

Research Report
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A FIELD AND LABORATORY COMPACTION
STUDY OF A MIXTURE OF RETORTED AND
RAW OIL SHALE FROM THE MEANS
PROJECT IN MONTGOMERY COUNTY

by

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INTRODUCTION

The oil shale retorting process will produce large volumes of spent shale and some raw oil shale that cannot be used in the retorting process. Consequently, it is anticipated that on-site disposal embankments will be constructed using these materials. A report by Drnevich, et al. (1) has recommended that site-specific compaction studies be done at the start up of a mining and disposal operation. Holtz (2) has reported on a detailed study of the compaction characteristics of a western oil shale that had been retorted by the Paraho vertical retort process.

This study was performed to develop background data on compaction characteristics of retorted material when mixed with a small percentage of raw shale that is generated as a result of the crushing process. The test site was located in Montgomery County, Kentucky, and the shales that were used were the Sunbury and Cleveland oil shales obtained in the same county.

Figure 1 shows the approximate dimensions of the test pad and the locations where most of the field testing was done.

METHODOLOGY

A pit measuring roughly 100 feet by 15 feet was excavated to a sandstone cap, approximately 2 feet below the surface. A shale pad was placed in three layers, with each layer approximately 1 foot thick prior to compaction. Material for the pad was obtained by mixing retorted shale

with 12 percent unprocessed shale (by weight). This unprocessed shale was a waste product of the crushing operation. The shale, before processing, was a mix of one part Sunbury and three parts Cleveland shales. Mixing was accomplished by first spreading the retorted shale. The raw shale was then placed in a thin layer over the retorted shale and the mixture was stirred with the loader bucket. The test area of each layer received an average of 80 passes of the loader during placement.

The first and second layers were compacted using a vibratory roller. After the first layer was in place, the roller made one pass on each side of the pad (see Figure 1) before any testing was done. A total of eight passes was made on each side with density tests performed and samples collected between passes. The same procedure was used for the second layer, with a total of seven passes per side.

On the third layer, only the tracked loader was used for compaction, with a single series of tests performed in the area over which the track passed. Tests were run and samples collected after placement of the layer and at intervals of 2, 4, 6, 8, and 12 passes of the loader during compaction. Care was taken to be sure the testing and sampling was done precisely in the area compacted by the track of the loader.

Equipment used for compaction and placement was a DYNAPAC CA-15 vibratory roller and a CATIPILLER 943 tracked loader. The roller was self propelled and produced 22,000 pounds of centrifugal force at 1,750 vibrations per minute.

The loader, which was used for placement on all three layers and for compaction on layer three, has an operating weight of 24,707 pounds and a ground contact area of 2,402 square inches.

FIELD TESTS

Initially, in-place density tests consisted of the sand cone method, rubber balloon method, and nuclear method. Due to the granular nature and large particle sizes of the material being used, the balloon method proved unsuitable and was omitted. To avoid end effects and vehicle speed variations, no tests were performed within 25 feet of either end of the pad. The number and location of tests are listed in Table 1.

The nuclear method gave inconsistent density results (Figure 2). That was probably due to hydrocarbons in the shale. However, the method was used throughout the study in an effort to determine the reliability of the nuclear gage when used with this material. Moisture content data obtained by the nuclear method yielded a poor correlation, when compared with the moisture content of samples collected in the field by conventional means (see Figure 3). In general, there was more scatter in the nuclear gage data, and the moisture content was generally higher than when measured by use of the sand cone.

The sand cone method proved more useful and was used throughout as the primary check for density. Test results (Figure 4) indicated an optimum of five passes with the

vibratory roller or six passes with the tracked loader. Field densities, after five passes of the vibratory roller, on Lifts 1 and 2, were 98.0 and 99.9 percent, respectively, of maximum dry density of laboratory compacted specimens. The tracked loader (after six passes) provided a field density of 94.6 percent of the maximum laboratory dry density. The density after each pass, expressed as a percentage of maximum laboratory dry density, is listed in Table 2. It should be noted that the density is not as consistent on the third (top) lift as on the first two lifts. This was probably due to disturbance of the top few inches of material by the treads on the tracked loader.

In an effort to determine the degree of compaction in relation to depth, sand cone density tests were performed at depths of 5 inches and 8 inches on the second lift. Results of those tests indicated a reduction in density as depth increased. Dry densities (pounds per cubic foot) of 103.2 at the surface, 99.5 at a depth of five inches, and 97.1 at a depth of 8 inches were recorded. Although not shown, those results were supported by data obtained with the nuclear gage. At 8 inches, the compacted density was only 93 percent of the maximum laboratory dry density. Drnevich, et al. (1) indicated the possibility of placing this material in 20- to 23-inch lifts and compacting with a heavy tracked crawler. However, results of these tests indicated that this recommendation may be somewhat optimistic and that it may be necessary to maintain uncompacted layer thickness somewhere

between 12 and 20 inches, even with heavier compaction equipment than was used in this study. This difference in layer thickness supported the recommendation of Drnevich, et al. for site specific compaction testing.

