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NUCLEAR MOISTURE-DENSITY EVALUATION
PART II, FINAL REPORT
RESEARCH PROJECT NO. 62-1SB
LOUISIANA HPR 1(3)

Mr. F. E. Hawley
Division Engineer
Bureau of Public Roads
3444 Convention Street
Baton Rouge, Louisiana

Dear Mr. Hawley:

Enclosed are six copies of the final draft of the final report for the captioned project entitled NUCLEAR MOISTURE-DENSITY EVALUATION, PART II, FINAL REPORT.

This is being submitted for your review and approval prior to publication.

Yours very truly,

Verdi Adam
Research and Development Engineer

CMH:skw
cc: Mr. Grady Carlisle
Mr. C. J. Crouse, Sr. (2)
Soils Project Advisory Committee

# LOUISIANA HIGHWAY RESEARCH

NUCLEAR MOISTURE-DENSITY EVALUATION

PART II

FINAL REPORT

by

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Research Report No. 22

Research Project No. 62-1SB

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research & Development Section
in Cooperation with
U. S. Department of Commerce
BUREAU OF PUBLIC ROADS

June 1966

# SYNOPSIS

The results included in this report are from tests run by the Louisiana Department of Highways field and laboratory techicians with only general guidance at the professional level, as is ordinarily done for all routine testing and inspection work.

The portable nuclear moisture-density devices evaluated in this study were found to be accurate tools for the determination of in-place density. They were also found to be sufficiently rugged for field use with little more than normal care.

From extensive field testing it was found that some revisions needed to be made in the testing procedure and calibration of the nuclear devices as reported in Louisiana Department of Highways Research Report No. 16, published in November, 1964. These changes are considered to be essential for efficient use of the nuclear devices. A new test method has been prepared for the use of this equipment as an aid to compaction control (LDH TR 401-65) and is included in the appendix.

# EVALUATION OF A NUCLEAR METHOD FOR DETERMINING SOIL MOISTURE AND DENSITY

## PART II

## FINAL REPORT

## INTRODUCTION

The determination of in-place density by the use of nuclear moisture-density devices has proven to be an exceptionally useful tool to the modern Highway Engineer. In order to adequately adapt this new testing equipment to efficient field use, evaluation of many tests under nearly every type of field condition possible was made.

The research program which began in August 1962 has evaluated one of the several portable nuclear moisture-density devices now on the market and additional units have been purchased as recommended from the results of this program. Twenty-five nuclear units are now being used by construction and laboratory personnel of the Louisiana Department of Highways. This extensive field use of nuclear moisture-density devices has enabled the Research and Development Section to re-evaluate its original operating and testing procedures for these devices.

## SCOPE

The research program was designed to investigate the operational characteristics and durability of the nuclear equipment. Once these factors had been established the next steps were to develop a practical procedure for the use of this equipment in the field and a method of calibration.

It was originally intended to investigate several increments of depth simultaneously with respect to density. However, when this became too time consuming, the emphasis was shifted to cover primarily a depth of six inches.

## METHOD OF PROCEDURE

The first nuclear unit was purchased by the Louisiana Department of Highways in 1962. The immediate objective of the Research and Development Section was to study its operational characteristics. Once these factors were known the next course of action was to find out if the equipment could be suitably adapted to field use.

Having accomplished the above mentioned objectives, additional units were purchased and placed in the hands of construction personnel. As these units were used to make field determinations, data on each test run was sent to the Research and Development Section for evaluation. When the need for changes in procedure became evident, revisions were made in the original procedure to compensate for difficulties encountered in the field. Through this method of cooperation of construction and research personnel, the present procedure was established.

## MATERIALS TESTED

This investigation covered a wide range of materials on construction projects over the entire State. It included determinations made on materials ranging from A-2-4 to A-7-6 and stabilized materials from A-6 to sand clay gravel and sand shell.

The testing program included nearly 4, 000 individual observations under a rather wide range of climatic conditions.

## RADIOLOGICAL SAFETY

The Research and Development Section has closely supervised the use of nuclear devices throughout the state. Three schools have been conducted for the operators and supervisors of the nuclear equipment. With the cooperation and assistance of the Nuclear Science Centers of Louisiana State University, The University of Southwestern Louisiana, and Louisiana Polytechnic Institute, three day sessions were held at each campus to familiarize personnel with radiological safety and the operation of the nuclear moisture-density devices. Upon completion of these schools, personnel attending received nuclear device operators cards. These cards are now in the possession of all Louisiana Department of Highways personnel who operate the nuclear devices of the Department. Film badges have been issued to all operators for their protection against over-exposure to radioactivity.

A radiation protection officer has been appointed by the Safety Section of the Department to keep records of film badge exposures and is responsible for statewide safety control of all nuclear devices.

## TEST PROCEDURES

The soil samples and density determinations were tested in accordance with the following methods:

1. LDH TR-401 - Method of Test for the Determination of In-Place Density.

2. LDH TR-407 - Method of Mechanical Analysis of Soils.

3. AASHO-T89-60 - Methods of Determining Liquid Limit of Soils.

4. AASHO-T-90-56 - Methods of Determining the Plastic Limit of Soils.

5. AASHO-T-91-54 - Method of Calculating the Plasticity Index of Soil.

6. Procedure for Nuclear Determinations (This is discussed under the heading of Discussion of Results).

## DISCUSSION OF RESULTS

The results of extensive field testing brought about some changes in operating and testing procedures for the nuclear moisture-density devices. In the early phases of the evaluation of these devices it had been thought that taking more than one "reading" (1) at each test site would enhance the accuracy of the density value. For this reason a testing procedure was written which called for three "readings" to be taken 120° apart and then averaged for each test. Later testing, however, proved this procedure to be not only time consuming but also little more accurate than single "reading" testing. Therefore, since one of the major objectives of nuclear testing is the reduction of the time involved in taking in-place densities and since the extensive field testing has shown one "reading" to give an accurate density, the taking of three "readings" was eliminated from the new test procedure. The new test method, LDH TR-401-65, Method of Test for the Determination of In-Place Density, is included in the appendix.

Another area which was investigated in the early phases of evaluation of the nuclear moisture-density devices was durability of the equipment under field conditions. There have been improvements in both the operational characteristics and durability of the Troxler Nuclear Devices since the last report on this project was published. The halogen quenched Geiger-Müller tube (with end window construction) in the density device has been replaced with two side window Geiger-Müller tubes. This change seems to have decreased the rapid deterioration of the detector element which had been noted in the earlier models.

The general construction of both the moisture and density gauges has been changed to increase their durability. There have been very few problems involving equipment failure due to lack of durability. The modular construction of the

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(1) (A nuclear "reading" consists of a minimum of 3 one-minute counts, all of which must fall within the statistical range of 1.5 times the square root of the average).

scaler has enabled repairs to be made with a minimum loss of time.

One of the major fields of interest lies in the development of a calibration procedure for the nuclear devices. Since the devices are no better than their calibration, much time and effort was devoted to the development of a procedure for calibration. Included in the appendix is a recommended procedure for preparing nuclear moisture and density calibration curves. At the present time a study of all calibration curves established on various projects in Louisiana during normal construction, by use of the calibration procedure shown in the appendix, are being examined to see if specific calibration curves can be established for particular soil types. Since chemical differences in the soils are believed to be a principal cause of deviation from the manufacturers curves, we are hopeful that curves can be established for certain soil types within specific geographical areas where chemical composition is similar.

Figures 1 through 6 show the relationship between the manufacturer's moisture and density calibration curves and the calibration curves developed by field personnel. The number on each field curve represents the number of times that particular curve was used as the calibration curve for testing. The field curves were developed using the method, Calibration Of Nuclear Moisture And Density Curves, which is included in the appendix. Calibration curves were plotted for depths of six, seven, and eight inches on soils ranging from A-2-4 to A-7-6 and stabilized soils from A-6 to sand clay gravel and sand shell.

## CONCLUSIONS

The following conclusions are based on non-selective data obtained under a variety of field conditions by sub-professional personnel.

1. The equipment used in this program is sufficiently rugged for field use with little more than normal care.

2. A test procedure has been developed as a guide for the use of this equipment in the field, including certain laboratory check procedures. These are given in the appendix.

3. In general the calibration curves for density do not coincide with the manufacturer's calibration curve. A check is being made to see if calibration curves for specific soil types in specific areas can be developed.

