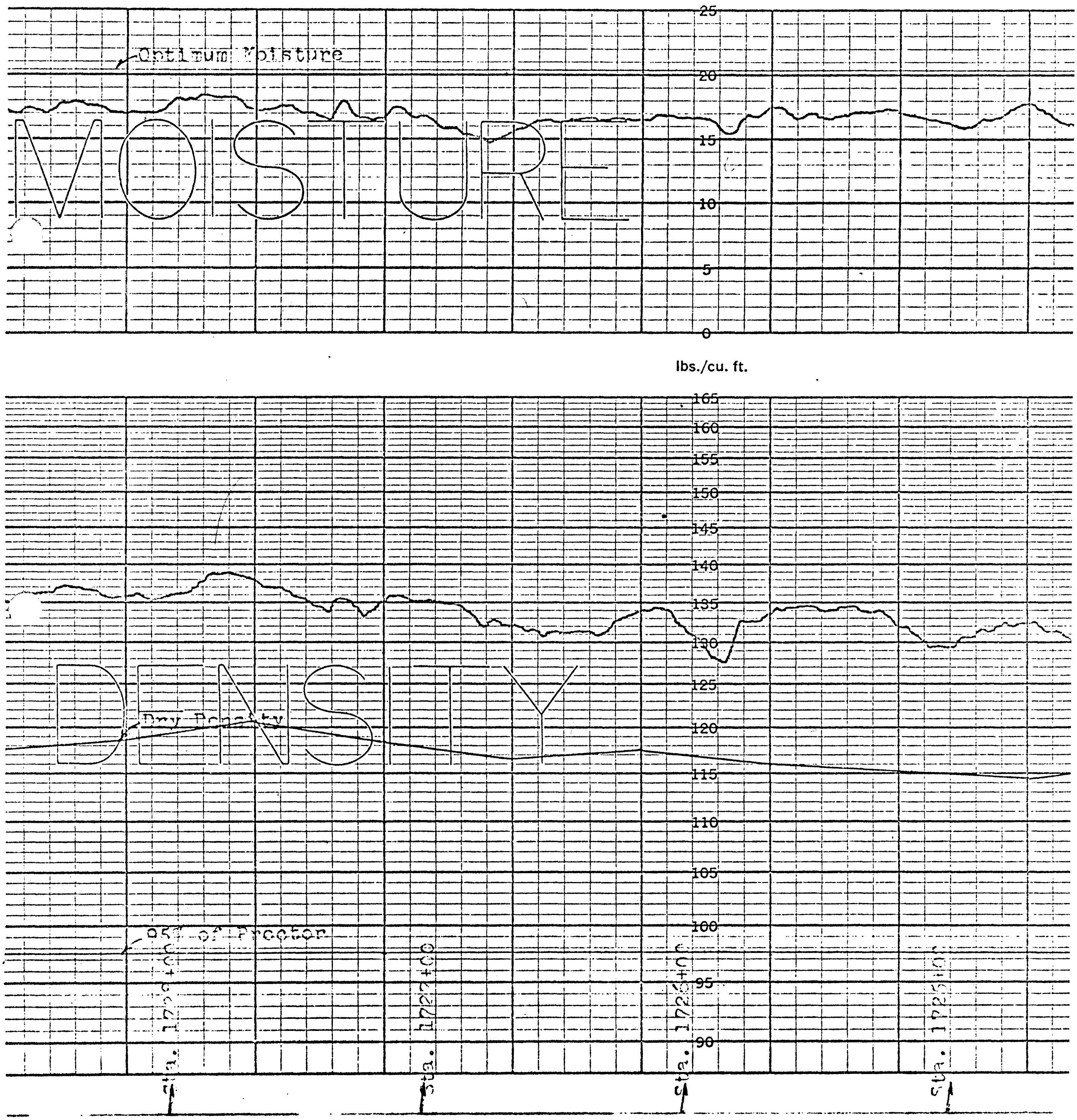
Pottawattamie County
I-80-1(34)31
Subgrade
Optimum Moisture = 20.9 lb/cu. ft.
Proctor Density = 101.9 lb/cu. ft.
Required 95% of Proctor

Figure 9

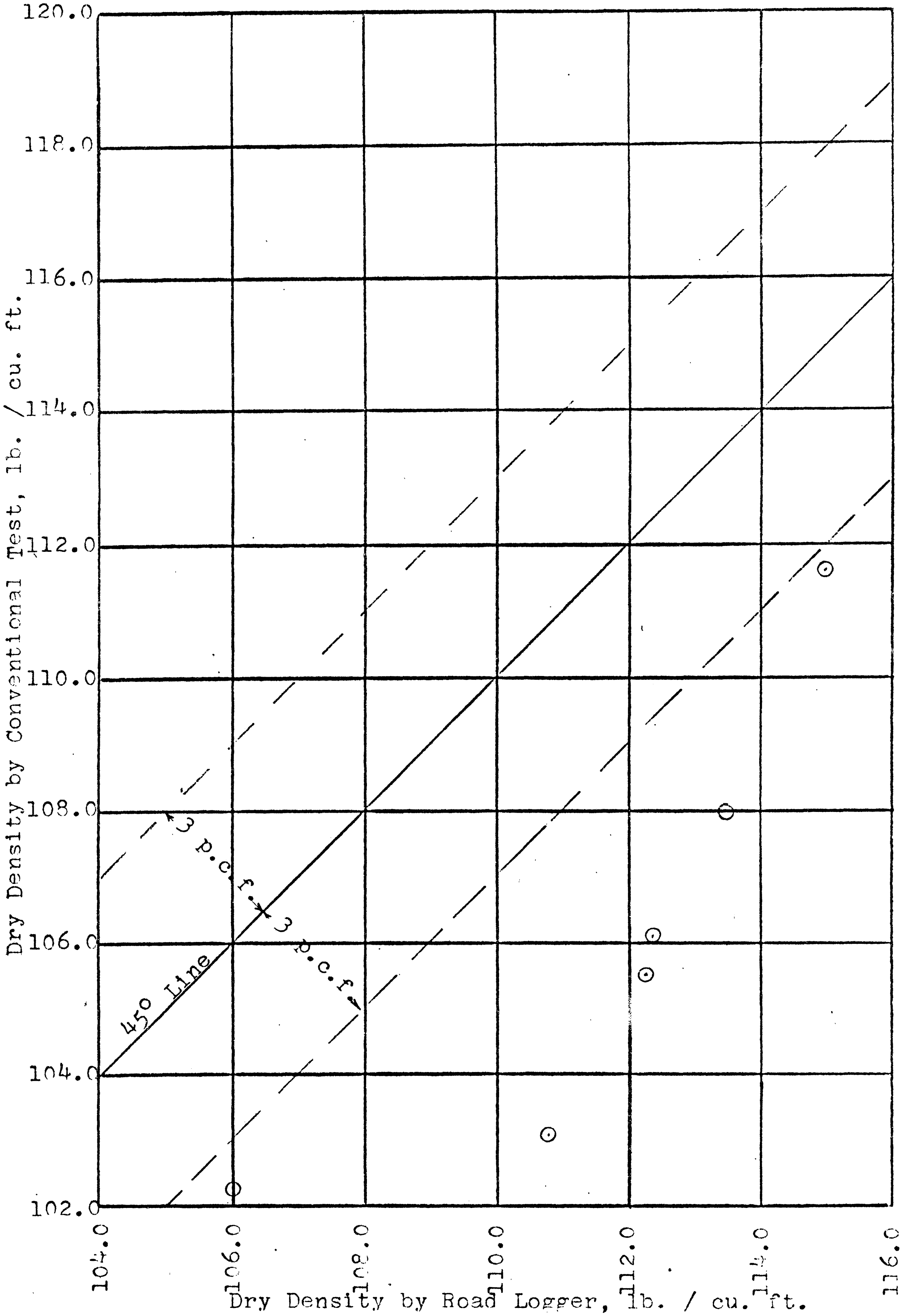


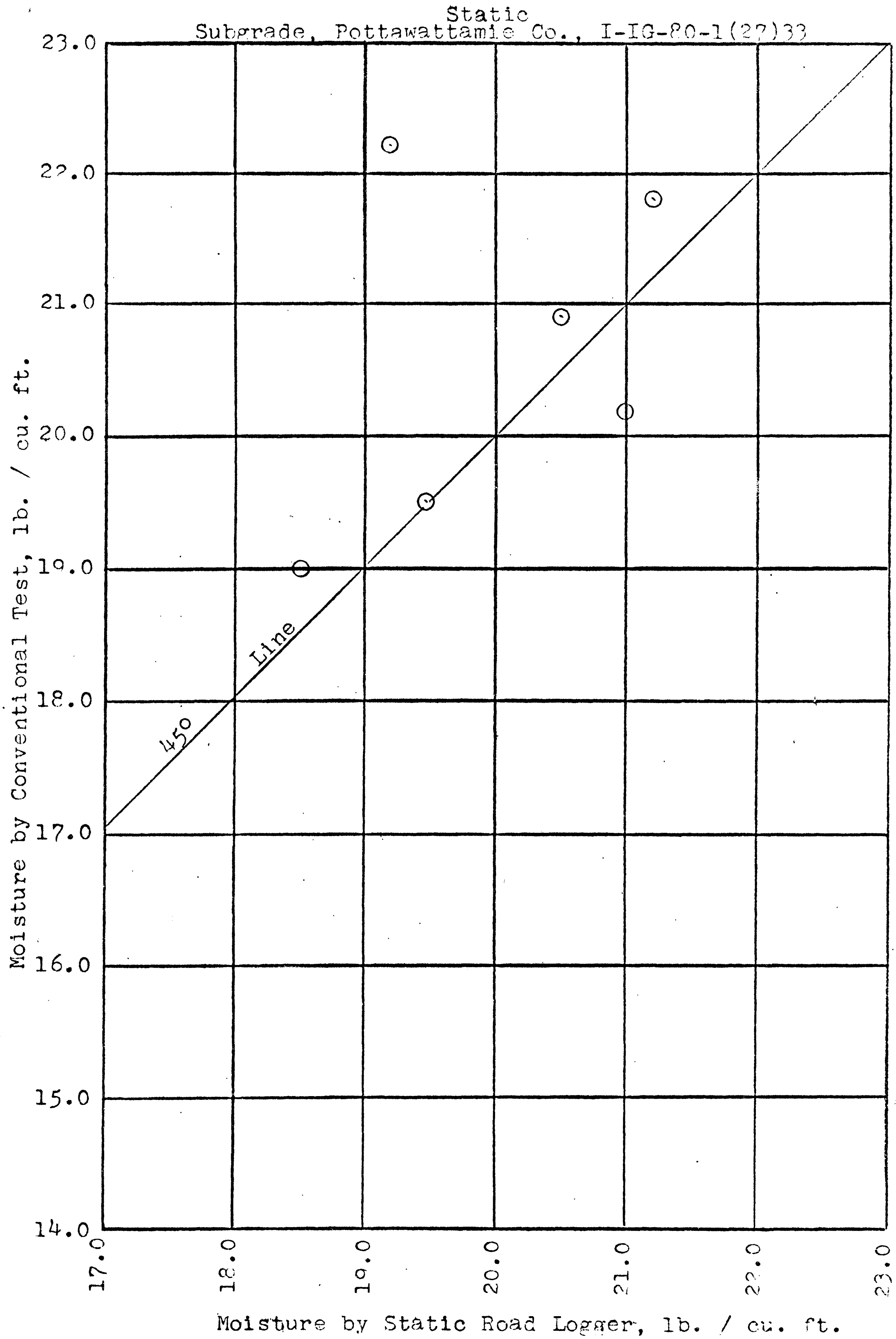
Pottawattamie County
I-80-(21)40
Subgrade
Optimum Moisture = 20.3 lb/cu. ft.
Proctor Density = 102.4 lb/cu. ft.
Required 95% of Proctor

Figure 10



Static
Subgrade, Pottawattamie Co., I-IG-80-1(27)33




Static
Subgrade, Pottawattamie Co., I-IG-80-1(27)33
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
45° Line
Moisture by Conventional Test, lb. / cu. ft.
17.0
18.0
19.0
20.0
21.0
22.0
23.0
Moisture by Static Road Logger, lb. / cu. ft.