LABORATORY TESTS

Samples were collected from each layer of the pad for a series of laboratory tests consisting of moisture content measurements, moisture-density relationships, particle-size analysis, and slake-durability. Test results were compared to material reported by Robl and Koppenaal (3) and identified as "Retorted Blend".

Moisture content data of samples returned to the laboratory ranged from 3.2 percent to 11.6 percent, with an average of 4.5 percent, as compared to a range of 2.6 percent to 8.1 percent and an average of 5.7 percent obtained by use of the nuclear gage (Figure 3).

A particle-size analysis of the material, using method ASTM D 422-63 (4), indicated a significantly higher percentage of fines, in either layer, than was present in the retorted blend previously investigated by Robl and Koppenaal (3). The particle-size distributions shown in Figures 5, 6, and 7 indicated a higher percentage of fines in Lift 2. This was reflected in a higher density as seen in Figures 2 and 4.

The moisture-density relationship of the material was determined in accordance with procedures outlined in ASTM D 698, method C (4). Materials from all three layers were

combined to obtain a sample for testing. The optimum dry density of 104.7 pounds per cubic foot (Figure 8) was significantly higher than the 86.4 pounds per cubic foot for the retorted blend reported by Robl and Koppenaal (3) this was probably due to the high percentage of fines. Optimum moistures of the two materials were nearly identical at 11.3 percent and 11.6 percent.

To evaluate weathering characteristics of the material, slake durability tests were performed. Two types of tests were used, one being KM 64-513-79 published in "Kentucky Methods for Materials Testing and Control" (5). In that method the sample is oven dried prior to testing and is cycled twice (10-minute cycles) with oven drying between cycles. The second method was proposed by Hopkins and Gilpin (6). That method utilizes air dried material with one cycle (60 minutes) and tends to produce lower indices than KM 64-513-79.

Each slake-durability sample contained approximately 30 particles with each particle averaging about 17 grams in weight. Two tests of each type were performed with indices of 98.9 for both tests performed by the KM 64-513-79 (5) method and indices of 97.0 and 97.3 by the other. Those values compare well with an index of 99.4 reported by Robl and Koppenaal (3) and indicate a competent material.

CONCLUSIONS

The mixture of retorted and raw oil shale, when compacted in 1-foot lifts, reached a high relative density with

a relatively low compactive effort. However, checks made at various depths in a lift indicated a drop in density toward the bottom of the lift, making lifts of compacted depths greater than one foot questionable, particularly when using lightweight compaction equipment. The addition of water does not appear to be necessary for good compaction but should probably be used to minimize dust pollution.

Compaction with the vibratory roller attained the best results with 98 percent of maximum laboratory dry density on Lift 1 and 100 percent on Lift 2 at an optimum of five passes on both lifts. However, the tracked loader provided good results (95 percent maximum laboratory dry density with an optimum of six passes) and may be more practical for placement of large quantities. Indices obtained by the slake-durability tests of 97 percent by the Hopkins and Gilpin method and 98 percent by the KM-64-513-79 method indicated a material of high weathering resistance.

REFERENCES

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2. Holtz, W. G., "Compaction and Related Properties of Retorted Oil Shale," Journal of Geotechnical Engineering, American Society of Civil Engineers, Volume 109, Number 10, October 1983.
3. Robl, T. L., and Koppenaar, D. W., "The Chemical and Engineering Properties of Eastern Oil Shale," Institute for Mining and Minerals Research, University of Kentucky, 1982.
4. American Society for Testing and Materials. Annual Book of ASTM Standards, Natural Building Stones, Soil and Rock. Part 19, 1983
5. "Kentucky Methods for Materials Testing and Control," Division of Materials, Kentucky Department of Highways. KM 64-513-79, 1979
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TABLE 1. Number of Field Density Tests Performed

SIDE	LIFT	NUMBER OF PASSES	NUCLEAR GAGE	SAND CONE
NORTH	1	8	6	8
	2	7	4	7
	3	--	--	--
SOUTH	1	8	7	8
	2	7	4	7
	3	12	6	6

TABLE 2. Percent of Maximum Laboratory Dry Density as a Function of Number of Passes for Field Tests

PERCENT OF MAXIMUM LABORATORY DRY DENSITY			
NUMBER OF PASSES *	LIFT 1	LIFT 2	LIFT 3
0	-----	-----	90.6
1	86.5	92.0	-----
2	86.0	77.2	88.2
3	91.7	92.9	-----
4	94.2	97.3	90.2
5	98.0	99.9	-----
6	96.2	94.1	94.6
7	94.5	98.6	-----
8	89.9	-----	92.4
12	-----	-----	87.4

