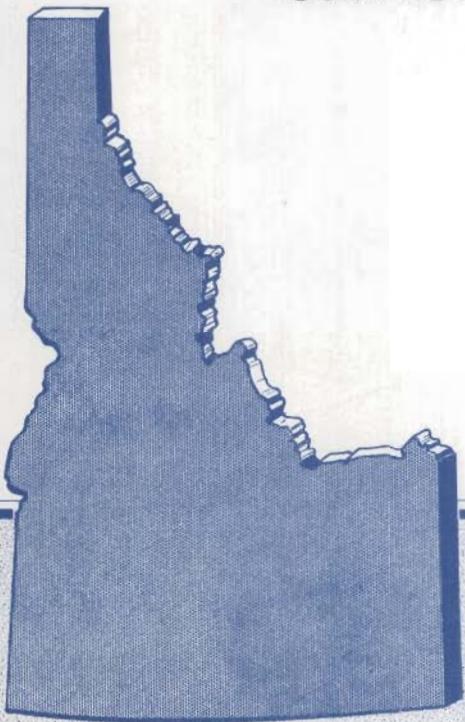


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DETERMINATION OF THE EFFECT OF ENVIRONMENTAL TEMPERATURES ON COMPACTION OF ASPHALTIC PAVEMENTS

IDH - RPOS4



RESEARCH PROJECT NO. 54

STATE OF IDAHO DEPARTMENT OF HIGHWAYS

DETERMINATION OF THE EFFECT OF
ENVIRONMENTAL TEMPERATURES ON COMPACTION
OF ASPHALTIC PAVEMENTS

Research Project No. 54

By

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July 1970

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Boise, Idaho

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TABLE OF CONTENTS

	<u>PAGE</u>
Acknowledgments	i
List of Figures	iii
List of Tables	iii
Introduction	1
Conclusions	2
Recommendations	4
Discussion	5
Bibliography	18
Appendix A - Temperature-Time, Rolling Pattern & Density-Air Voids .	
Appendix B - Density-Air Voids Tables	
Appensix C - Nuclear Density & Core Density vs. Distance from Pavement Edge	

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>	<u>Page</u>
1	Typical Installation of Thermocouples for Recording Pavement Temperature During Construction	6
2	Rate of Cooling for Thick vs. Thin Lifts Typical of Warm Weather Paving	8
3	Rate of Cooling - Thick vs. Thin Lifts Typical of Cool Paving Weather	9
4	Comparison of Cooling Rates of T_2 in 0.4' Plantmix Base	10
5	Comparison of Cooling Rates of T_2 in 0.2' Plantmix Surfacing	11
6	Ranges in % Air Voids at 2-foot Intervals Across Pavement	14

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
1	Temperature at Completion of Rolling	12
2	Test Results of 0.4' ATB	15
3	Test Results of 0.2' Top Course	16

INTRODUCTION

Research has shown that air voids, density and asphalt film thickness are important factors in determining the durability of asphalt pavement. Reduction of air voids to a minimum (3-5%) is essential to satisfactory performance. The temperature of the mixture, air and base temperature, wind velocity and solar radiation influences the rate of cooling of a mixture placed on a base. Pavement courses of different thicknesses also materially affect the cooling rate. Idaho Specifications require plantmix surfacing to be placed at temperatures above 40°F. In several instances this temperature has been raised to 50°F. for 0.2' courses and 60°F. for thinner courses. One objective of this study was to determine the realistic ambient temperatures for laydown of asphaltic concrete mixtures.

During the fall of 1969 a field study was conducted to learn the effect of ambient temperatures and conditions on the cooling rate for 0.2' and 0.4' plant-mix courses during the laydown and rolling phases of construction. Thermo couples were placed in the top, middle and bottom of the pavement course. Temperatures were recorded at frequent intervals beginning with laydown and continuing until all rolling had been completed. Air and base temperatures, cloud cover and wind conditions were recorded.

During the rolling operation the location of each passage of a roller was made recording the distance to the pavement edge and the time since the laydown of the mixture.