4. The calibration curves for moisture content do not coincide with the manufacturer's calibration curve.

5. The nuclear equipment is safe enough for use by the average construction worker, so long as he is properly instructed as to the hazards involved.

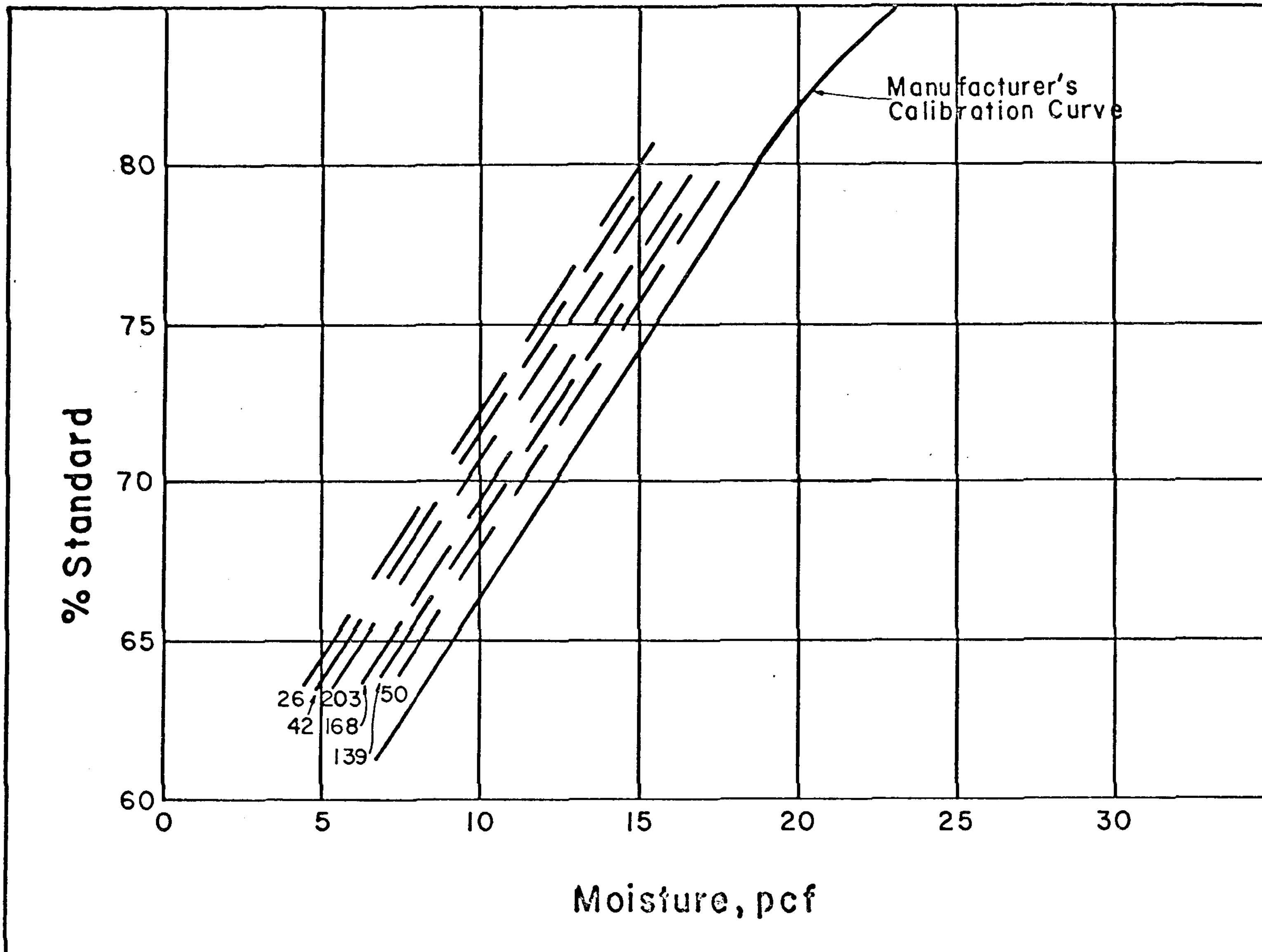


Figure 1 - Relationship of Percent of Standard Count to Moisture Content (pcf) for both Stabilized and Raw Soils at a Depth of Six Inches.

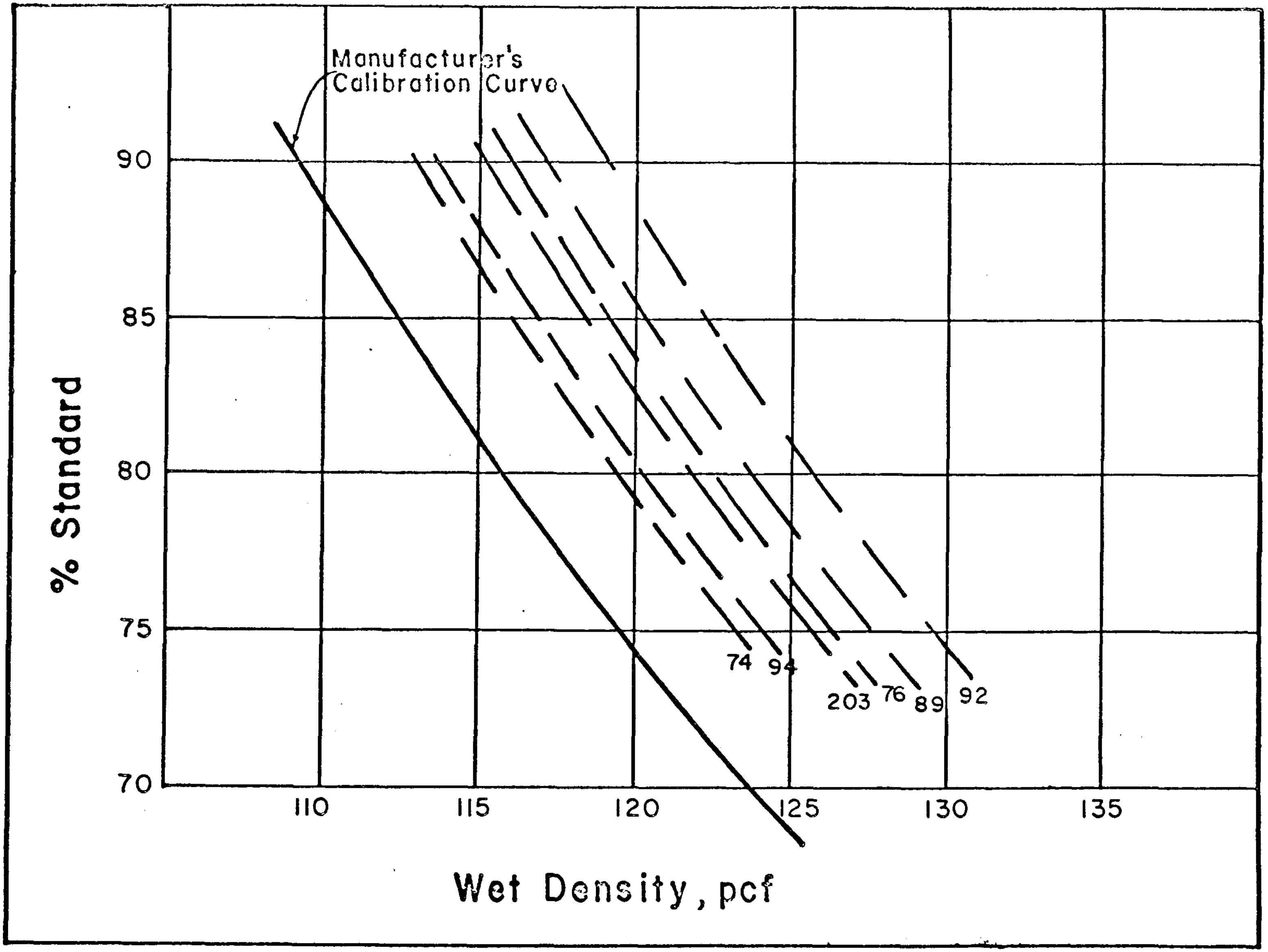


Figure 2 - Relationship of Percent of Standard Count to Wet Density (pcf) for both Stabilized and Raw Soils at a Depth of Six Inches.