* NUMBER OF PASSES AFTER PLACEMENT AND MIXING

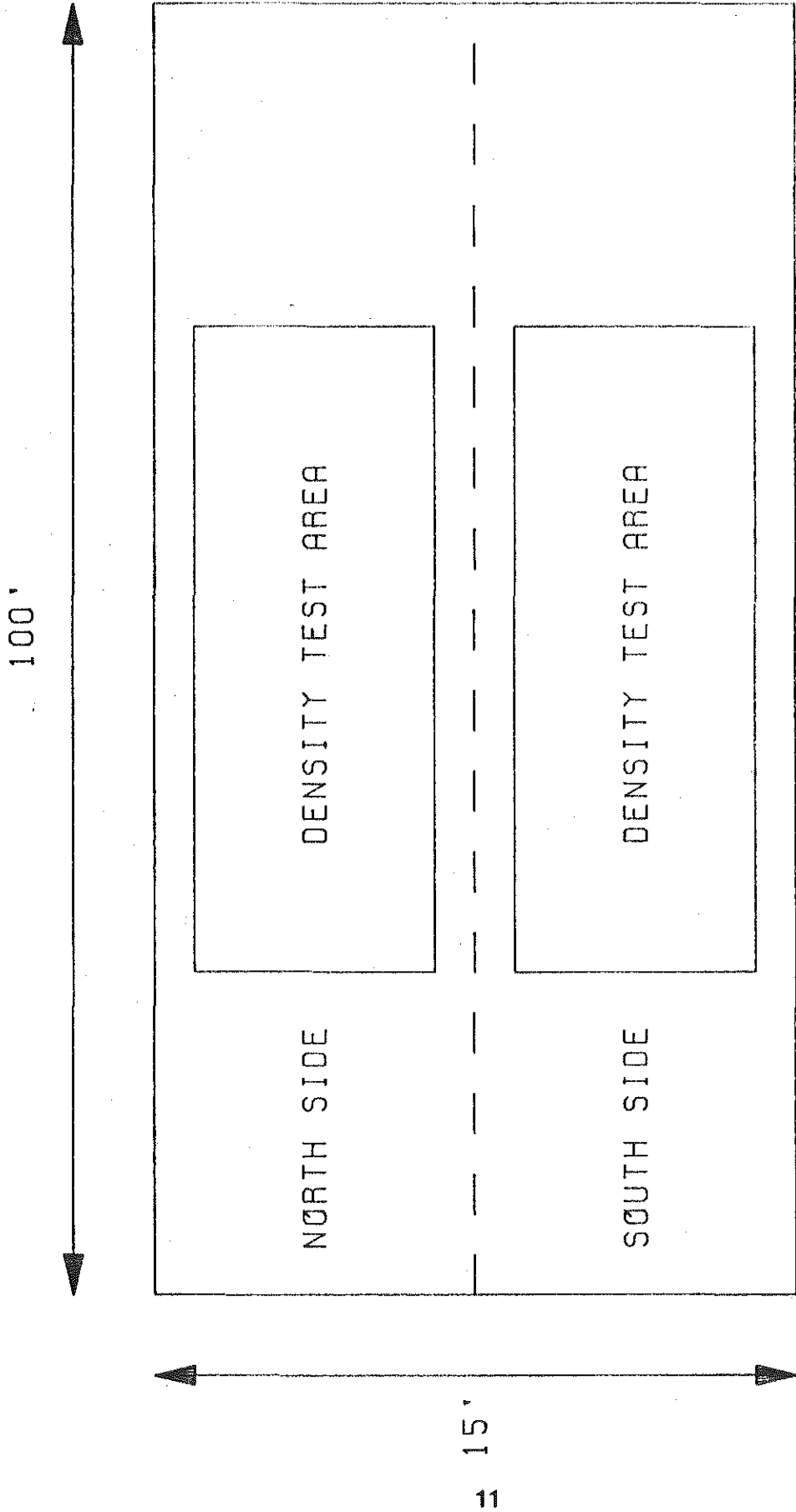
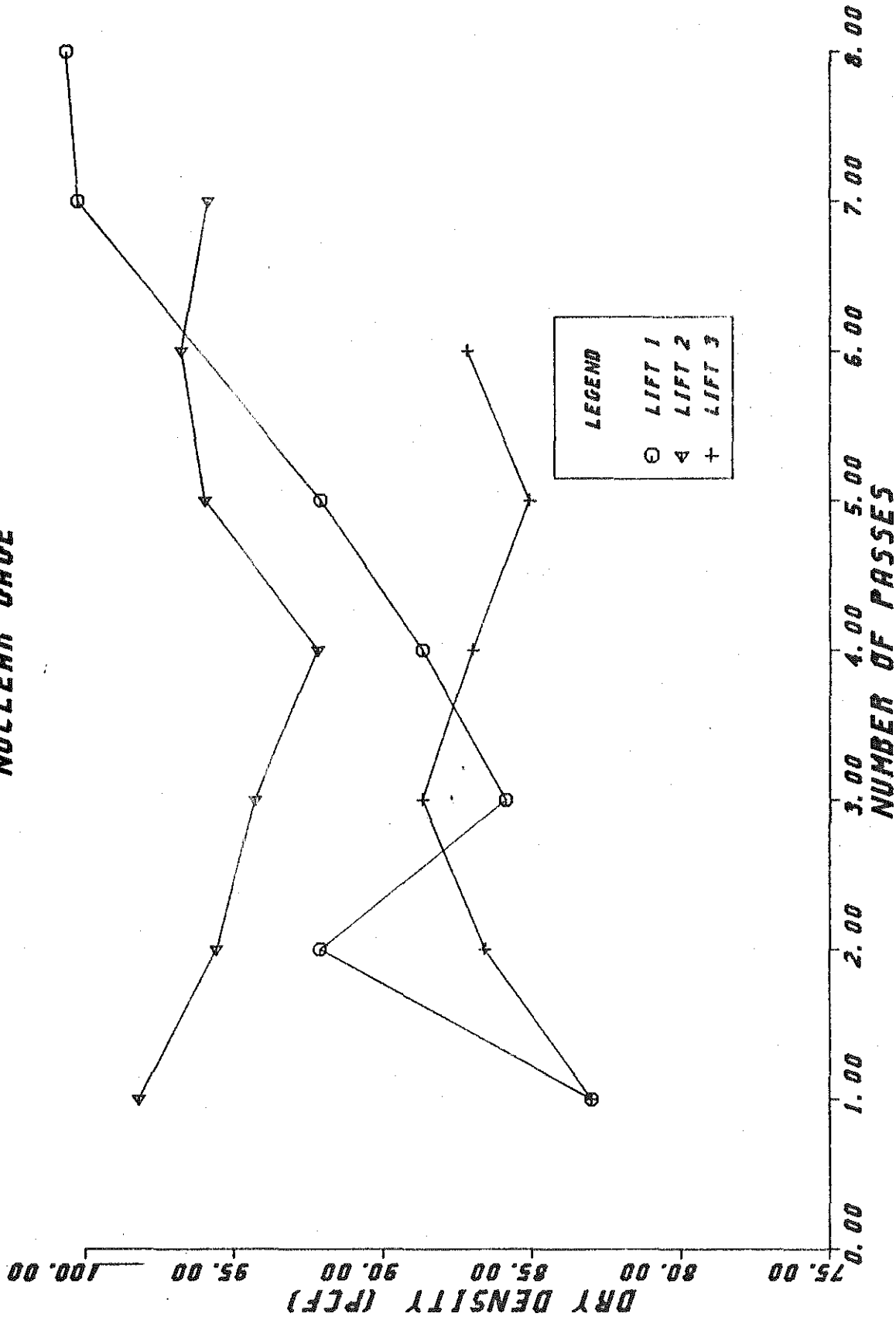