Densities of the finished pavement after final rolling were determined by both nuclear methods and by cores taken at two foot intervals across the lane. Air void measurements were made on each core. A correlation between the roller coverages, temperatures during rolling and the densities and air voids obtained from tests on the cores was made of the finished pavement.

CONCLUSIONS

Results from this study show that:

1. The temperature drop within the middle of the 0.2' course of plantmix is much more rapid than in a 0.4' course. The time for the mixture to cool 100°F. after laydown ranged from 28 to 42 minutes for the 0.2' course and from one hour twenty minutes to two hours twenty four minutes for the 0.4' course.
2. The temperatures at the middle of the course were consistently 5-15 degrees hotter than at the top. The temperature at the bottom of the course cooled very quickly (less than 10 minutes) as much as 100°F. and then leveled off at this temperature, until the whole mat had cooled to this same temperature.
3. Breakdown and intermediate rolling was completed above the specified temperature of 140°F. and in some instances much higher. The 0.4' courses were rolled at temperatures well above those for the 0.2' courses averaging at mid-point of the course 13°F. higher on breakdown, 30°F. higher on intermediate and 26°F. higher on final rolling, at time of completion. This would indicate that rolling of the 0.2' course could have been accomplished at an earlier time when temperatures were higher.
4. Rolling coverage of the pavement was generally well above specification minimums, except for the outside 2-3 feet of the lay, where only 20-50 percent of the required coverages were obtained. The final rolling gave a uniform consistent pattern, whereas breakdown and intermediate rolling tended to concentrate in the center of the lane.
5. The 0.4' course pavement averaged higher densities and lower air voids than the 0.2' course. The 0.4' course air voids ranged between 2 and 5.5 percent with an average of about 4 percent, whereas the 0.2' course

ranged from 5 to 8.5 percent and averaged about 7 percent.

6. The density of the top, middle and bottom portion of 0.4' course cores correlates with the temperatures actually measured at these levels.

The middle third of the core consistently gave 0.5 to 1.5 percent less air voids than the top third and 1.5 to 3.0 less than the bottom third of the core.

7. The 0.2' core was cut into two portions and did not show any difference in density or voids. Temperatures were measured at top, middle and bottom and it is believed that had the core been cut into three portions a correlation with temperature would have resulted.

DISCUSSION

PROCEDURE

The data desired for this project was obtained using the following procedures:

Thermocouples were installed in the top, middle and bottom of the plantmix course. The thermocouples and recorders to which they were attached are shown in Figure 1. The temperatures were recorded at T_1 for the top thermocouple, T_2 for the middle thermocouple and T_3 the bottom thermocouple. These temperatures were recorded at intervals from the time of laydown until final rolling was completed.

Air temperatures and weather conditions were recorded at the beginning and end of the laydown and rolling operation. Changes in wind and cloud cover conditions were observed and recorded throughout each test. Mixture temperature in the paver and base temperature was recorded before laydown.

The beginning and ending time of each roller phase were recorded. The distance from the edge of pavement to the roller was measured to the nearest half foot for each roller pass so that the total amount and location of rolling effort could be plotted. Weight, type and tire pressure were recorded for each roller.

After completion of final rolling, nuclear density tests were made at 2 foot intervals across the pavement at each test section. Later, 4 inch diameter cores were taken at the same location as the nuclear density tests. These 0.4' cores were also tested for density and air voids in three sections corresponding to the top, middle and bottom thermocouples. The 0.2' cores, because of their thinner overall dimension, were tested in two sections for density and air voids by cutting them in half at mid-height.