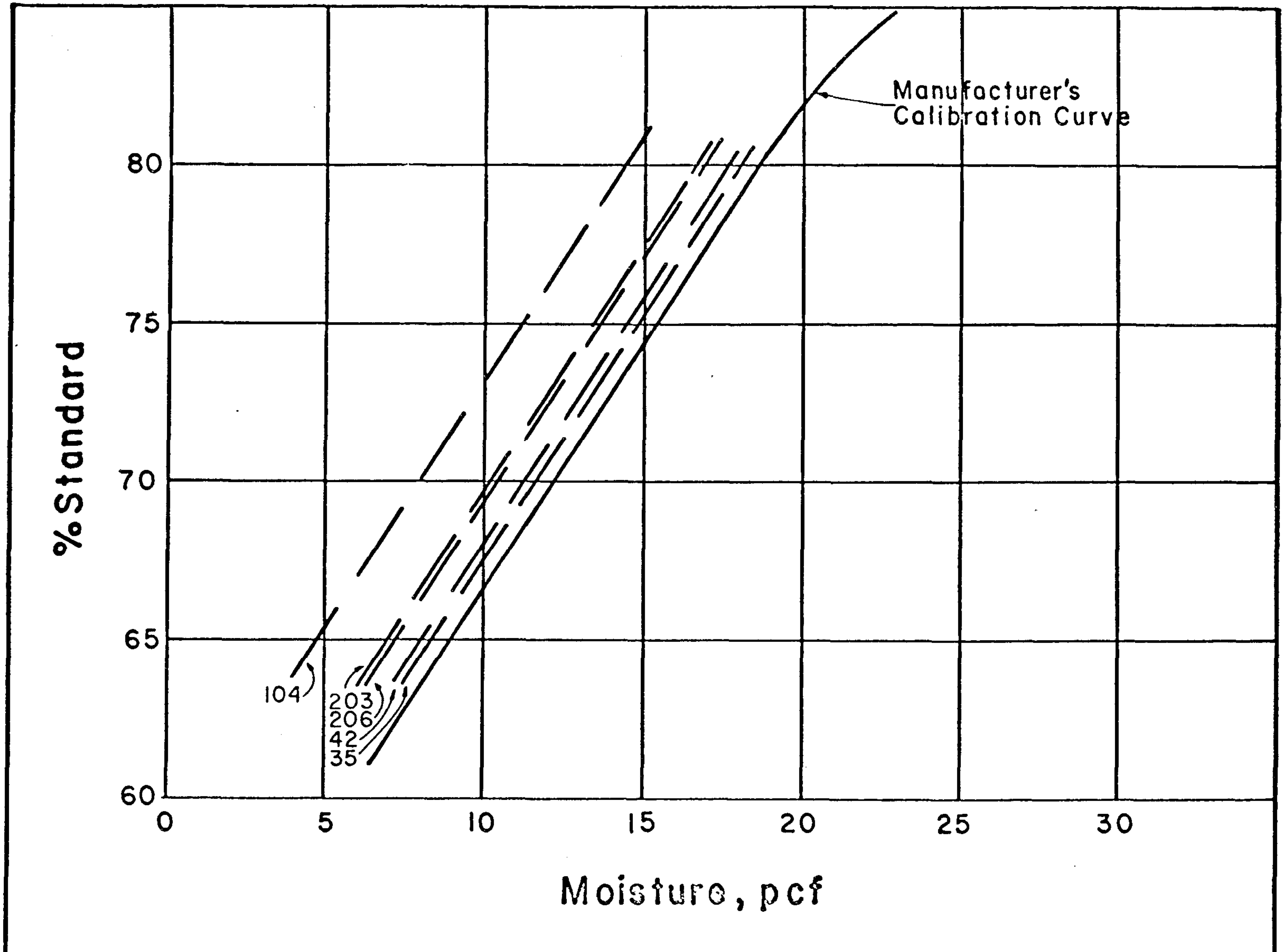


Figure 3 - Relationship of Percent of Standard Count to Moisture Content (pcf) for both Stabilized and Raw Soils at a Depth of Seven Inches.

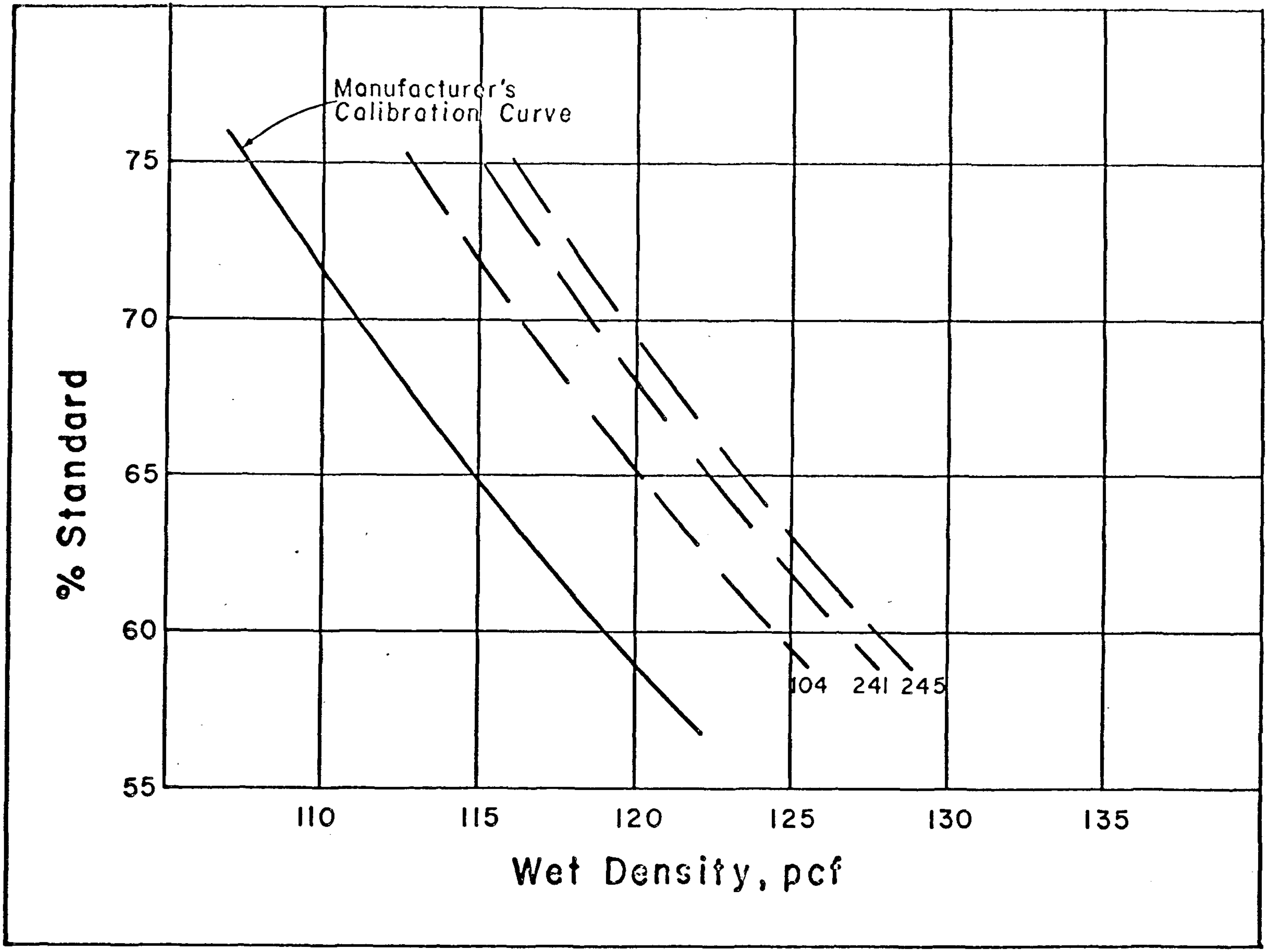


Figure 4 - Relationship of Percent of Standard Count to Wet Density (pcf) for both Stabilized and Raw Soils at a Depth of Seven Inches.