FIGURE 1. Plan View of Test Pad.

NUCLEAR GAGE



**FIGURE 2. Dry Density as a Function of Number of Passes-
Nuclear Density.**

LEGEND	
⊖	LIFT 1 N
△	LIFT 1 S
+	LIFT 2 N
×	LIFT 2 S
←	LIFT 3 S

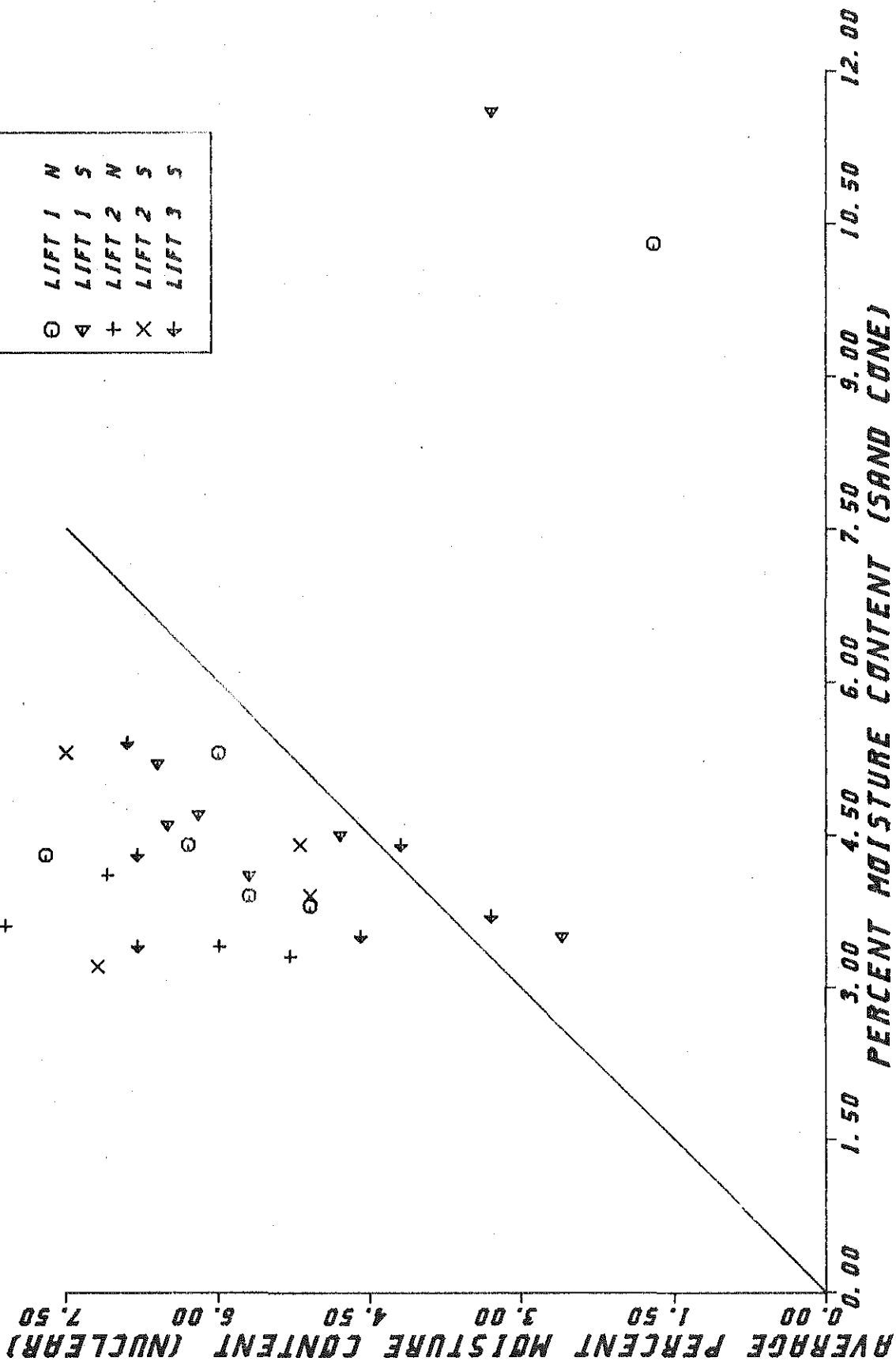


FIGURE 3. Moisture Content from Nuclear Gage versus Moisture Content from Sand Cone.