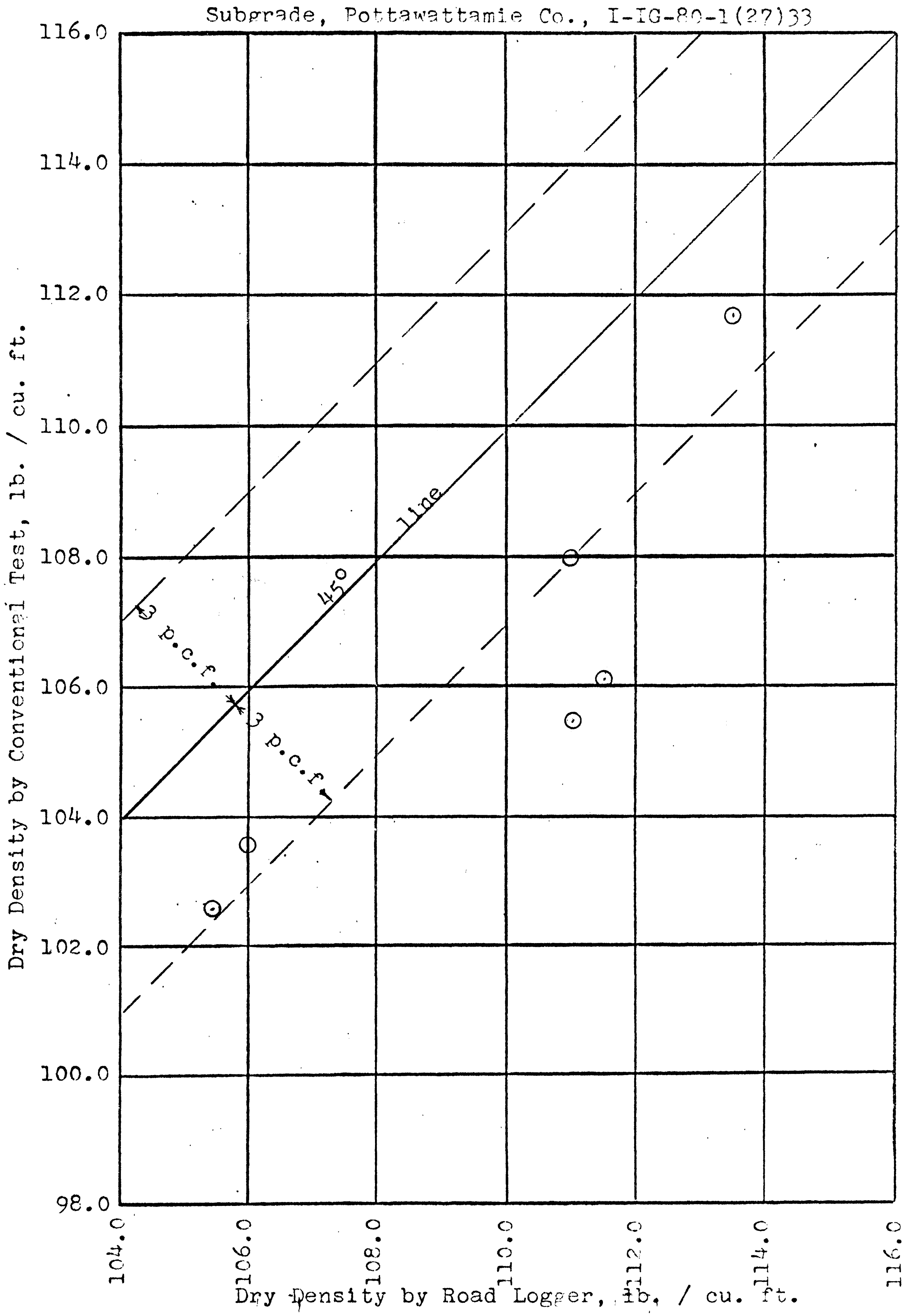
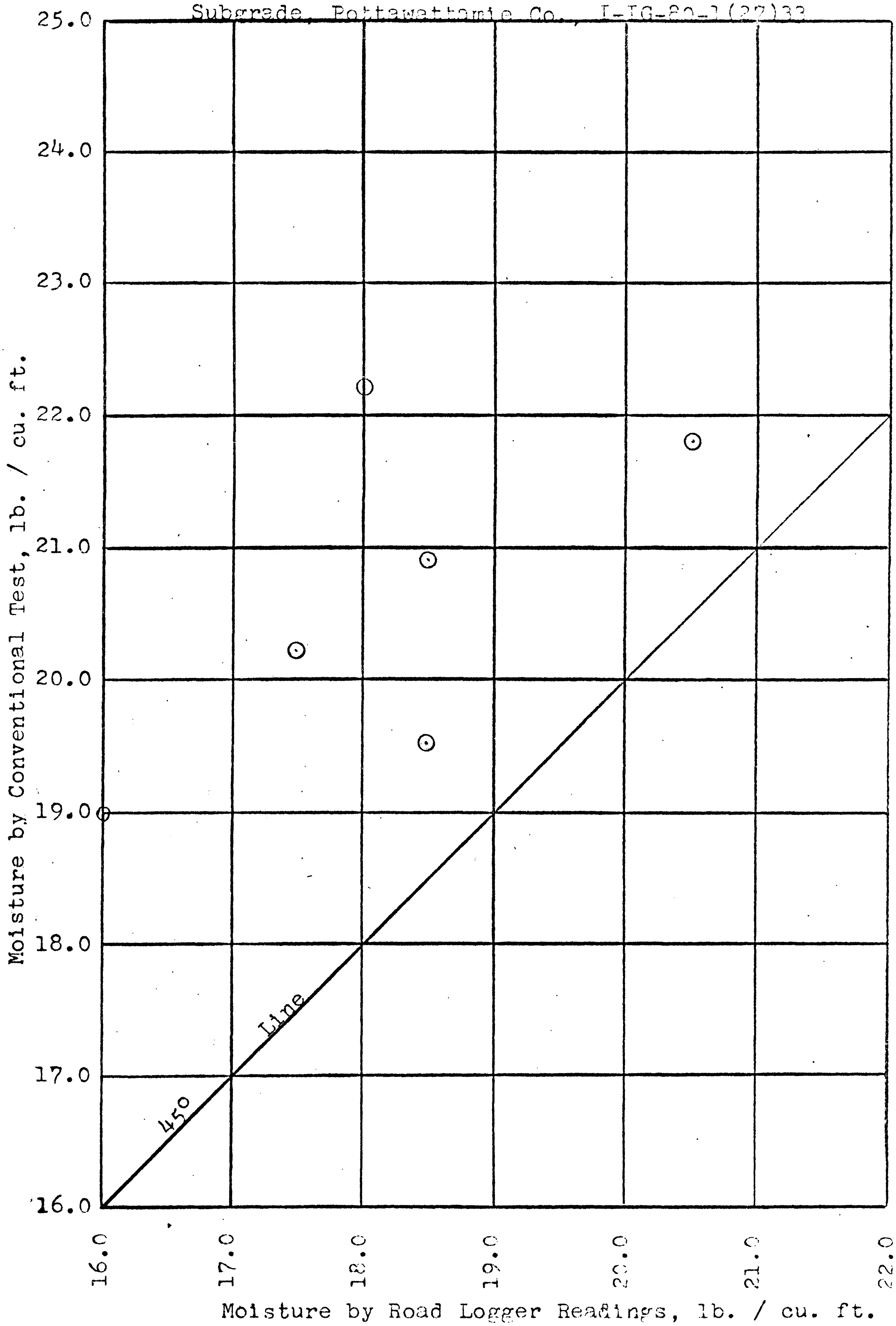
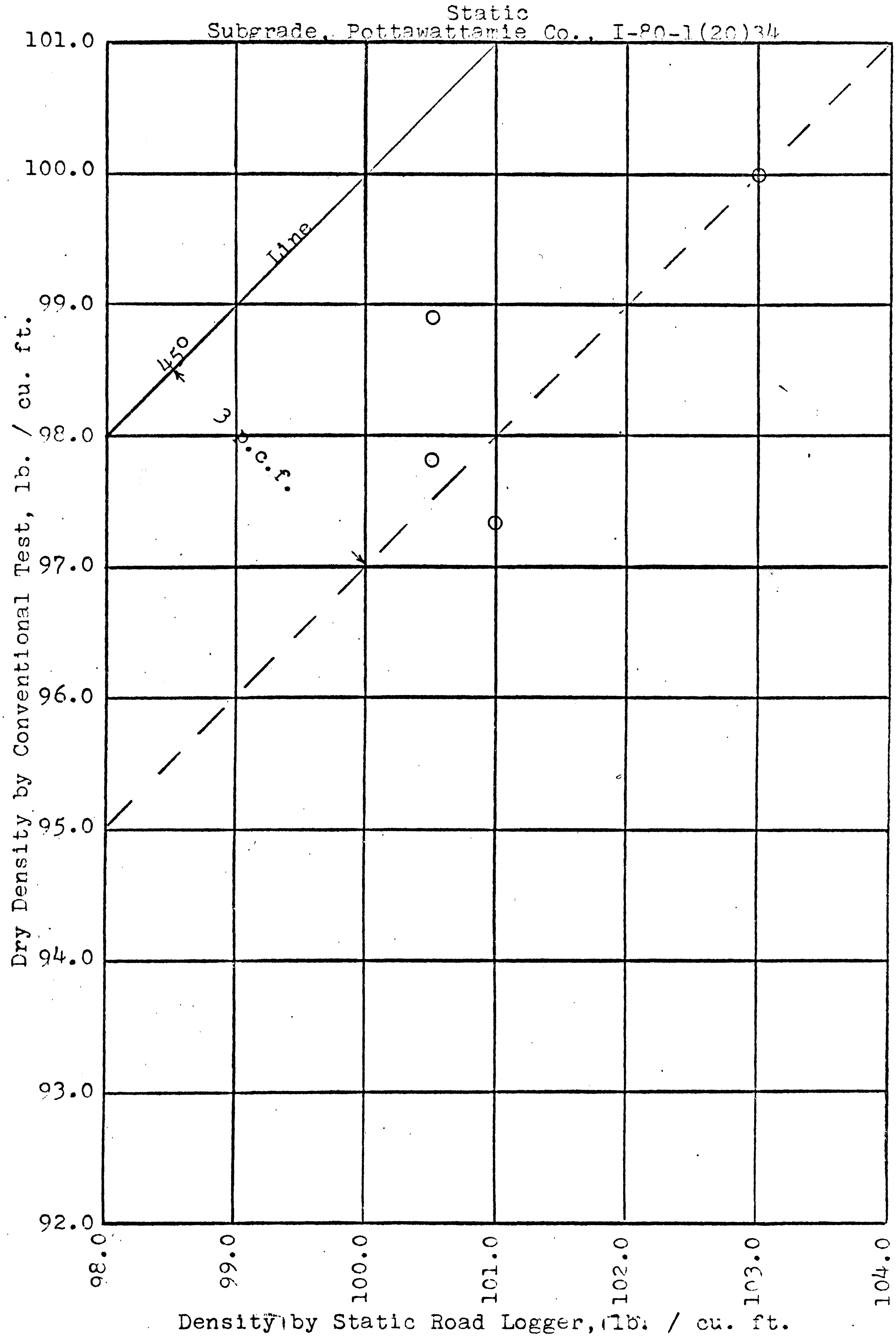

Subgrade, Pottawattamie Co., I-IG-80-1(27)33
116.0
114.0
112.0
110.0
108.0
106.0
104.0
102.0
100.0
98.0
104.0
106.0
108.0
110.0
112.0
114.0
116.0
45° line
3 p.c.f.
3 p.c.f.
Dry Density by Conventional Test, lb. / cu. ft.
Dry Density by Road Logger, lb. / cu. ft.