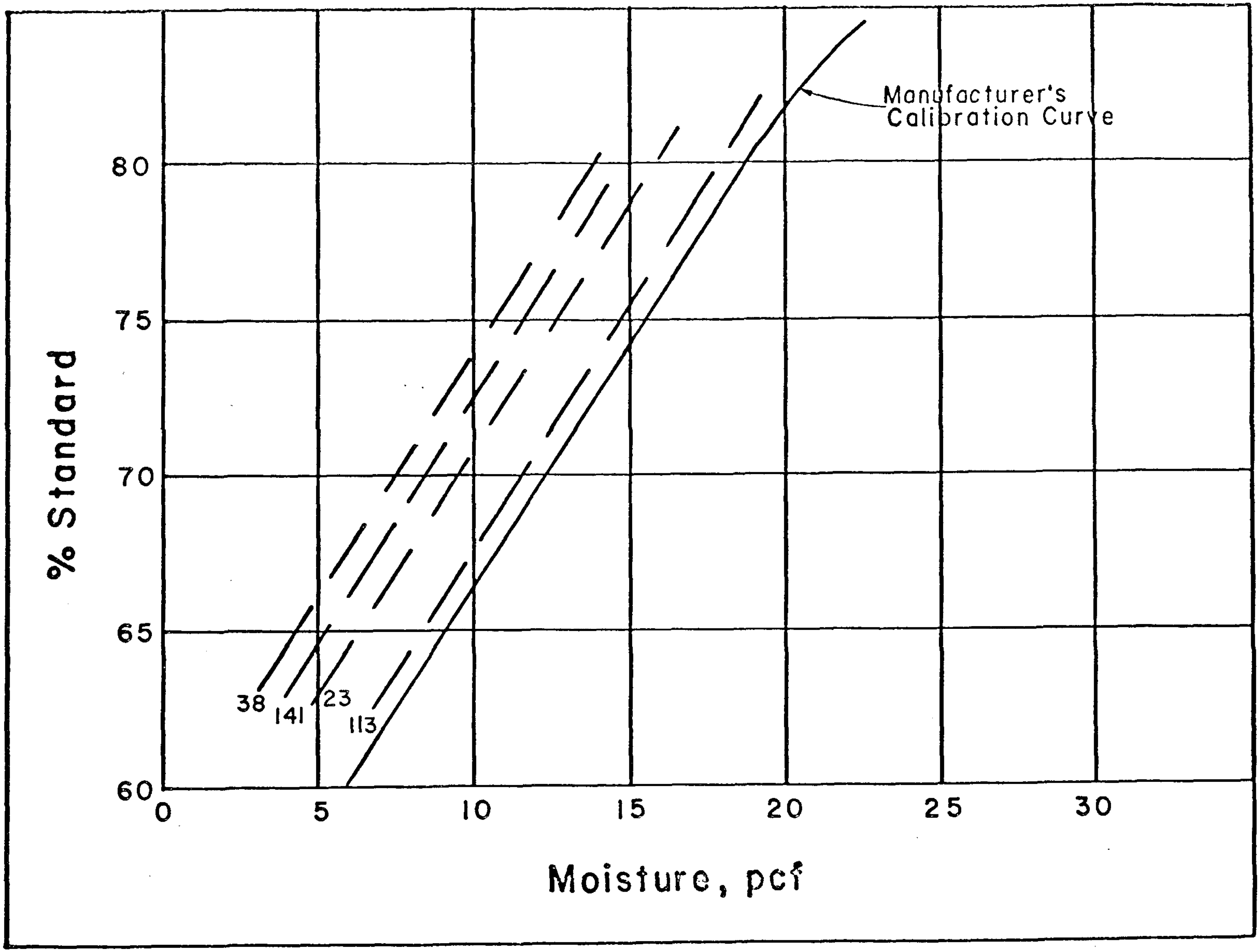


Figure 5 - Relationship of Percent of Standard Count to Moisture Content (pcf) for both Stabilized and Raw Soils at a Depth of Eight Inches.

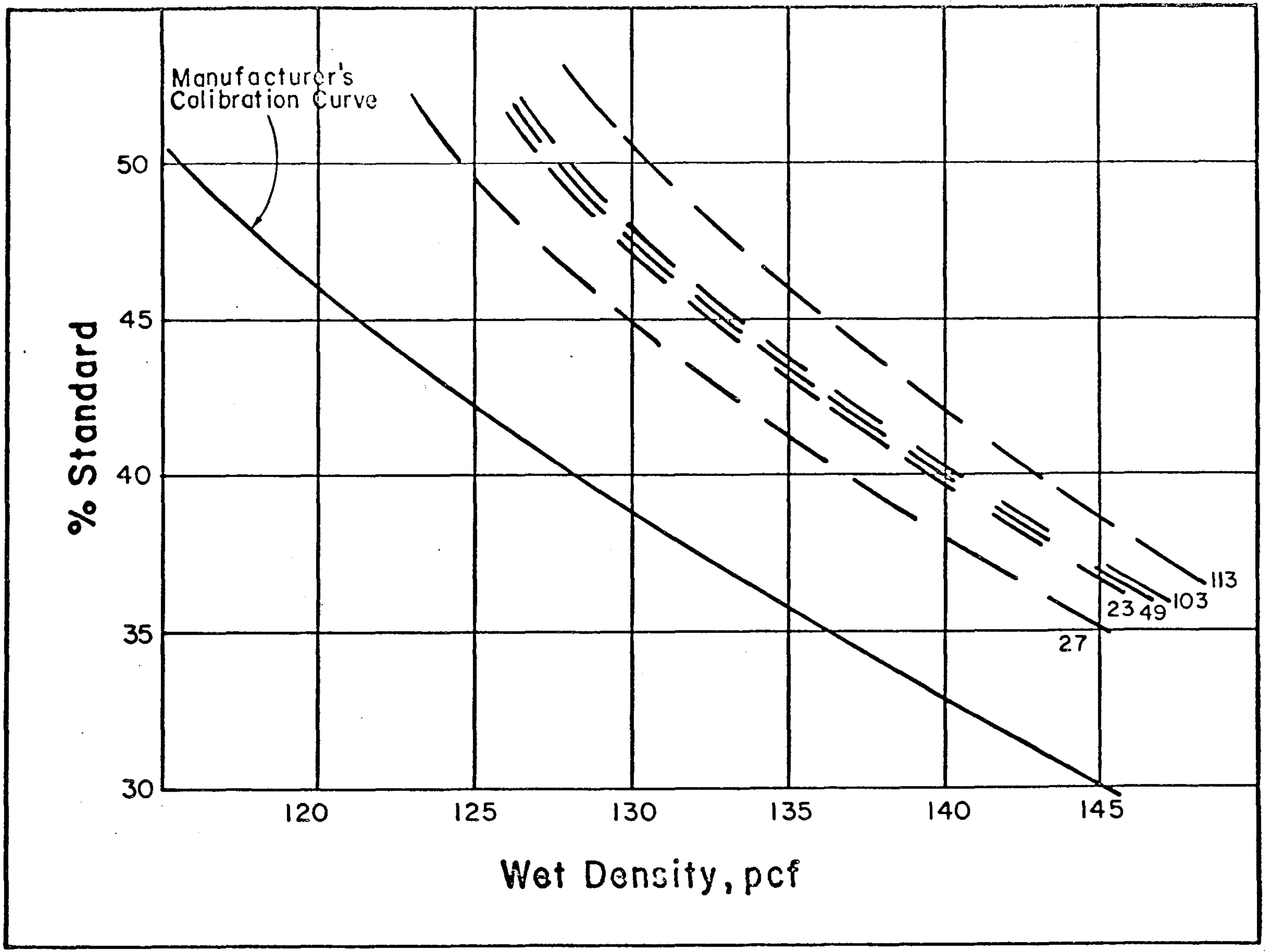


Figure 6 - Relationship of Percent of Standard Count to Wet Density (pcf) for both Stabilized and Raw Soils at a Depth of Eight Inches.

# APPENDIX

# CALIBRATION PROCEDURE

Density Devices:

The calibration curves as established by the factory for the individual devices are <u>not</u> satisfactory for use without checking and/or modification as described below:

Nuclear density readings shall be taken at three locations as close together as possible. The percents of standard shall be added together and an average for the area obtained. Conventional sand cone densities shall then be determined at these same locations. The three in-place sand cone densities shall be added together and an average for the area obtained.

The average percent of standard obtained shall be plotted versus the average in-place wet density obtained by the sand cone on the graph showing the factory calibration curve. If the point thus established lies on the factory calibration curve, the curve shall be considered satisfactory for use. If the point does not fall on the factory calibration curve, then a line shall be drawn through the point parallel to the factory curve and used as the calibration curve.