SAND CONE

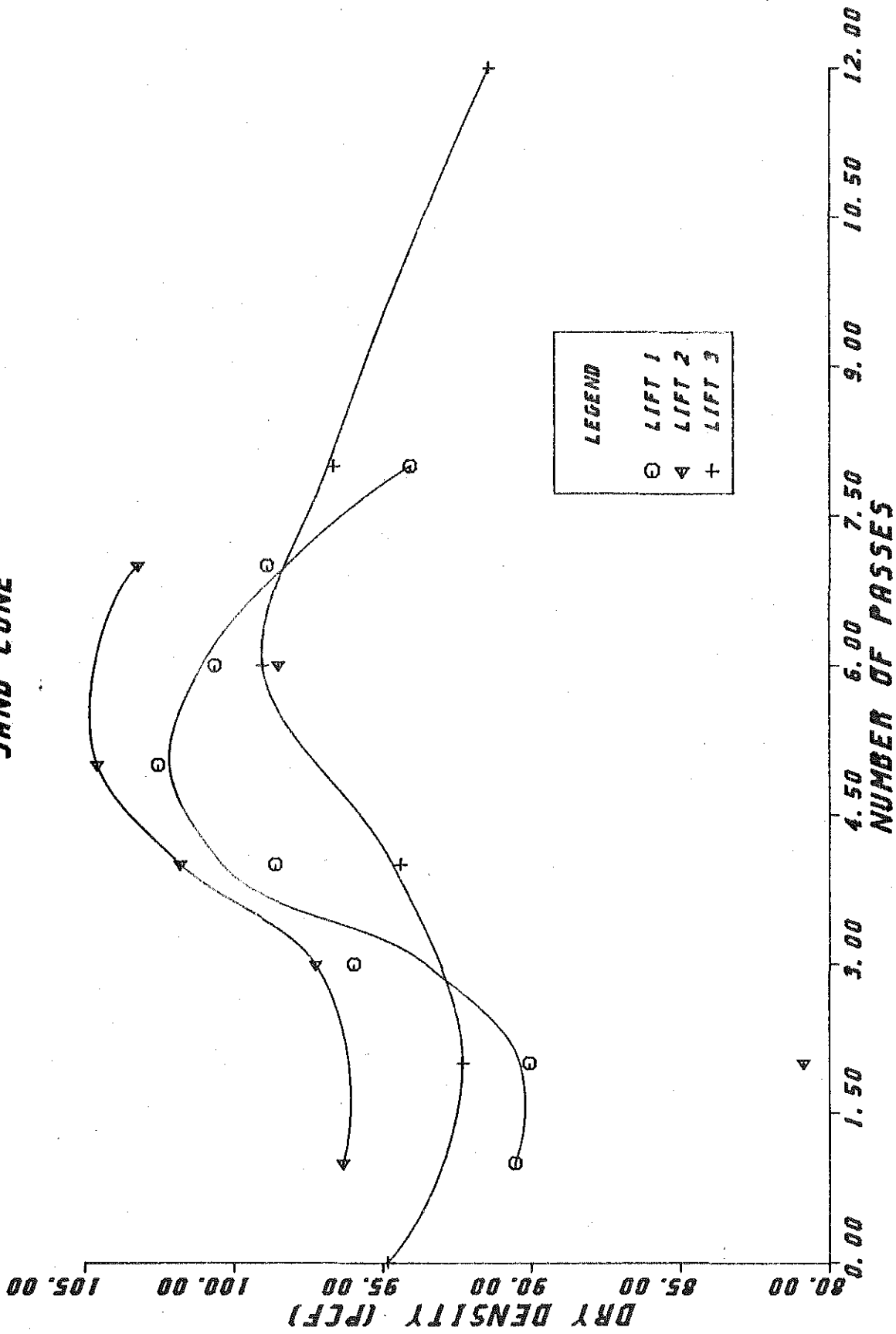