Figure 14

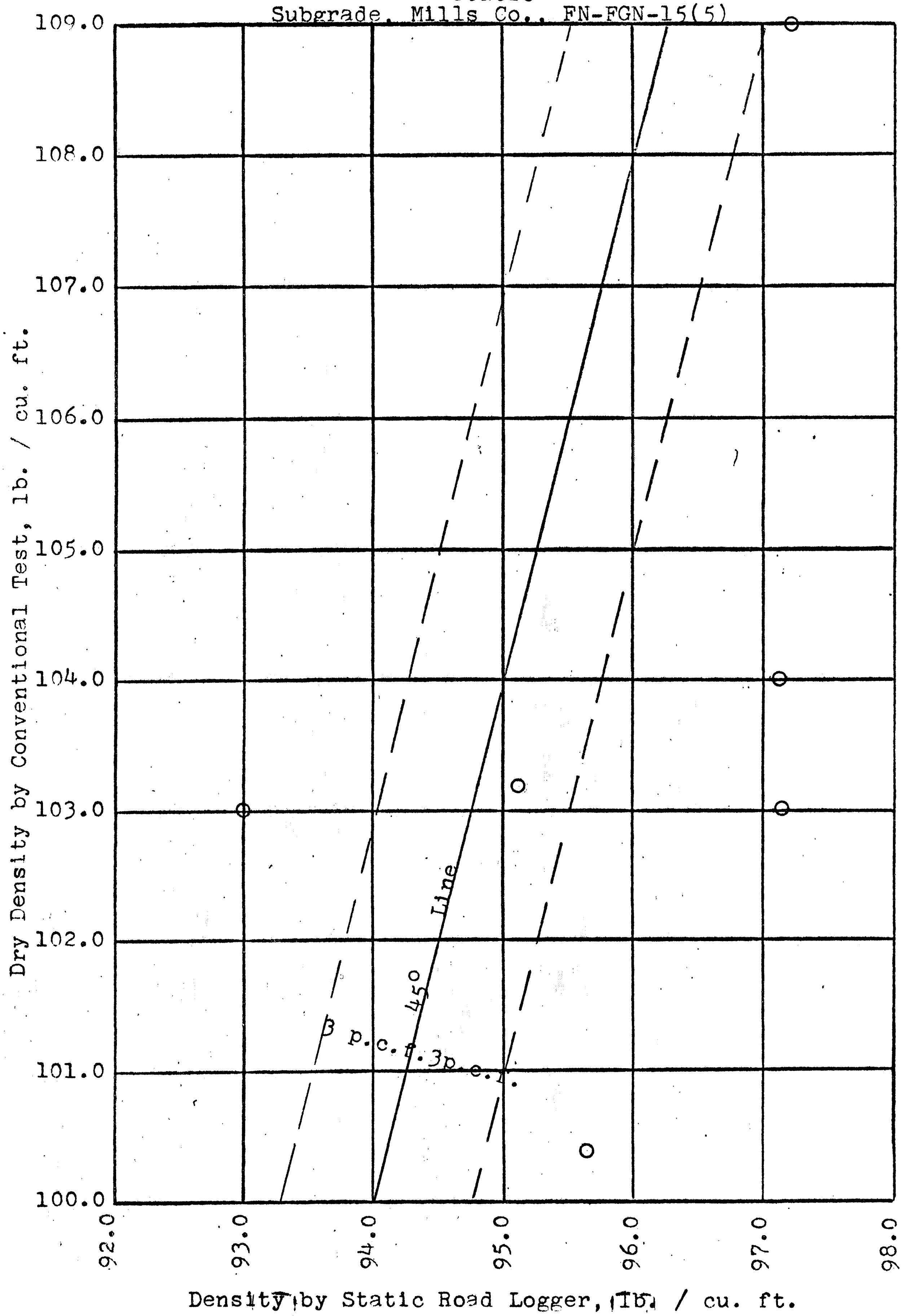
Subgrade, Pottawattamie Co., I-IG-80-1(27)33

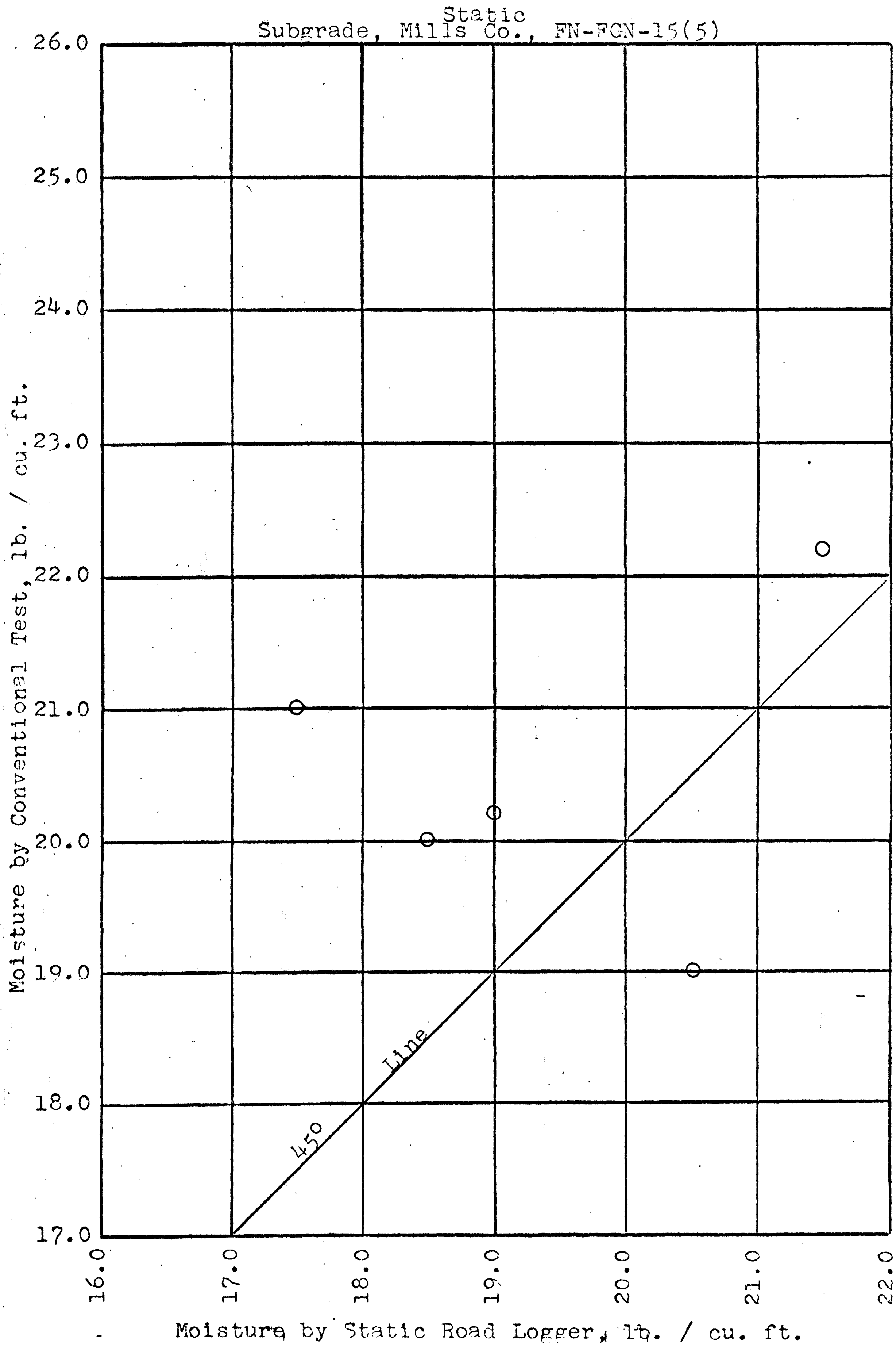


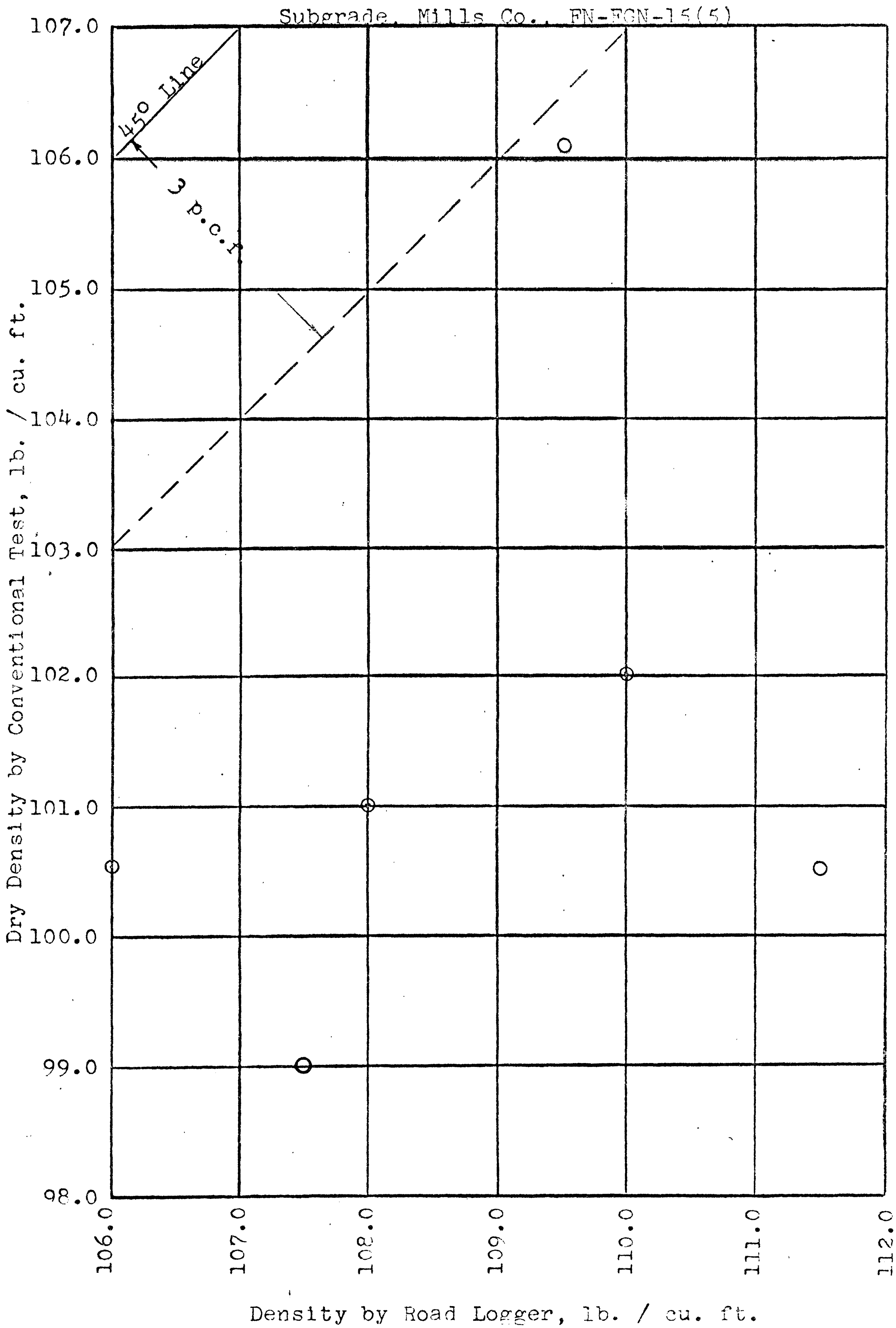

Static
Subgrade, Pottawattamie Co., I-80-1(20)34
Line
45°
3 p.c.f.
101.0
100.0
99.0
98.0
97.0
96.0
95.0
94.0
93.0
92.0
Dry Density by Conventional Test, lb. / cu. ft.
98.0
99.0
100.0
101.0
102.0
103.0
104.0
Density by Static Road Logger, lb. / cu. ft.

Static

Subgrade, Mills Co., FN-FGN-15(5)




Static
Subgrade, Mills Co., FN-FGN-15(5)
Moisture by Conventional Test, lb. / cu. ft.
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
45o Line
16.0
17.0
18.0
19.0
20.0
21.0
22.0
Moisture by Static Road Logger, lb. / cu. ft.


Subgrade, Mills Co., FN-FGN-15(5)
107.0
106.0
105.0
104.0
103.0
102.0
101.0
100.0
99.0
98.0
45o Line
3 p.c.f.
106.0
107.0
108.0
109.0
110.0
111.0
112.0
Dry Density by Conventional Test, lb. / cu. ft.
Density by Road Logger, lb. / cu. ft.