Moisture Devices:

The calibration curves as established by the factory for the individual devices are <u>not</u> satisfactory for use without checking and/or modification as described below:

Nuclear moisture readings shall be taken at three locations as close together as possible. The percents of standard shall be added together and an average for the area obtained. Conventional moisture contents shall then be determined at these same locations. The three moisture contents in lbs. per cu. ft. shall be added together and an average for the area obtained. The moisture in lbs. per cu. ft. can be found by multiplying the percent of moisture by the unit dry weight of the conventional test or by subtracting the dry weight density from the wet weight density.

The average percent of standard obtained shall be plotted versus the average moisture, lbs. per cu. ft., obtained by conventional methods on the graph showing the factory calibration curve. If the point thus established lies on the factory calibration curve, the curve shall be considered satisfactory for use. If the point does not fall on the factory calibration curve then a line shall be drawn through the point parallel to the factory curve and used as the calibration curve.

Method of Test for
# THE DETERMINATION OF IN-PLACE DENSITY
LDH DESIGNATION TR 401-65

## PART I - MECHANICAL METHODS

### Scope

This method of test is intended to determine the density of soil, sand clay gravel, iron ore, shell, sand-shell, soil lime, soil asphalt and soil cement courses in the natural state or after compaction in an embankment by finding the weight and moisture content of a disturbed sample and measuring the volume occupied by the sample prior to removal. It is a modification of "Standard Method of Test for the Field Determination of Density of Soil In-Place", A.A.S.H.O. Designation: T 147-54.

### Apparatus

1. Sampling Tools-An Iwan type auger 3½ in. in diameter, or other cutting tool suitable for cutting a hole to the desired depth for materials containing no aggregates. For aggregate bases, an ice pick, chisel, screwdriver or other hand tools of similar type may be used. Also small brush, trowel, spoon or similar articles for taking sample from hole.
2. Balances-A balance or scale of 30 lb. capacity and sensitive to 0.01 lb. and 1 Kg. capacity balance sensitive to 0.1 gram.
3. Measure-A container of known volume preferably a thirtieth of cubic foot Proctor Mold.
4. Compaction Hammer-The compaction hammer shall consist of a 5.5 lb. rammer having a 2 in. diameter face and a free drop of 12 inches.
5. Drying Equipment-A butane stove or other suitable device and a 10 in. frying pan or other suitable container for drying samples in the field.
6. Sand-Any clean, dry, free-flowing, uncemented sand having few, if any, particles passing the No. 200 or retained on the No. 10 sieves. The sand shall not have a variation in calibration greater than that indicated herein.
7. Volumetric Device-Any approved volumeter as recommended by the Central or District Testing Laboratory.
8. Compaction Block-Precast solid concrete house pier obtainable from the District Laboratory. Block must have a smooth, level surface on the top and bottom.

### Preparation

#### 1. Equipment

A. Field Laboratory - The Project Engineer shall require that small laboratory building as described in the standard specifications be furnished for each project and that the building is conveniently and properly located, being level and on a firm foundation.

B. Checking Scales - Scales or balances shall be checked at least once a day and adjusted if necessary. All scales shall be installed on a firm and level table or bench.

C. Sand - The sand is not to be re-used without proper screening and is to be rejected when considered dirty by the chief inspector.

D. Density Devices

1. Volumeter - The volumeter should be checked every day for air leaks in the valve and lines, and for water leaks in the balloon. The water should be clean and changed when necessary.
2. Sand Cone - The valve gate should be checked for proper and smooth functioning.
3. Cutting Mold - The use of the cutting mold should be discontinued except as directed by the laboratory.
4. Sand Can - The pouring of sand by hand is to be used only when absolutely necessary. When necessary, the sand shall be poured from a can equipped to assure a uniform rate of flow. The pouring of sand from a sack will not be permitted. (Note - A small kerosene can with pouring spout is recommended.)

E. Tools - The tools used should be cleaned immediately after using to avoid any errors in the tests. Hammers are not to be used in excavating the density hole, unless absolutely necessary and if so, should not be heavier than 8 ozs. and are to be used with extreme care.

#### 2. Sand Calibration

The sand must be checked at least once each day and additionally when necessary, such as when there is a change in humidity.

To determine the unit weight of the sand, use one of the following methods:

Method I
(Using sand cone and one point Proctor mold)

A. Place the Proctor mold on a firm, level, vibration free surface.

B. With valve closed, invert the sand cone and place it on top of the mold.

C. Open valve and let sand flow in the mold to a stop. Close valve. In no case is the mold, cone, or surrounding area to be disturbed or vibrated during this operation.

D. Carefully remove sand cone without disturbing mold.

E. Using a 12" steel straightedge, strike off excess sand with not more than two strokes, avoiding any vibration which will disturb the sand in the mold.

F. Clean excess sand from sides of mold, obtain total weight of sand and mold.

G. Subtract weight of mold from total to obtain weight of sand.

H. Repeat same procedure three times. Any difference between weights shall not be more than 0.02 lbs., otherwise the same procedure is to be repeated. Average the results and record on compaction work sheet as "A-Weight of Sand in Cylinder."

### Method II
### (Using sand cone and mold with welded plate)

A. Weigh and record weight of sand or of sand cone and jar filled approximately 3/4 full of sand.

B. With valve closed, invert sand cone and place on a smooth level surface.

C. Open valve and let sand flow in the cone to a stop. Close valve. In no case is the cone or surrounding area to be disturbed or vibrated during this operation.

D. Remove sand cone, weigh and record the weight of sand, or of sand cone, jar and sand. Determine the weight of the sand in the cone.

E. Repeat procedure three times. Any difference of the weights of sand in the cone shall not be more than 0.01 lbs., otherwise the same procedure is to be repeated. Average the results of the three tests and record. (Note - Sand used in these determinations, if kept clean, may be re-used without screening.)

F. Refill sand cone jar. Weigh and record weight of sand, or of sand cone and jar.

G. With valve closed, invert sand cone and center on the mold and welded upper plate.

H. Open valve and let sand flow in the cone to a stop. Close valve. In no case is the mold, cone or surrounding areas to be disturbed or vibrated during this operation.

I. Remove sand cone. Determine the weight of the sand in the mold and cone.

J. Repeat procedure three times. A difference of the weights of sand in the mold and cone shall not be more than 0.02 lbs., otherwise the same procedure is to be repeated. Average the results of the three tests, and record.

K. Subtract the results of "E," above, from that of "J," above, and record on the compaction work sheet as "A-Weight of Sand in Cylinder."

### Method III
### (Using can and one-point Proctor mold)

A. Place the Proctor mold on a firm, level, vibration-free surface.

B. Pour sand from previously weighed sand can into mold, being careful to follow the same pouring technique (i.e., height of pour, rate pour, etc.) as that which is to be used in the field test density hole. (Note - In the use of this test procedure, the operator that pours the sand for the sand calibration must also pour the sand in the excavated density test hole for the compaction test. If several operators are to be used, then each must calibrate his sand. In no event may one operator use the sand calibration of another operator.)

C. Finish the surface of the sand in the mold in the same manner as it will be finished in the field test density hole. (Note - Do not 'cone' sand in the mold until spillage occurs, then remove excess by cutting with straightedge. This does not duplicate compaction test pouring conditions.)

D. Clean any sand spillage from sides of mold, obtain total weight of sand and mold.

E. Subtract weight of mold from total to obtain weight of sand.

F. Repeat same procedure three times. Any difference between weights shall not be more than 0.02 lbs., otherwise the same procedure is to be repeated. Average results and record on compaction work sheet as "A - Weight of Sand in Cylinder."

## DETERMINATION OF IN-PLACE VOLUMES

### The Volumeter Method

After checking the volumeter for proper working conditions, intactness of rubber balloon and leaks, the following steps should be followed in the field for volume measurements:

A. Level and clean carefully an area approximately 18 in. x 18 in. Avoid leaving any loose material on the surface.

B. Place volumeter with base plate on prepared surface and mark exact location on the ground so that it can be replaced at same position later on (Note - If the volumeter seems to be unstable and/or not leveled, remove and repeat steps A and B.)