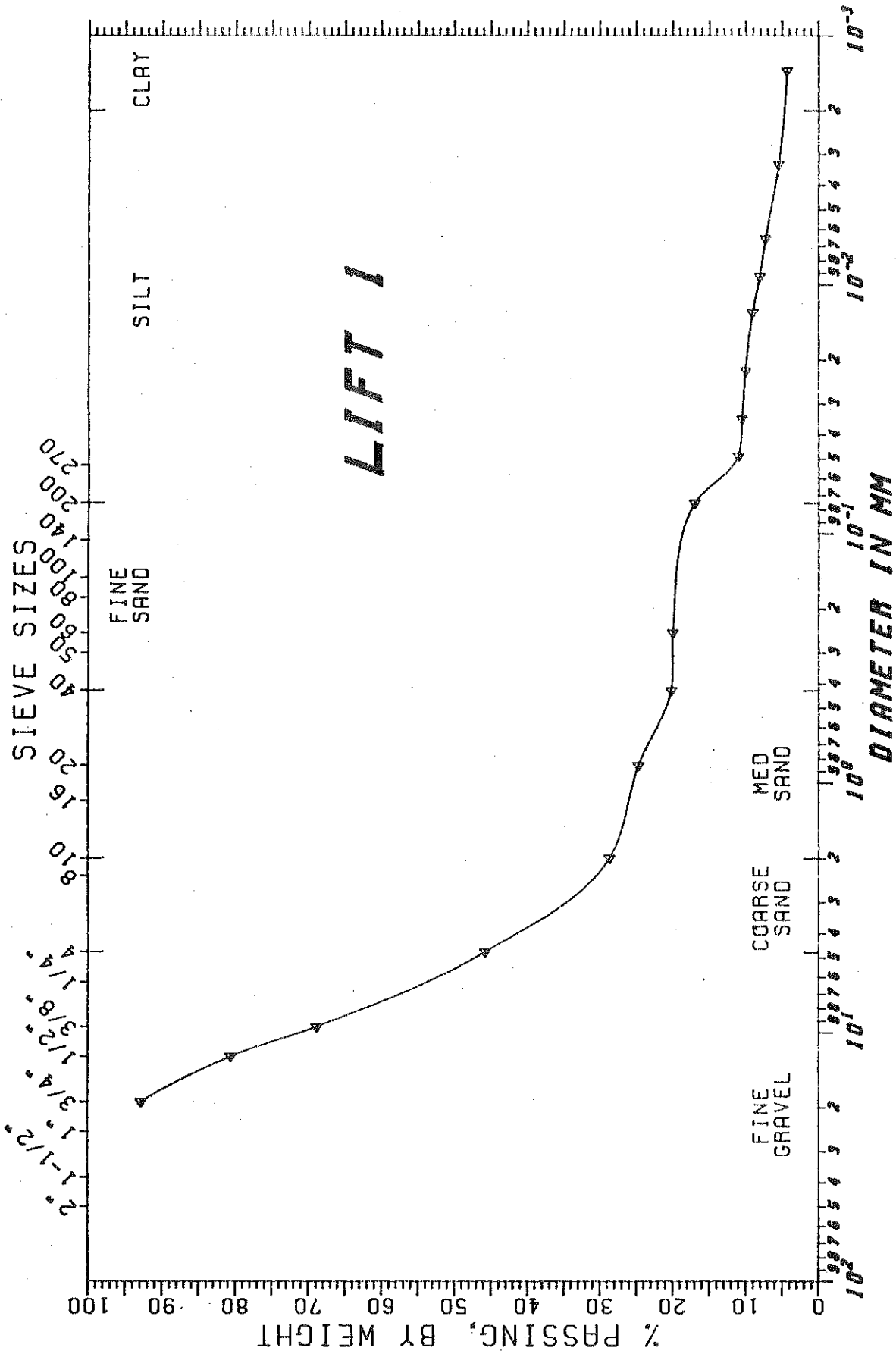
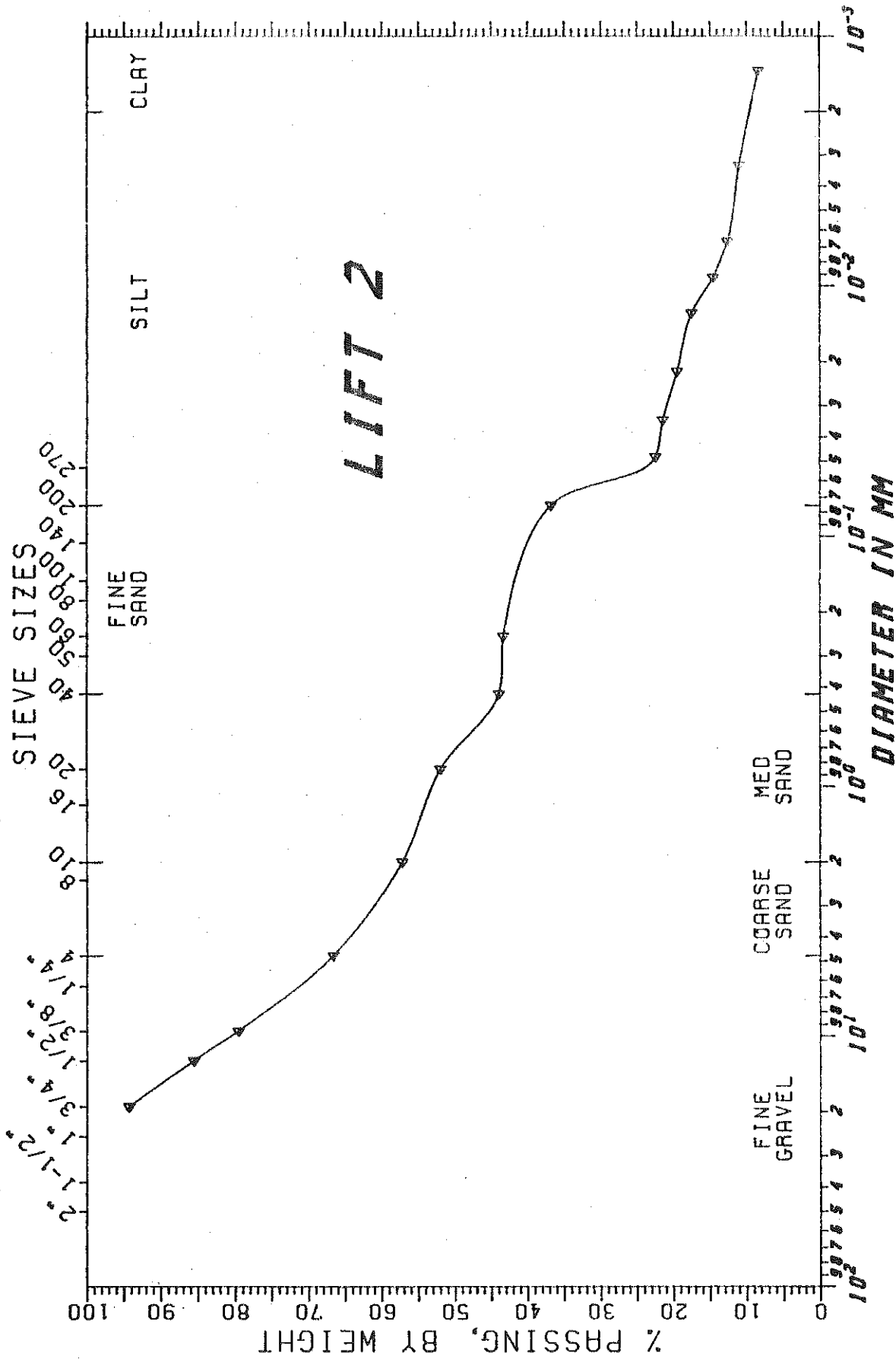