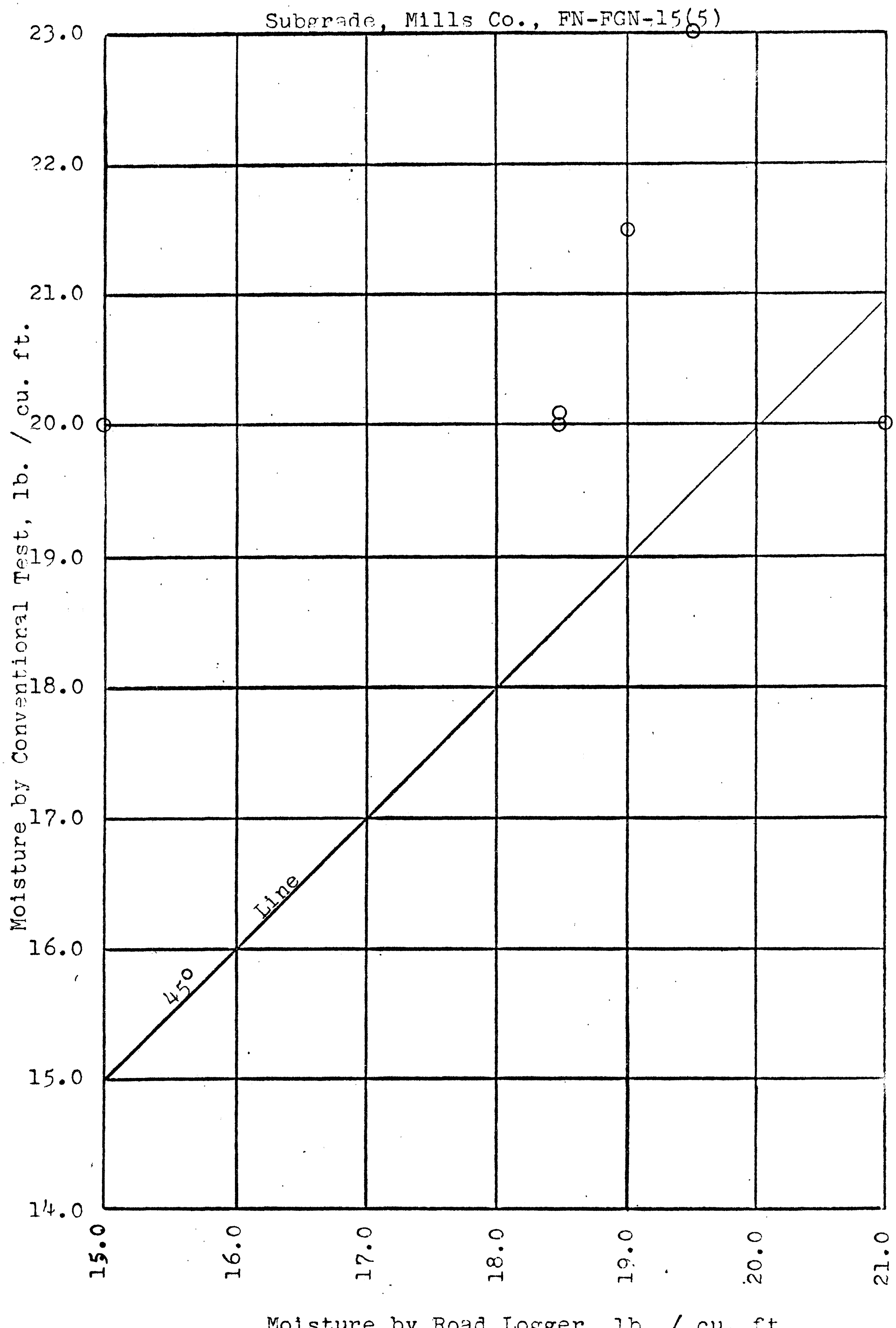
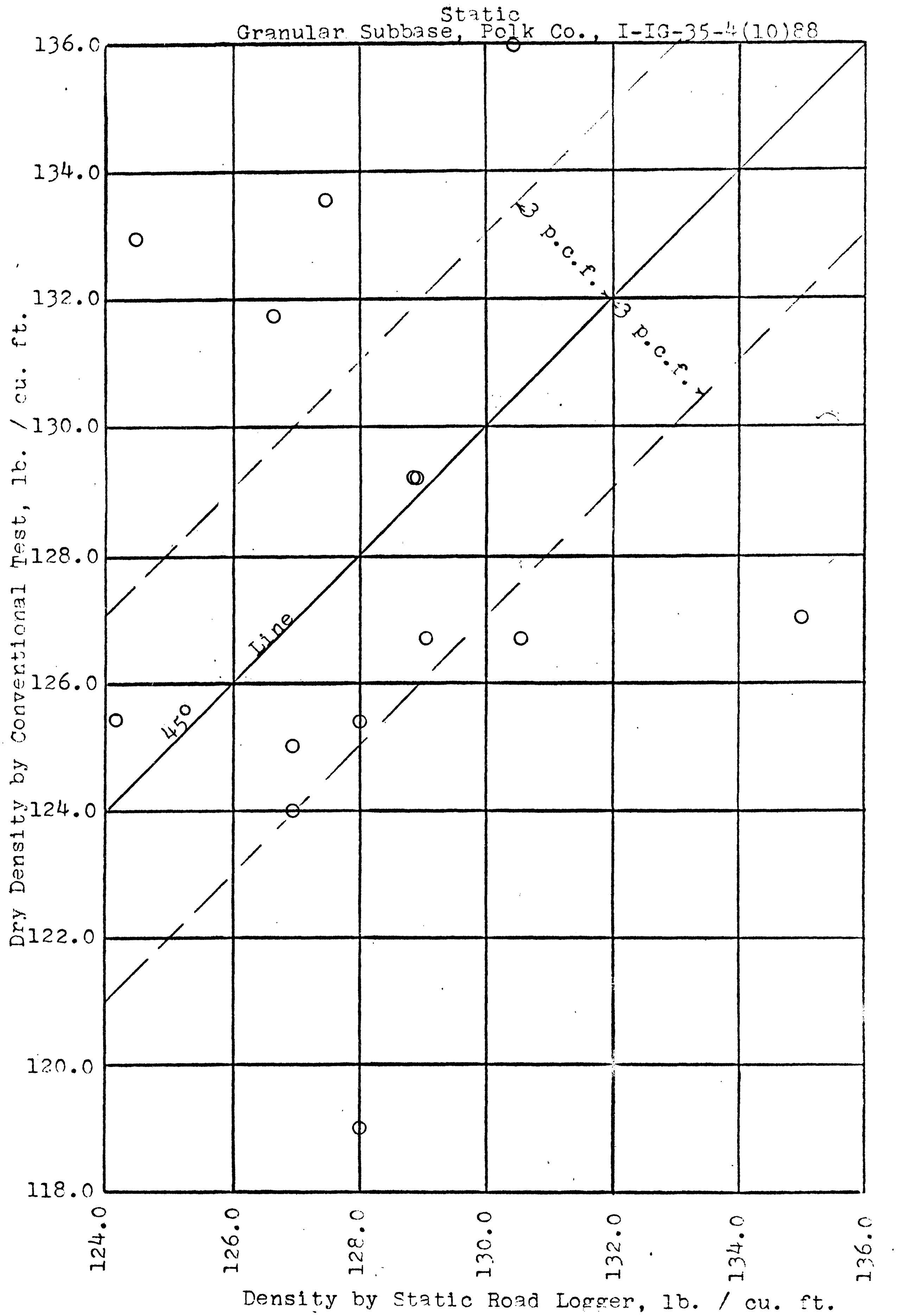

Subgrade, Mills Co., FN-FGN-15(5)
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
Moisture by Conventional Test, lb. / cu. ft.
45° Line
15.0
16.0
17.0
18.0
19.0
20.0
21.0
Moisture by Road Logger, lb. / cu. ft.

Figure 20


Static
Granular Subbase, Polk Co., I-IG-35-4(10)88
Dry Density by Conventional Test, lb. / cu. ft.
Density by Static Road Logger, lb. / cu. ft.
136.0
134.0
132.0
130.0
128.0
126.0
124.0
122.0
120.0
118.0
124.0
126.0
128.0
130.0
132.0
134.0
136.0
3 p.c.f.
3 p.c.f.
45° Line