C. Hold volumeter firmly down against leveled surface, open valve and pump air into volumeter until desired pressure is reached or until water level stays constant ; avoid excess pressure which might cause breakage of balloon. Close valve. (Note - for those volumeters without pressure gages use only that pressure which will give a constant reading. Do not continue to pump air into the voluj eter. If there is a continuing "creep)' or lowering of water level, raise baloon, and check condition of density test area. This creep condition can indicate an expanding hole, leaking balloon or leaking volumeter. Any of these conditions invalidates the density test.)

D. Read carefully at water line and record as zero reading.

E. Open valve again and, reversing pump, raise balloon into cylinder before removing volumeter; shut valve.

F. After removing volumeter, begin excavating the hole within the opening of the base plate, without removing or disturbing base plate. Exercise care not to lose any material and do not disturb the sides of hole. The smoother and more vertical the sides of the hole, the more accurate the test will be. If a moisture content of in-place material is desired, care must be taken to insure no moisture loss. A 1 gal. can with tightly fitted lid may be used. Care should be exercised to keep can and sample out of direct sun during summer.

G. Make sure hole is deep enough to represent the height of the lift but not deep enough to penetrate underlying lift. Avoid a "square bottom" hole. The bottom of the hole should be rounded to fit the configuration of the balloon.

H. After removing all loose material from hole, place volumeter at exact location marked when taking zero reading as in "B" above. Holding volumeter firmly down, open valve and pump air until desired pressure is obtained or until the water line is at a constant reading. See Note in "C" above. Shut valve and take final reading at water line. Record reading. Open valve and, reversing pump, raise balloon into cylinder. Remove volumeter.

I. The difference between the final reading and the zero reading represents the volume of the hole in cubic feet.

**The Sand Cone Method**

After checking the sand cone for proper working conditions of the valve and cleanliness of the sand, the following steps should be followed in the field for volume measurements:

A. Level and clean carefully an area approximately 18 in. x 18 in. Avoid leaving any loose dirt on the surface.

B. Record weight of cone and sand as $W_A$; invert the sand cone on the prepared surface and mark exact location on the ground so that it can be replaced at same position later on. If sand cone seems to be unstable and/or not level, which might result in excess sand leaking between the cone and the ground, remove and repeat step A.

C. After setting sand cone firmly against surface, open valve and let sand flow to a stop. Shut valve, remove sand cone, weigh and record as $W_B$. Do not allow any disturbance or vibration during this step.

D. The difference between $W_A$ and $W_B$ represents the zero reading, $W_O$, in pounds

E. Remove all sand from cleaned surface carefully without disturbing prepared area and without leaving any loose sand on the ground. Do not replace this sand in the sand jar as it might contain foreign material; but save in another container for re-screening.

F. After removing the sand cone and sand, start excavating hole in the center of original position of sand cone, exercising care not to lose any material and without disturbing sides of hole. The smoother and more vertical the sides of the hole, the more accurate the test will be.

G. Make sure hole is deep enough to represent the height of the lift but not deep enough to penetrate underlying lift. Avoid a "square bottom" hole.

H. Refill sand and record weight of sand and cone as $W_C$. (Note - To avoid the carrying of a scale on the roadway to weigh the sand, several filled and preweighed sand cans may be used provided they are carefully marked.)

I. After removing all loose material from hole, place sand cone at exact same location marked when taking zero reading. Open valve and let sand flow to a stop. Again, do not allow any disturbance or vibration during this stop. Shut valve, remove sand cone, and record weight $W_D$. Remove sand and place in extra can for re-screening.

J. The difference between $W_C$ and $W_D$ represents the final weight $W_F$ of sand in hole and sand in cone.

K. Subtract $W_O$ from $W_F$ to obtain the weight $W_T$ of sand in pounds in the hole. This $W_T$ weight divided by the previously calibrated unit weight of sand represents the volume of the hole in cubic feet.

**The Sand Can Method**

This method is to be used only when absolutely necessary and when the previous two methods are not practicable, such as for sand blankets. In this event, the can should be furnished with a pouring device that will assure constant flow of sand and in no case shall the use of a sack as a pouring container be allowed. (Note - A small kerosene can with spout is recommended.) The following steps should be followed in the field for volume measurements.

A. Level and clean carefully an area approximately 18 in. x 18 in. Avoid leaving any loose dirt on the surface.

B. Start excavating hole in the center of the prepared surface, exercising care not to lose any material and without disturbing sides of hole. The smoother the sides of the hole, the more accurate the test will be.

C. Make sure hole is deep enough to represent the height of the lift but not too deep to penetrate underlying lift.

D. Record weight of sand and can as $W_C$. After removing all loose material from hole, start pouring sand in hole in the same manner, particularly rate of flow and height, as that used in calibration. Fill hole to such a height that there will not be a surplus of sand when checked with a straightedge. Do not over fill hole because in no case will the removal of sand from the hole be allowed. In such a case, abandon test and start over from Step A.

E. When necessary, use the straightedge to smooth sand in hole, with as few strokes as possible in order to avoid excessive disturbance in sand. The top of the sand-filled hole should be as close to the original appearance of the prepared surface as possible.

F. Weigh the remaining sand and can and record as $W_D$.

G. Subtract $W_D$ from $W_C$ to obtain the weight $W_T$ of sand in pounds in the hole. This weight, divided by the previously calibrated unit weight of sand, represents the volume of the hole in cubic feet. (Note - To avoid the carrying of a scale on the road to weigh the sand, preweighed sand and cans can be used, provided they are carefully marked.

**The Cutting Mold Method**

This method should not be used, except as directed by the laboratory.

## FIELD DENSITY TEST METHODS

### 1. Soils

The best methods of determining in-place volumes for this category are the volumeter and the sand cone; however, in soft materials, the use of the volumeter should be avoided as excessive pumping of the balloon might cause enlargement of the hole and decrease the apparent density of the material.

After completing the chosen procedure as outlined, the below listed is to be done at the field laboratory:

**A. Moisture Content**

After determining the total weight of the material taken from the hole, a representative sample of not less than 200 grs. is obtained for the moisture content determination. All weights are to be made to the nearest 0.1 gram. The sample can be heated in a frying pan over gas burner until completely dry. If additional material has been obtained for a one point Proctor from another hole adjacent to the density hole, or by enlarging the density hole after completion of the volume determination, it is preferable to dry the entire material from the density hole for a truer moisture content. An approved speedy moisture device may be used for moisture determinations in the field.

(Note - Moisture contents obtained prior to and during the compaction operation are to be run as above.)

**B. One Point Proctor**

A one point Proctor density should be run for each soil density test. Care must be taken to prevent moisture loss which might result in a point beyond the limits of the compaction control curve. The material is placed in the 1/30 cubic foot mold in 3 equal layers with each layer being compacted at 25 blows of the 5.5 lb. rammer falling 12 in, unless otherwise noted. The surface is then struck level with a straightedge and the net weight of the material, when divided by the volume of the mold, gives the unit weight of the material. The moisture content is then checked by obtaining a sample from the center of the mold and drying thoroughly. The one point Proctor shall always be run by placing the mold on a cast concrete unit generally obtainable from the District Testing Laboratory.

**C. Selecting Proper Curve**

After obtaining the one point Proctor density and the moisture content, the proper curve should be selected from those furnished by the laboratory. The point should fall within 1.5 lbs. cu. ft. at given moisture of any curve considered, and the closest one of that general soil type is to be used; however, supplemental data can be used for the selection of the correct curve, such as -

1. Arbitrary classification of the soil by the inspector who must be able to easily differentiate between a sandy soil and a clayey soil, or between a non-plastic material and a plastic one.

2. By referring to subgrade soil surveys and knowing the origin of the hauled material. After selecting the correct curve, the maximum dry density of this curve will be the value to which the in-place dry density is to be compared. Note - In case of inability to find correct curve, run a field density curve or request the Laboratory to run the curve on the material submitted as obtained from vicinity of density hole. Where the Family of Curves is to be used, refer to LDH Designation TR 415.

### D. Calculation of Work Sheets

All information for calculations is shown on work sheet.

## 2. Aggregates

The recommended density method for aggregate base, subbase, and shoulder courses is the sand cone method. After following the procedure outlined in the sand cone method, the following is to be done at the Field Laboratory.