FIGURE 4. Dry Density as a Function of Number of Passes - Sand Cone.



**FIGURE 5. Particle-Size Distribution for Lift 1.
(After Field Compaction)**



**FIGURE 6. Particle-Size Distribution for Lift 2.
(After Field Compaction)**

COMBINED SOLE

OPTIMUM MOISTURE CONTENT (%) = 11.6

OPTIMUM DRY DENSITY = 104.7 PCF

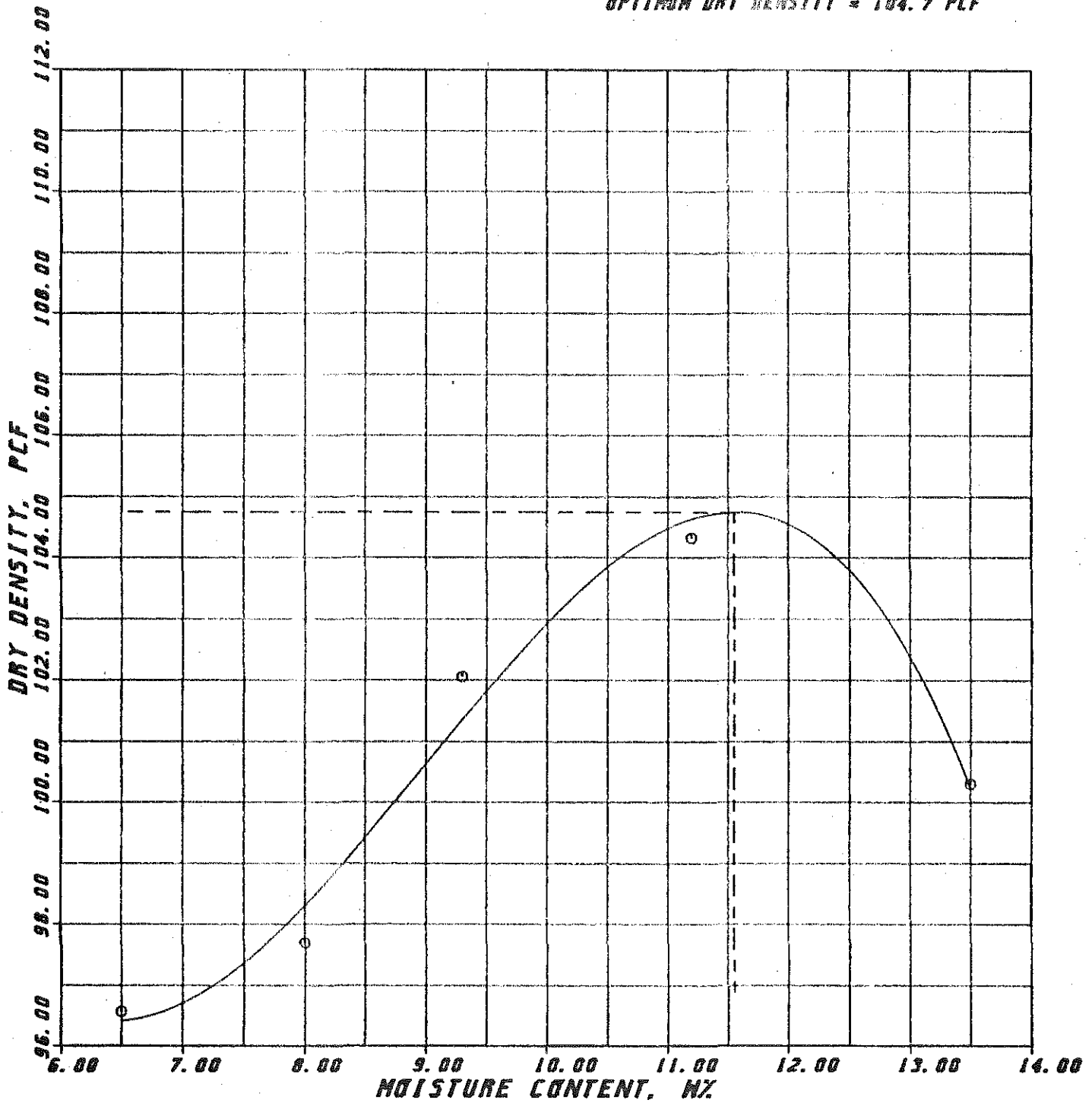


FIGURE 8. Moisture-Density Curve