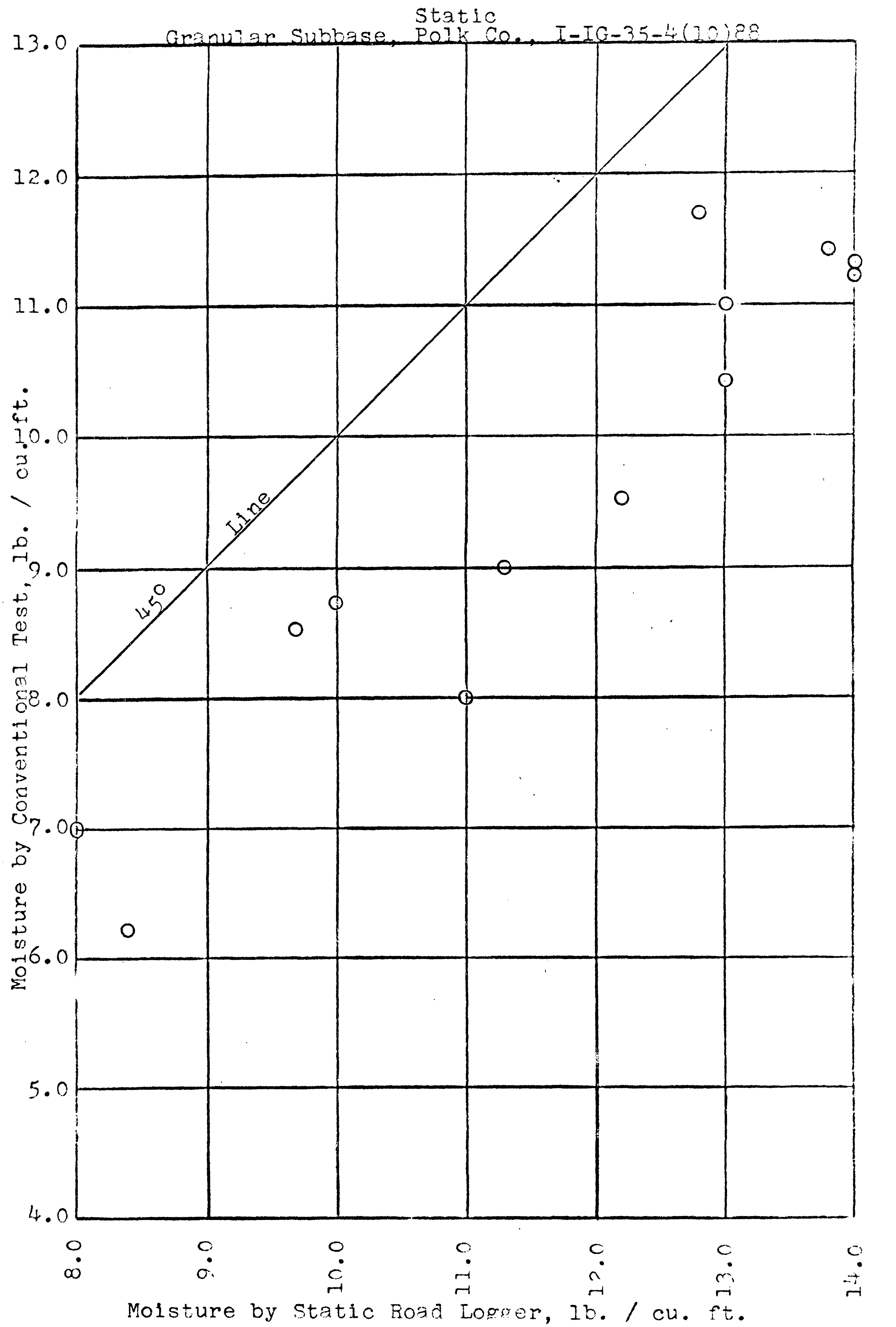
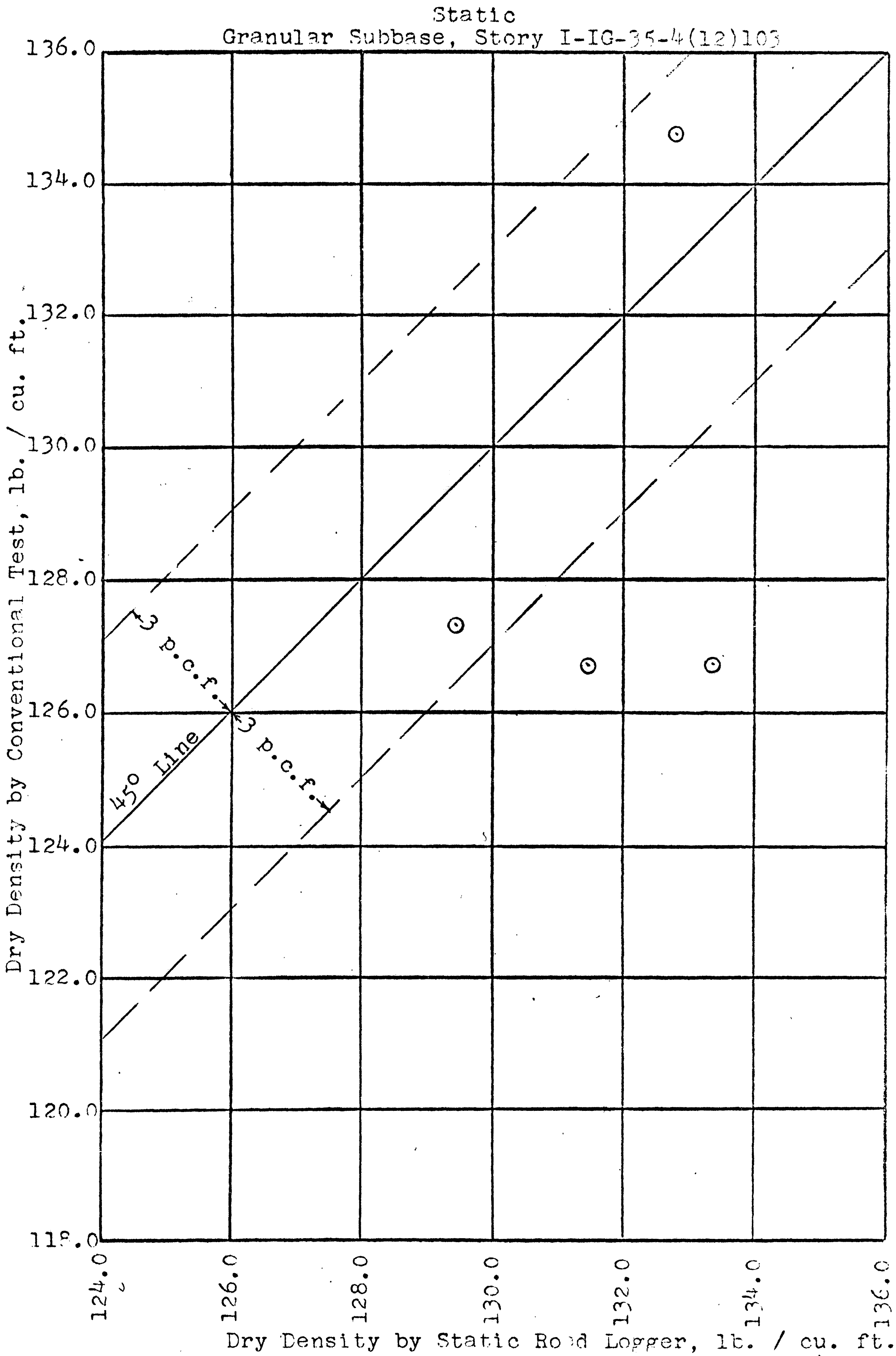
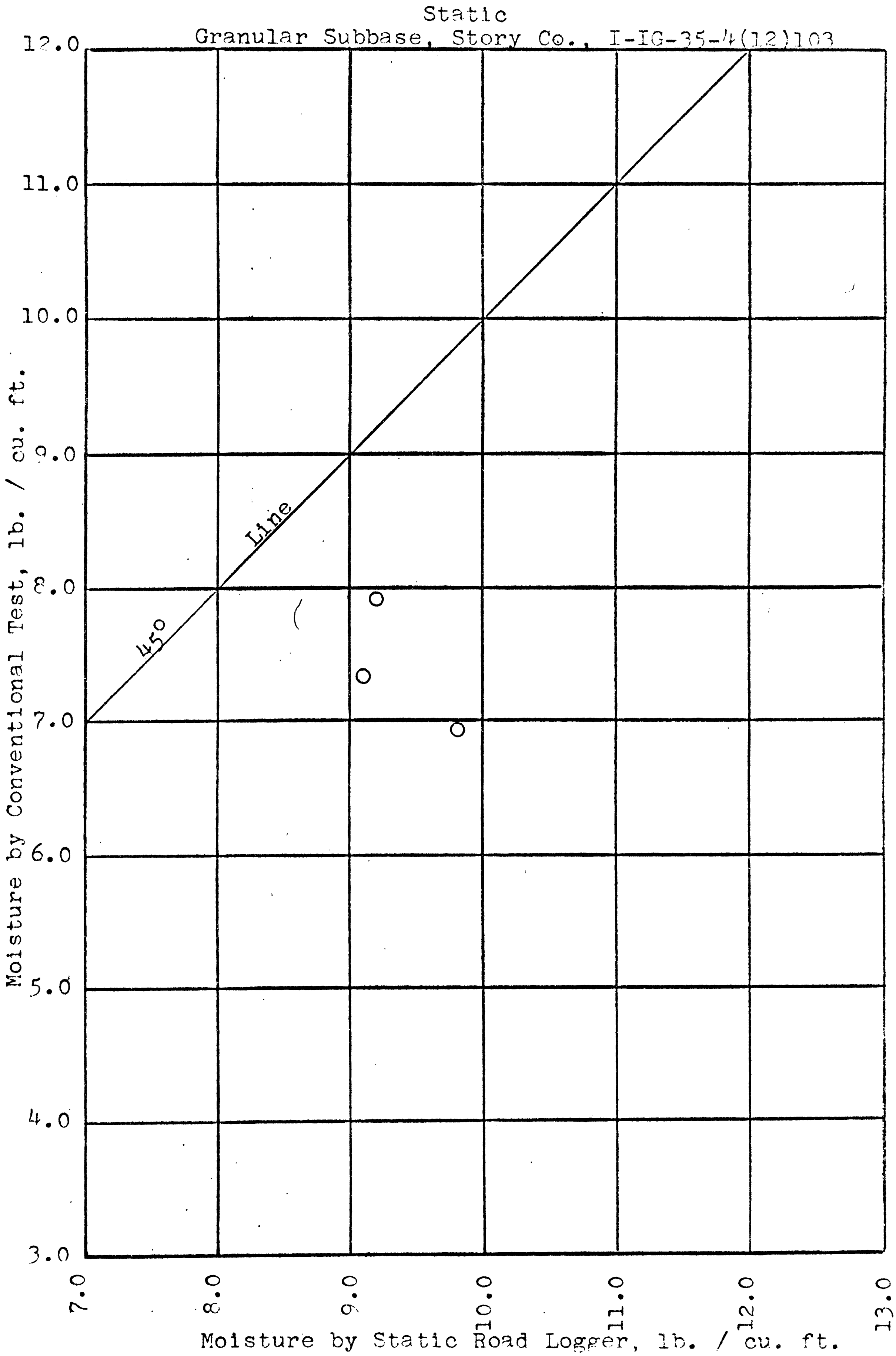
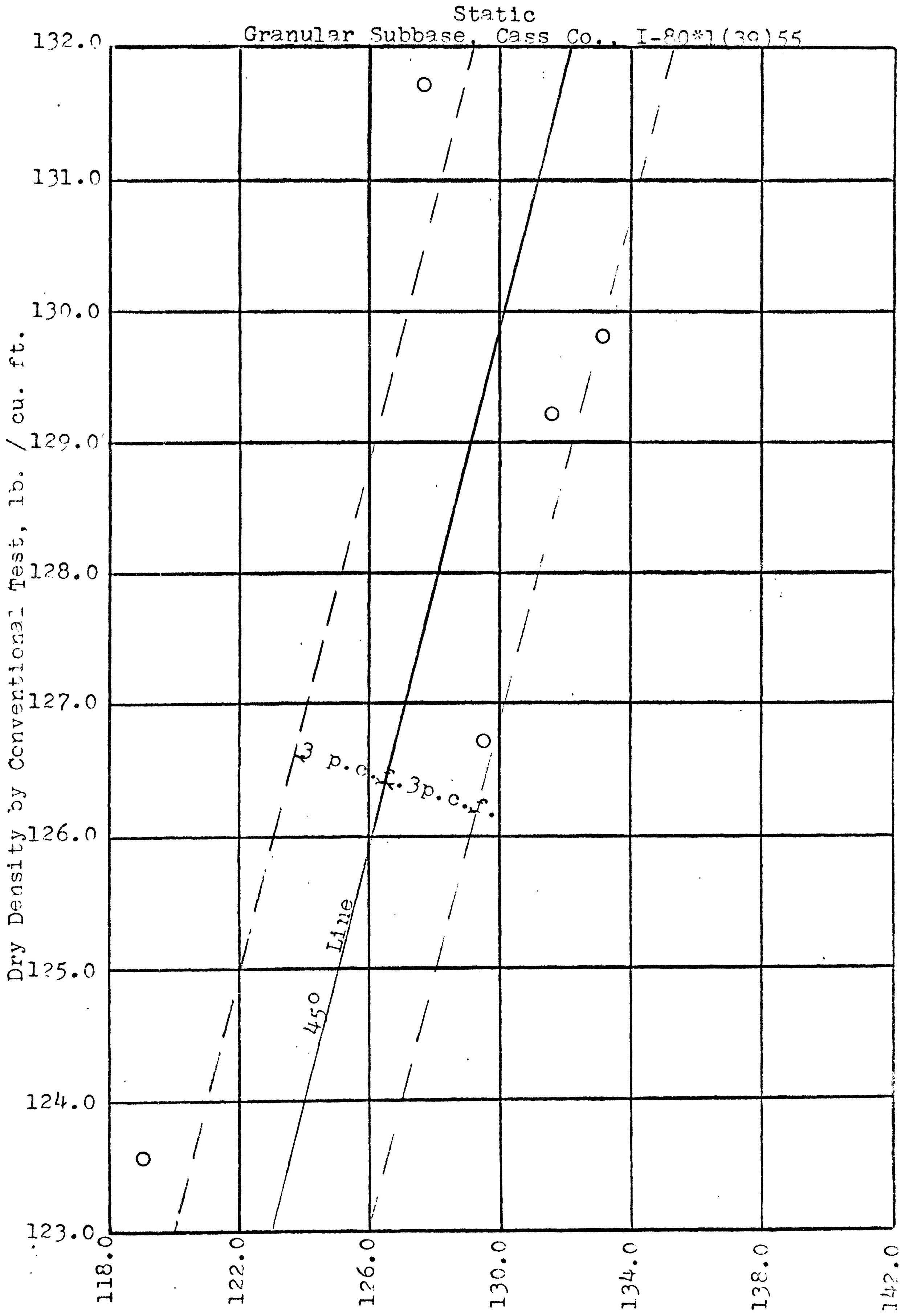

Static
Granular Subbase, Polk Co., I-IG-35-4(10)88
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
45° Line
8.0
9.0
10.0
11.0
12.0
13.0
14.0
Moisture by Conventional Test, lb. / cu. ft.
Moisture by Static Road Logger, lb. / cu. ft.