### A. Moisture Content

The moisture content determination on shell and iron ore bases shall be run on the entire sample by drying it in a large pan over a gas burner. The moisture content determination of sand clay gravel courses is to be run on that portion passing the No. 4 sieve, using not less than 400 grams, and drying in a small pan on a gas burner.

Generally, moisture contents are not necessary on aggregate bases, except during the compaction processes. Therefore, it is recommended that the total material from the density test be dried, weighed, and recorded as "N", total dry weight of material in hole, with no moisture determination being made.

### B. One Point Proctor

Generally, one point Proctors are not necessary on aggregate courses. If it should be necessary to run a one point Proctor in the field, then the total material will be compacted in the applicable mold following LDH TR-418, Standard Method of Test for Moisture-Density Relationship, for that aggregate material being tested.

### C. Calculation of Work Sheet

Calculating the density results can be done by following the work form with the exception that there is no specific need for moisture content and there will be no correction for material retained on a No. 4 sieve for the theoretical density. The dry weight density of the total material (including material retained on a No. 4 sieve) will be furnished by the laboratory.

## 3. Stabilized Soils and Stabilized Aggregates

The recommended methods of determining in-place volumes of stabilized soils are the volumeter and the sand cone. The recommended density method for stabilized aggregates is the sand cone method.

### A. Moisture Content

Moisture tests are to be periodically run just prior to, or during the compaction operation to aid the contractor in exercising proper moisture control as the stabilized material is being compacted. A Speedy Moisture Tester is recommended for compaction control moisture determinations of soil cements. On stabilized aggregates, moisture content determinations will be made on representative samples of not less than 400 grams and dried over a gas burner or hot plate. All weights are to be made to the nearest 0.1 gram.

Moisture contents in sand clay gravels are to be run on that portion of the material passing the No. 4 sieve. Moisture contents of the stabilized iron ores and the various shell bases are to be run on the total material.

Moisture contents are not generally necessary after the completion of the compaction processes. Therefore, it is recommended that the total material from the density test be dried and recorded as "N", total dry weight of material in hole, without determining moisture contents.

### B. One Point Proctor

Material for the one point Proctor shall be taken after mixing prior to the beginning of compaction. For lime stabilized courses, the one point Proctor can be run at the time of the density test.

The one point Proctor is not necessary for stabilized shell bases. The laboratory will furnish the total material optimum moisture and the total material maximum dry weight density. Asphalt stabilized courses also will not require one point Proctors, as the laboratory will furnish the optimum moistures and maximum densities.

Stabilized soil one point Proctors are to be run on the stabilized material excluding the aggregates retained on the No. 4 sieve. The stabilized material is placed in the 1/30 cu. ft. mold in 3 equal layers with each layer being compacted at 25 blows of the 5.5 lb. rammer falling 12 in. For soil-lime base courses and sub-bases immediately under concrete pavement, 50 blows per layer is to be used. Stabilized aggregate one point Proctors are to be run on the total material, with it being placed in the 1/10 cubic foot mold in 3 equal layers with each layer being compacted at 75 blows using the standard 5.5 lb. rammer freely falling 12 in. The one point Proctor shall always be run by placing the mold on a cast concrete unit embedded on the ground for stability. A moisture content determination is to be made on each one point Proctor. Moisture contents are to be run as called for under "A", "Moisture Content" above.

Where maximum density is to be determined in the field on the moist soil-cement mixture at the time of compaction, then two separate one point Proctors are to be run at each proposed in-place density site. If these two separate Proctors are not reasonably close (within 3 lbs. per cubic foot of dry weight density), a third one point Proctor is to be run. An average of the several one point Proctor tests is to be used as the maximum density requirement of the in-place density test. (Note - It is recommended that the two closest one point Proctors shall be averaged with the extreme results being rejected.) As the one point Proctor determines the density that can be expected of the contractor, care must be taken to have the one point Proctor tests and the in-place density test in the same general roadway location. A change in gradation or physical characteristics of the stabilized material between the one point Proctor and the in-place density will invalidate all tests.

### C. Calculation of Work Sheet

The calculation of the results will be made as outlined in the forms. The 1 point Proctor average dry density shall be shown as "R", dry weight density from curve, except for shell bases in which case "R" will be given by the laboratory. All stabilized bases may use the bold print portion of the work sheets if desired, excepting those few soil cement bases which may have some material retained on the No. 4 sieve. In which case, the minus No. 4 sieve 1 point Proctor is to be corrected for the plus No. 4 sieve material using the theoretical density portion of the work sheet.

FORM 825-C

Louisiana Department of Highways

## DENSITY AND MOISTURE CONTENT WORK SHEET
## (SAND METHOD)

Date ____________________ Project No. ____________________

| | | | |
|---|---|---|---|
| | *Station Tested* | | |
| | *Area Hauled From* | | |
| | | | |
| A | WT. OF SAND IN CYLINDER | | |
| B | VOLUME OF CYLINDER | | |
| C=A/B | UNIT WEIGHT IN SAND | | |
| | | | |
| WA | ORIGINAL WEIGHT OF SAND | | |
| WB | FINAL WT. OF SAND | | |
| WO=WA-WB | WEIGHT OF SAND IN CONE | | |
| | | | |
| WC | ORIGINAL WT. OF SAND | | |
| WD | FINAL WT. OF SAND | | |
| WF=WC-WD | WT. OF SAND IN CONE & HOLE | | |
| | | | |
| WT=WF-WO | WT. OF SAND IN HOLE | | |
| V=WT/C | VOLUME OF HOLE | | |
| | | | |
| *D* | *Wet Wt. of Material in Hole* | | |
| *E* | *Wet Wt. of Plus #4 Material* | | |
| *F* | *Wet Wt. of Minus #4 Material* | | |
| | | | |
| *G* | *Wt. of Wet Soil* | | |
| *H* | *Wt. of Dry Soil* | | |
| *J=G-H* | *Wt. of Water* | | |
| *K=J/H* | *%Moisture Content* | | |
| | | | |
| *L=100F/100+K* | *Dry wt. of minus #4 Material* | | |
| *M* | *Dry wt. of plus #4 Material* | | |
| N=L+M | TOTAL DRY WT. OF MATERIAL IN HOLE | | |
| *P=** | *% by Vol. of Plus #4 Material* | | |
| R | DRY WT. DENSITY FROM CURVE | | |
| *S=*** | *Dry Theoretical Density* | | |
| T=N/V | DRY WT. DENSITY OF TEST | | |
| U=T/S | % COMPACTION | | |

*NOTE:* * $P = 100M/160\,V$  ** $S = \frac{160 \times P}{100} + \frac{(100-P) \times R}{100}$

| | | | | | | |
|---|---|---|---|---|---|---|
| | *Station Tested* | | | | | |
| *a* | *Wt. of Mold & Soil* | = | | | | |
| *b* | *Wt. of Mold* | = | | | | |
| *c=a-b* | *Wt. of Compacted Soil* | = | | | | |
| *d=c x 30* | *Wet wt. Density* | = | | | | |
| *e* | *Wt. of Wet Soil* | = | | | | |
| *f* | *Wt. of Dry Soil* | = | | | | |
| *g=e-f* | *Wt. of Water* | = | | | | |
| *h=100 g/f* | *%Moisture Content* | = | | | | |
| *m=100 d/100+h* | *Dry Wt. Density* | = | | | | |

*Send To:* *Assistant Chief Engineer (Construction)*
*Cc:* *District Engineer*
*Testing & Research Engineer*
*District Laboratory Engineer*

FORM 825 D

*Louisiana Department of Highways*

**DENSITY AND MOISTURE CONTENT WORK SHEET**
**(VOLUMETER METHOD)**

*Date* ____________________ *Project No.* ____________________

| | | | |
|---|---|---|---|
| | *Station Tested* | | |
| | *Area Hauled From* | | |
| | | | |
| A | VOLUMETER FINAL READING | | |
| B | VOLUMETER ZERO READING | | |
| V=A-B | VOLUME OF HOLE | | |
| | | | |
| *D* | *Wet wt. of Material in hole* | | |
| *E* | *Wet wt. of Plus #4 material* | | |
| *F* | *Wet wt. of Minus #4 material* | | |
| | | | |
| *G* | *Wt. of wet Soil* | | |
| *H* | *Wt. of Dry Soil* | | |
| *J=G-H* | *Wt. of Water* | | |
| *K=J/H* | *% Moisture Content* | | |
| | | | |
| *L=100 F/100+K* | *Dry Wt. of Minus #4 material* | | |
| *M* | *Dry wt. of Plus #4 material* | | |
| N=L+M | TOTAL DRY WT. OF MATERIAL IN HOLE | | |
| *P=** | *% by Vol. of Plus # 4 material* | | |
| R | DRY WT. DENSITY FROM CURVE | | |
| *S=*** | *Dry Theoretical Density* | | |
| T=N/V | DRY WT. DENSITY OF TEST | | |
| U=T/S | % COMPACTION | | |