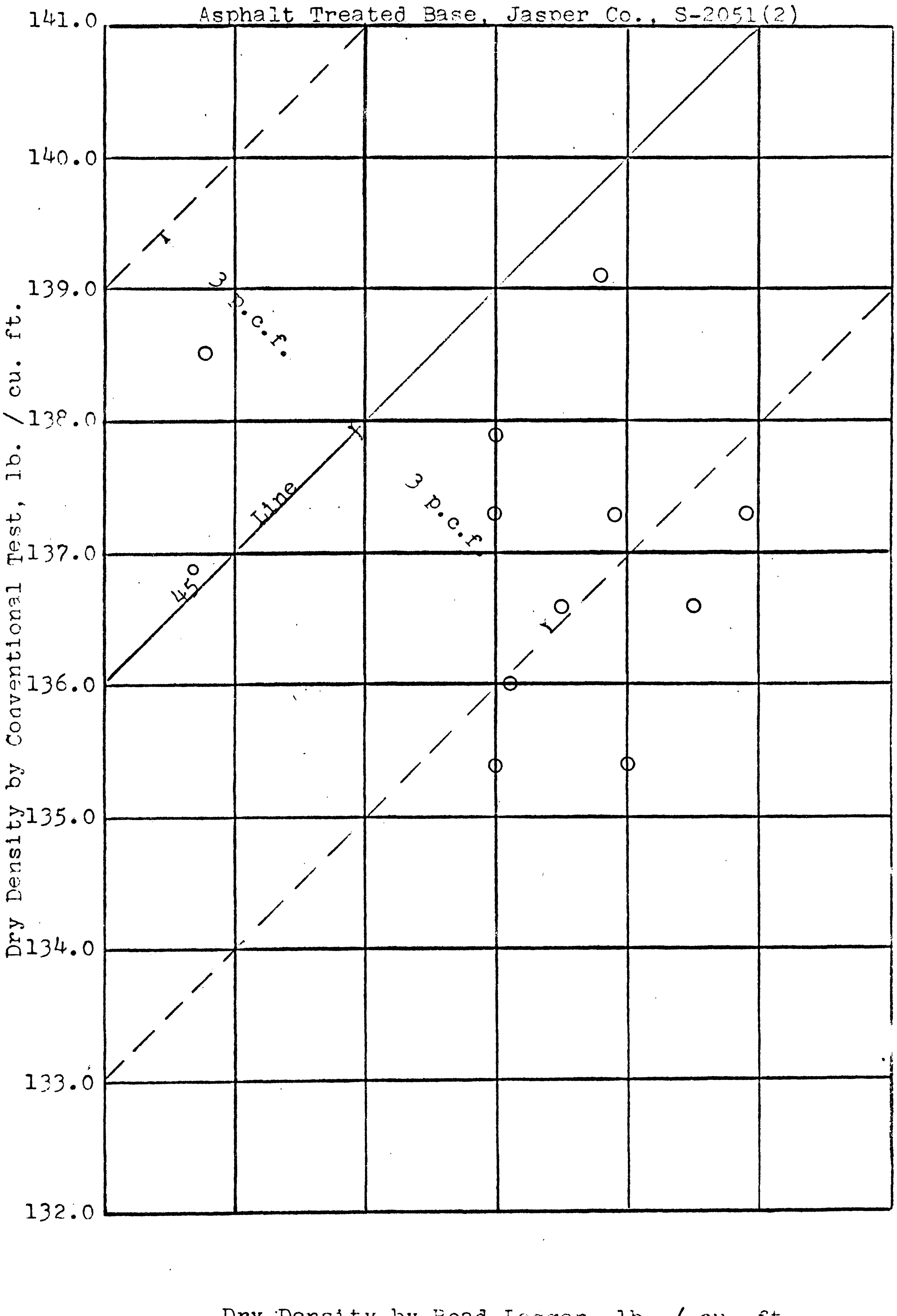
Figure 22

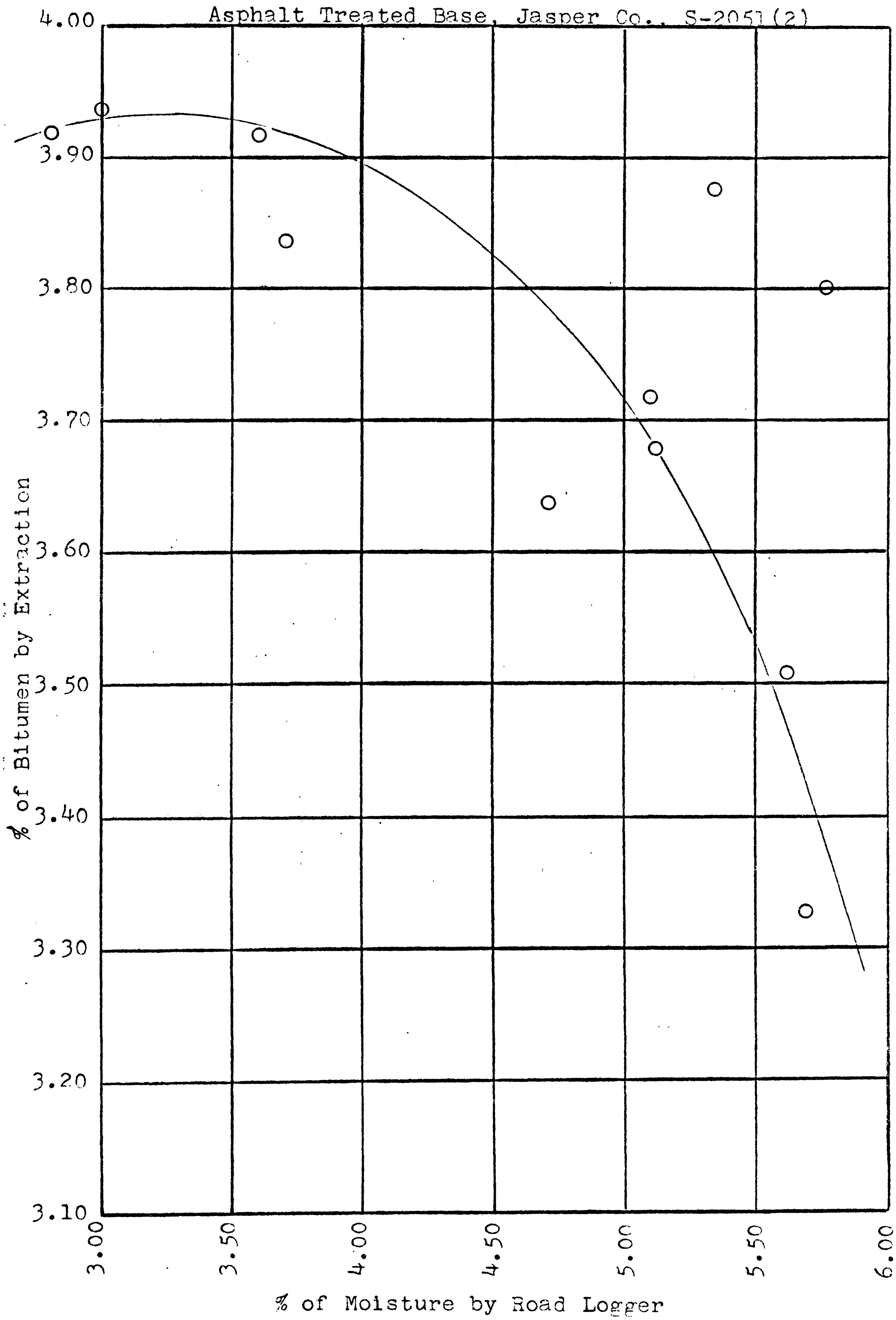


Static
Granular Subbase, Story I-IG-35-4(12)103
136.0
134.0
132.0
130.0
128.0
126.0
124.0
122.0
120.0
118.0
124.0
126.0
128.0
130.0
132.0
134.0
136.0
3 p.c.f.
3 p.c.f.
45° Line
Dry Density by Conventional Test, lb. / cu. ft.
Dry Density by Static Road Logger, lb. / cu. ft.

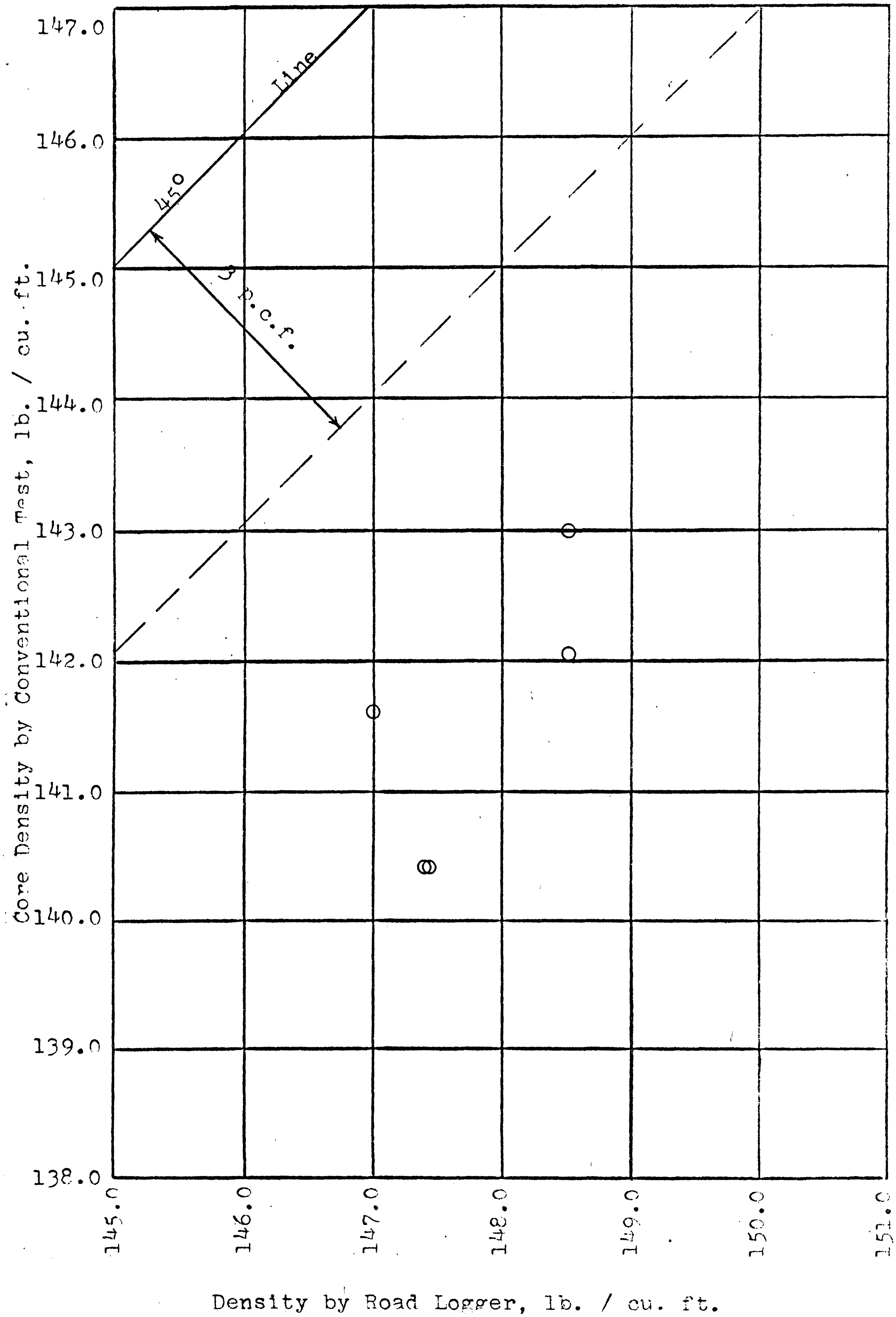

Static
Granular Subbase, Story Co., I-IG-35-4(12)103
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
Moisture by Conventional Test, lb. / cu. ft.
45° Line
7.0
8.0
9.0
10.0
11.0
12.0
13.0
Moisture by Static Road Logger, lb. / cu. ft.