*NOTE:* * $P = 100\,M/160\,V$ ** $S = \frac{160 \times P}{100} + \frac{(100-P) \times R}{100}$

| | | | | | | |
|---|---|---|---|---|---|---|
| | *Station Tested* | | | | | |
| *a* | *Wt. of Mold & Soil* | = | | | | |
| *b* | *Wt. of Mold* | = | | | | |
| *c=a-b* | *Wt. of Compacted Soil* | = | | | | |
| *d=cx30* | *Wet wt. Density* | = | | | | |
| *e* | *Wt. of Wet Soil* | = | | | | |
| *f* | *Wt. of Dry Soil* | = | | | | |
| *g=e-f* | *Wt. of Water* | = | | | | |
| *h=100 g/f* | *% Moisture Content* | = | | | | |
| *m=100 d/100+h* | *Dry Wt. Density* | = | | | | |

*Send To: Assistant Chief Engineer (Construction)*

*Cc: District Engineer*
*Testing & Research Engineer*
*District Labortory Engineer*

## PART II
## NUCLEAR METHOD

### Scope

This method of test is intended to determine the density and moisture content of soils, aggregates, stabilized soils, and stabilized aggregates in the natural state or after compaction by counting a proportional number of events occurring as a consequence of the interaction of a radioactive substance with the material to be tested.

### Apparatus

1. Scaler - Troxler Model 200B with a maximum counting rate of 25 kilocycles per second, equivalent to a resolution time of 40 microseconds, and associated electronic equipment.

2. Surface Moisture Gauge - Troxler Model 117 (w/source) and Reference Standard. Any Louisiana Department of Highways accepted standard method of determining moisture content may be used in lieu of the surface moisture gauge.

3. Surface Density Gauge - Troxler Model SC - 120 (w/source).

4. A 5/8 Inch Wood Auger With Extension - The auger cutting edges to be filed down so as to make an angle of approximately 45° with the horizontal.

5. Brace.

6. A hard steel spike 3/4 inches in diameter by 15 in. long.

7. Concrete block density reference standard with dimensions of approximately 15 inches x 6 inches x 12 inches of known density and painted with epoxy paint. This block should have a 3/4 inch hole centered 2 inches from one end of the block. This hole must be vertical.

8. A supply of dry fine sand to use as a sand blanket when needed.

9. Hand Tools - Such as 3 lb. hammer, shovel, etc., for leveling and smoothing the test area.

### Calibration

A factory calibration curve is included with each device. In the event that the factory curve does not produce a satisfactory correlation with field results, a new curve should be run using the sand cone as a standard. One point on the calibration curve should be checked at the beginning of each job and at any other time that a discrepancy is suspected.

### Procedure .

After selection of the test location, an area approximately 30 inches square is very carefully leveled and smoothed. If necessary, a very thin (1/8 inch or less) sand blanket is applied to reduce any large air voids.

The moisture device is connected to the scaler for a 3 minute warm up period (careful attention must be given to the manufacturer's instructions). A standard count is then run on the Polyethlene Block near the test location. A standard count shall consist of the sum of 3 one minute counts none of which shall deviate from the average by more than 1.5 times the square root of the average. It is important that the density gauge be at least 25 feet removed from the moisture device during this and subsequent operations. The moisture device is then firmly seated on the test location and 3 one minute counts obtained all of which must fall within the range of 1.5 times the square root of the average. The sum of the 3 one minute readings is divided by the standard count, as previously determined, to get the count ratio. The count ratio is plotted on the calibration chart and the water content in pounds per cubic foot is read on the ordinate.

The moisture device is then disconnected and removed 25 feet or more from the test location. The density device is connected to the scaler and allowed to warm up for 3 minutes. A standard count is run as described above either with the probe in self-standard position or preferably with the probe extended in to the concrete reference standard. A vertical hole is then drilled into the test location to the required depth using the modified auger (the steel spike is used where it is difficult or impossible to use the brace and bit). The density device is placed on the test location and the probe lowered to the desired depth.

The device is then pulled against the side of the hole and firmly seated. Three 1 minute readings are taken all of which must be within the range of 1.5 times the square root of the average. The sum of these readings is divided by the standard count to give count ratio which is plotted on the calibration chart

**Maximum Density and Optimum Moisture**

Curves for raw soils will be selected as outlined in Subsection C, Part I, Field Density Test Method for Soils. In the event soils with material retained on the number four screen are encountered in the field and curves representing only minus number four material are being used, a sample consisting of not less than five pounds of the material representing the density location shall be taken and a correction for the plus four material applied as shown on the attached work sheet.

Curves for aggregates will be furnished by the laboratory and will be total material curves (including material retained on the number four sieve).

Maximum density for stabilized soils and stabilized aggregates will be determined as outlined under the heading "ONE POINT PROCTOR" in Subsection B, Part I, Field Density Test Method for Stabilized Soils and Stabilized Aggregates.

**Calculations**

Calculation of the results will be made as outlined on the nuclear work sheet.

Dry density in pounds per cubic foot is obtained by subtracting the water content in pounds per cubic foot from the wet density in pounds per cubic foot. The percentage of moisture is obtained by dividing the pounds of moisture obtained by the moisture content device by the dry weight density obtained as outlined above.

Parts C, D, E, F, and H apply only where material retained on the number four screen is encountered in soil cement or raw soils. The dry theoretical density (H) includes a correction for the plus number four material in the soil.

STATE OF LOUISIANA FORM [illegible]
DEPARTMENT OF HIGHWAYS

DENSITY AND MOISTURE CONTENT WORK SHEET
([illegible])

Date ______________________

Project ______________________

Test Location ______________________

Battery Reading ________ Density High Voltage ________ Moisture High Voltage ________

Density Gain ______________________ Moisture Gain ______________________

| Moisture Standard | | Moisture Test | | | |
|---|---|---|---|---|---|
| 1 min. | ______ | 1 min. | ______ | % Standard | ______ |
| 2d min. | ______ | 2d min. | ______ | A = Lbs. $H_2O$/cu. ft. | ______ |
| 3d min. | ______ | 3d min. | ______ | | |
| Total 3 minutes | ______ | | ______ | | |

| Density Standard | | Density Test | | | |
|---|---|---|---|---|---|
| 1 min. | ______ | 1 min. | ______ | % Standard | ______ |
| 2d min. | ______ | 2d min. | ______ | B = Lbs. Wet Density | ______ |
| 3d min. | ______ | 3d min. | ______ | | |
| Total 3 minutes | ______ | | ______ | | |

| | | |
|---|---|---|
| C | Total Dry Wt. of Material | |
| D | Dry Wt. of Plus #4 Material | |
| E = C-D | Dry Wt. of Minus #4 Material | |
| F* | % by Vol. of Plus #4 Material | |
| G | Dry Wt. Density From Curve | |
| H** | Dry Theoretical Density | |
| J = B-A | Dry Wt. Density of Test | |
| K | % Compaction | |

[illegible] $\frac{[illegible]}{100\frac{C}{J}}$ **H = $\frac{[illegible]}{100}$ + $\frac{[illegible]}{100}$

| | Station Tested | | | | |
|---|---|---|---|---|---|
| a | Wt. of Mold & Soil | | | | |
| b | Wt. of Mold | | | | |
| c = a - b | Wt. of Compacted Soil | | | | |
| d = c x 30 | Wet Wt. Density | | | | |
| e | Wt. of Wet Soil | | | | |
| f | Wt. of Dry Soil | | | | |
| g = e - f | Wt. of Water | | | | |
| h = 100 g/f | % Moisture Content | | | | |
| m = 100 d/(100 + h) | Dry Wt. Density | | | | |

Send To: CHIEF CONSTRUCTION ENGINEER
Cc: DISTRICT ENGINEER
MATERIALS & TESTING ENGINEER
DISTRICT LABORATORY ENGINEER