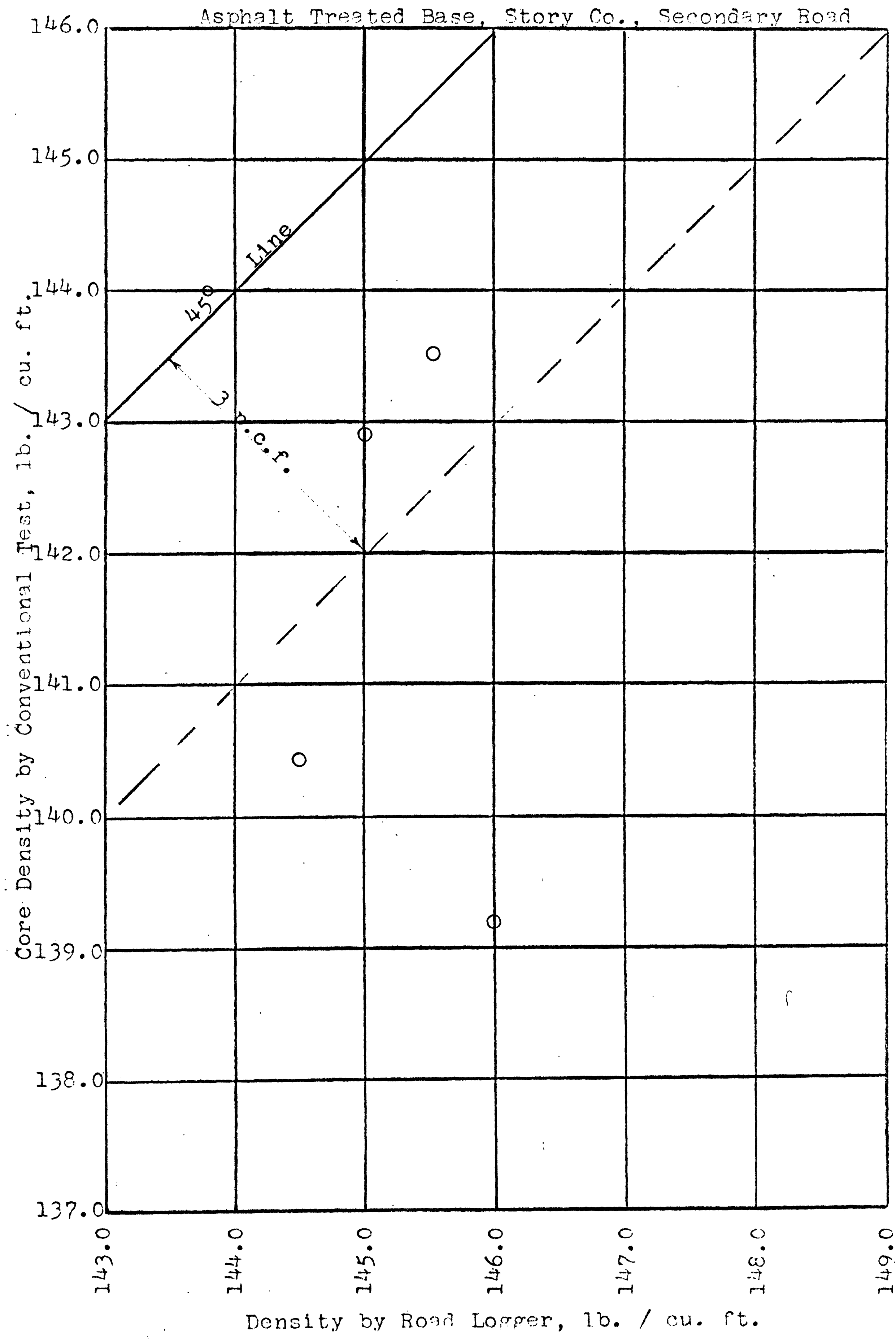

Static
Granular Subbase, Cass Co., I-80*1(39)55
132.0
131.0
130.0
129.0
128.0
127.0
126.0
125.0
124.0
123.0
Dry Density by Conventional Test, lb. / cu. ft.
3 p.c.f.
3p.c.f.
45° Line
118.0
122.0
126.0
130.0
134.0
138.0
142.0
Density By Static Road Logger, lb. / cu. ft.

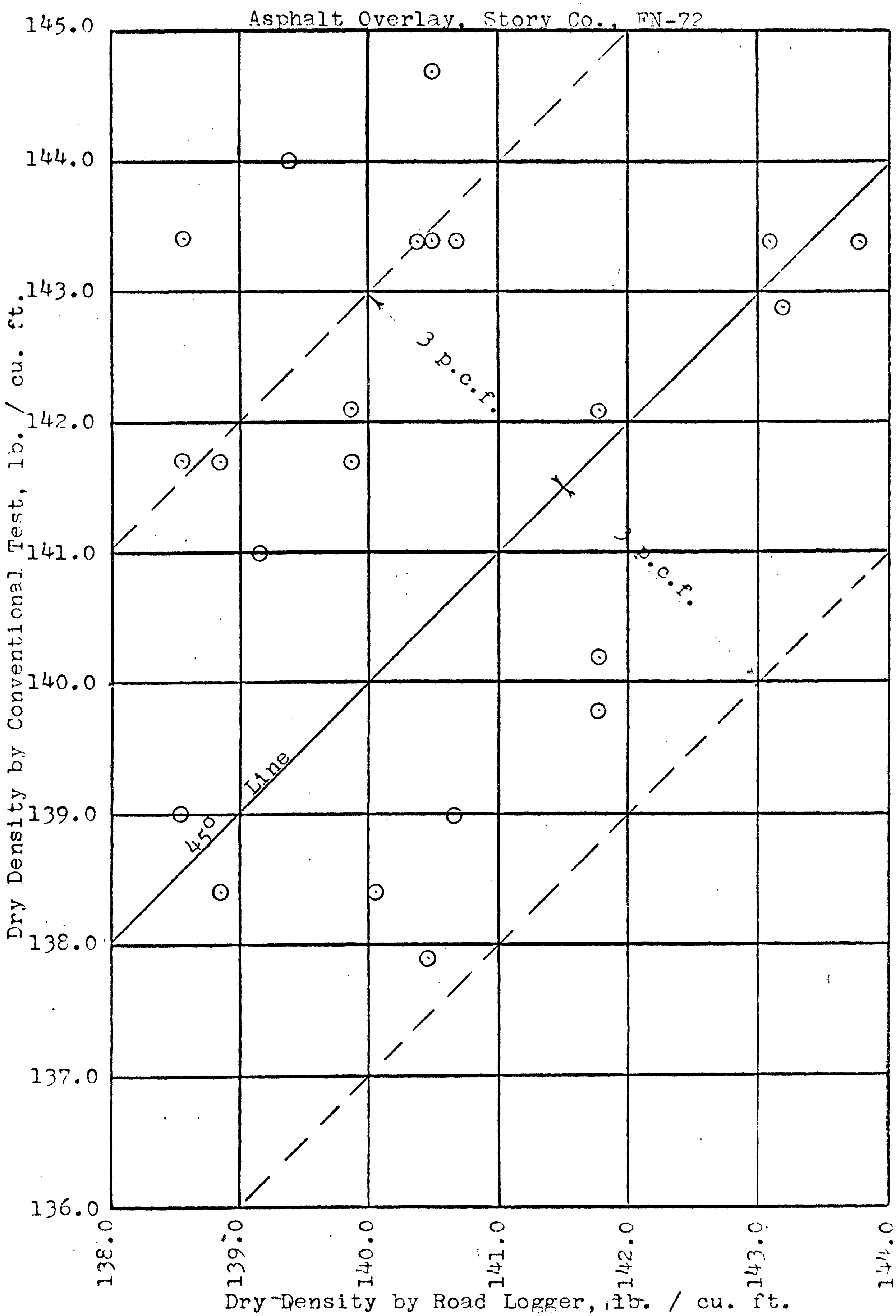

Asphalt Treated Base, Jasper Co., S-2051(2)
141.0
140.0
139.0
138.0
137.0
136.0
135.0
134.0
133.0
132.0
3 p.c.f.
45° Line
3 p.c.f.
Dry Density by Conventional Test, lb. / cu. ft.
Dry Density by Road Logger, lb. / cu. ft.


Asphalt Treated Base, Jasper Co., S-2051(2)
4.00
3.90
3.80
3.70
3.60
3.50
3.40
3.30
3.20
3.10
% of Bitumen by Extraction
3.00
3.50
4.00
4.50
5.00
5.50
6.00
% of Moisture by Road Logger

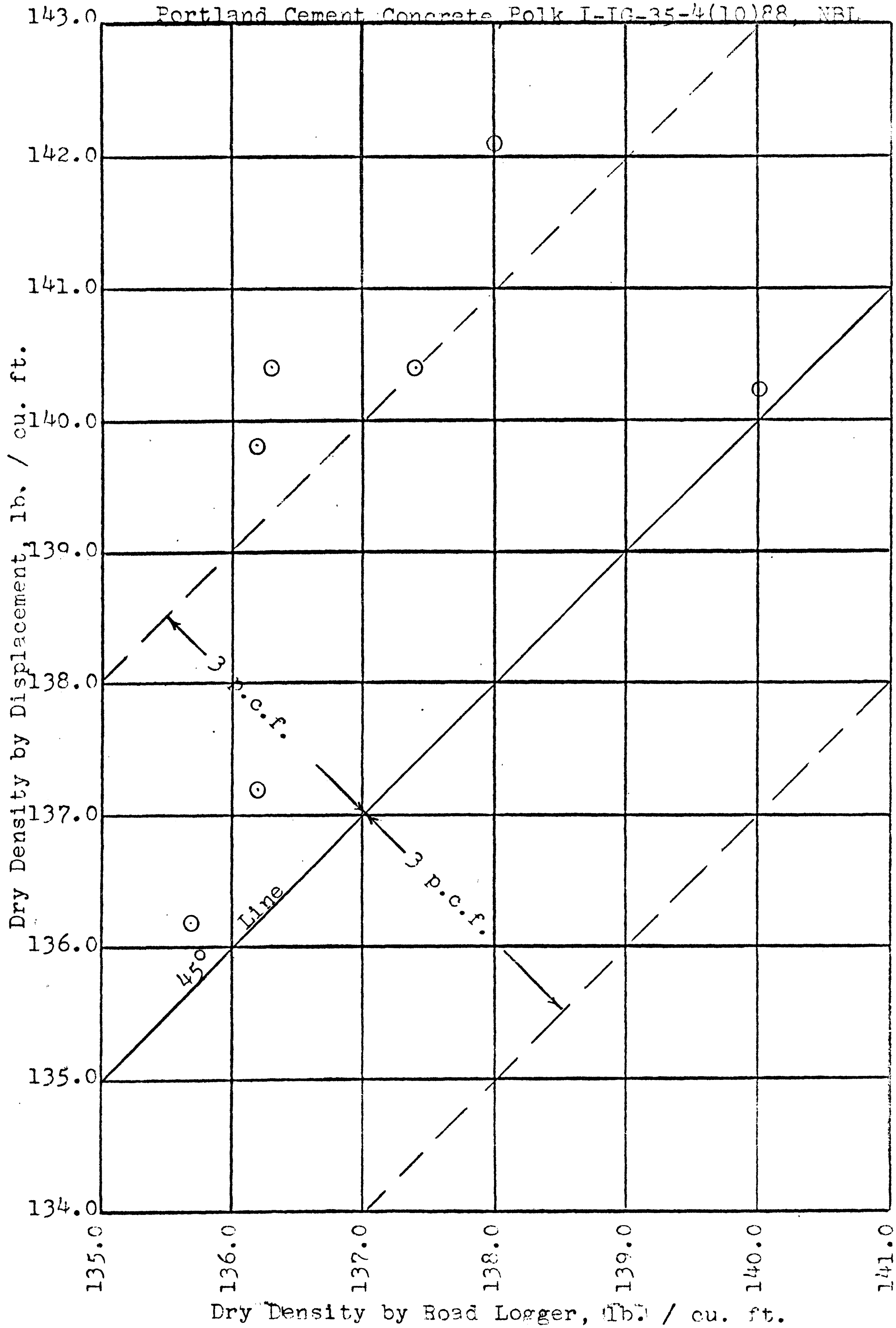
Asphalt Resurface, Hardin County, FN-79

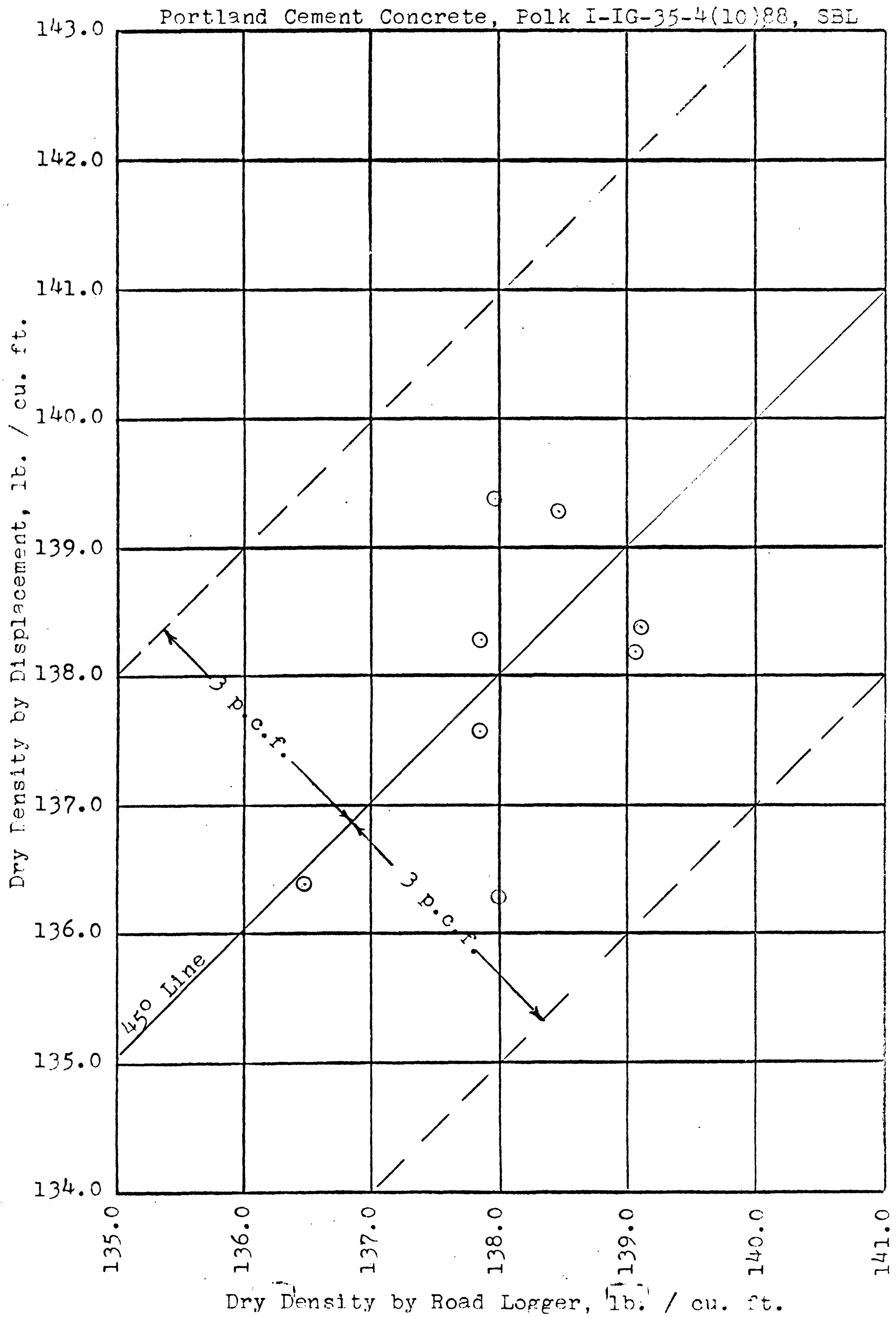


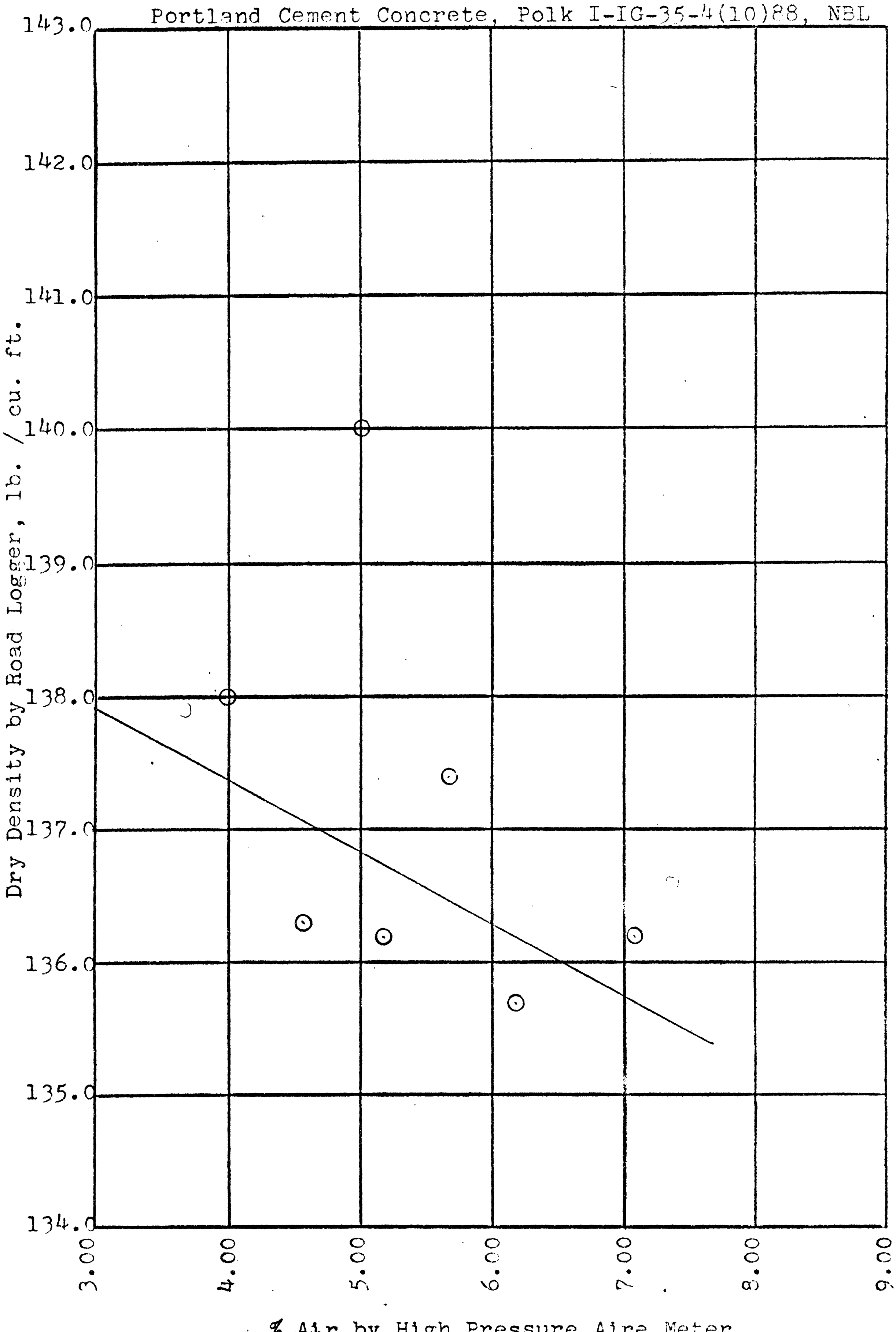

Asphalt Treated Base, Story Co., Secondary Road
146.0
145.0
144.0
143.0
142.0
141.0
140.0
139.0
138.0
137.0
45° Line
3 p.c.f.
143.0
144.0
145.0
146.0
147.0
148.0
149.0
Core Density by Conventional Test, lb. / cu. ft.
Density by Road Logger, lb. / cu. ft.

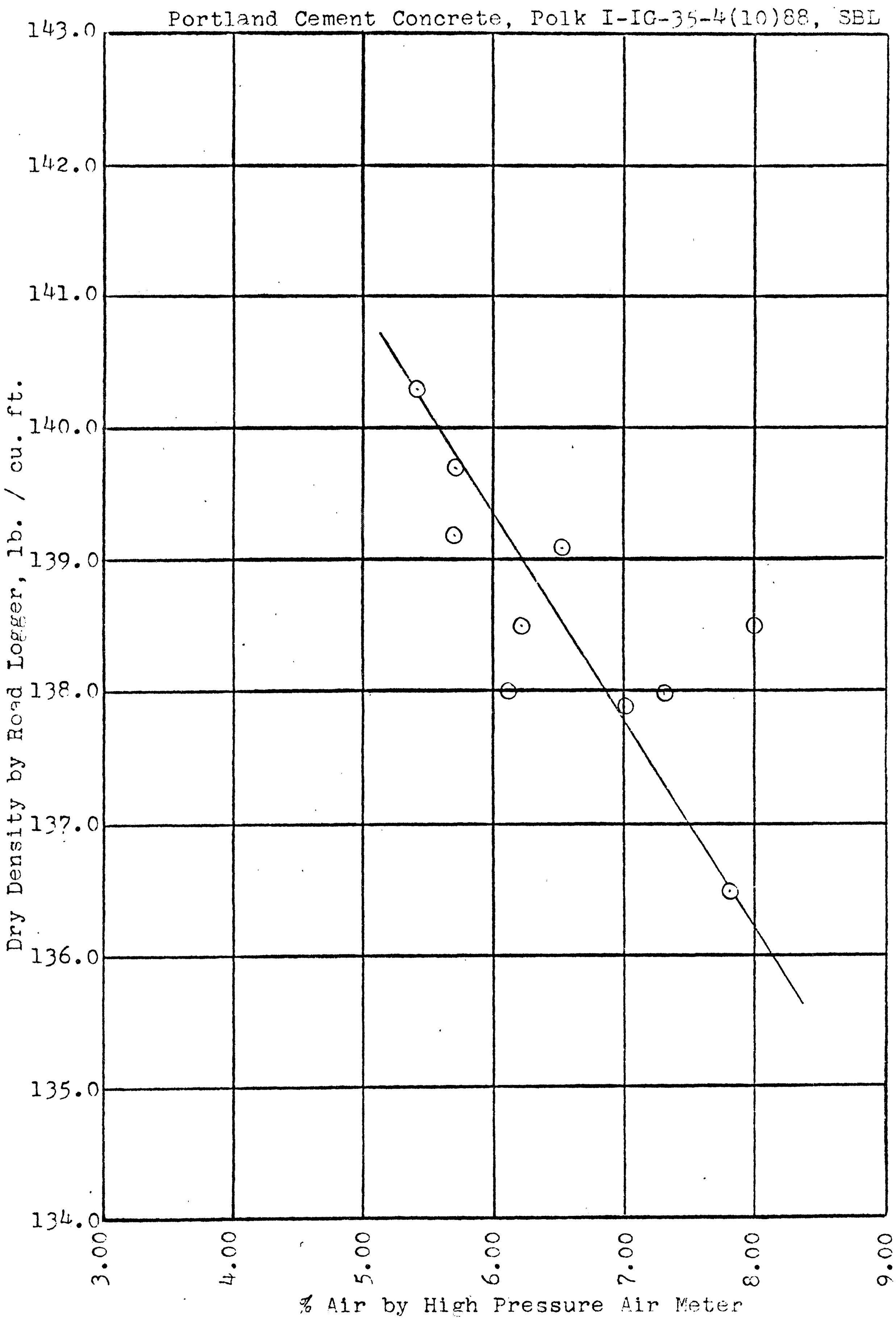

Asphalt Overlay, Story Co., FN-72
145.0
144.0
143.0
142.0
141.0
140.0
139.0
138.0
137.0
136.0
3 p.c.f.
3 p.c.f.
45° Line
138.0
139.0
140.0
141.0
142.0
143.0
144.0
Dry Density by Conventional Test, lb. / cu. ft.
Dry Density by Road Logger, lb. / cu. ft.

Portland Cement Concrete Polk I-IG-35-4(10)88, NBL




Portland Cement Concrete, Polk I-IG-35-4(10)88, SBL
143.0
142.0
141.0
140.0
139.0
138.0
137.0
136.0
135.0
134.0
Dry Density by Displacement, lb. / cu. ft.
3 p.c.f.
3 p.c.f.
45o Line
135.0
136.0
137.0
138.0
139.0
140.0
141.0
Dry Density by Road Logger, lb. / cu. ft.


Portland Cement Concrete, Polk I-IG-35-4(10)88, NBL
143.0
142.0
141.0
140.0
139.0
138.0
137.0
136.0
135.0
134.0
Dry Density by Road Logger, lb. / cu. ft.
3.00
4.00
5.00
6.00
7.00
8.00
9.00
% Air by High Pressure Aire Meter



Portland Cement Concrete, Polk I-IG-35-4(10)88, SBL
143.0
142.0
141.0
140.0
139.0
138.0
137.0
136.0
135.0
134.0
Dry Density by Road Logger, lb. / cu. ft.
3.00
4.00
5.00
6.00
7.00
8.00
9.00
% Air by High Pressure Air Meter