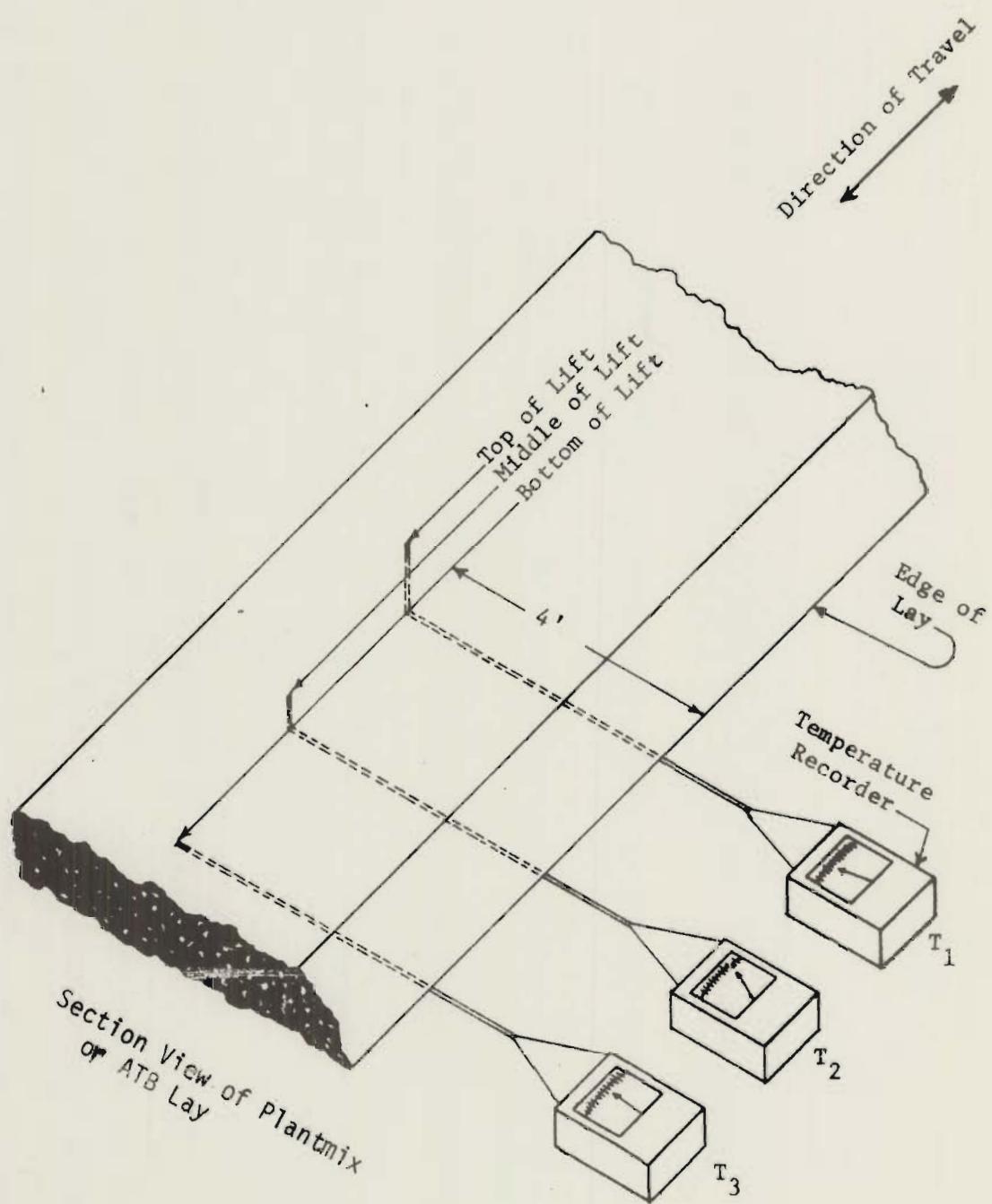


Figure 1 - Typical Installation of Thermocouples for Recording Pavement Temperature During Construction

PLANTMIX TEMPERATURE COOLING RATE

The temperature cooling rate measured by each thermocouple is shown in Appendix A. These figures show other information such as air and base temperatures, weather observations and beginning and ending of each rolling operation.

These figures show that there was a rapid loss of heat throughout the full depth of lay for a short time after laydown. The temperature change thereafter was more gradual. The temperature change at the bottom of the course was much more rapid than at the top.

These charts show that the 0.2' course cools more rapidly than the 0.4' course. Figures 2 and 3 show this relationship. Figure 2 shows that it took the thick mat about 105 minutes to cool to 200°F. but the thin lift cooled to this temperature in about 33 minutes. Figure 3 shows this same type of relationship but uses data obtained while paving during cooler weather. It is obvious that the thicker lift allows a greater time interval to complete the rolling.

Figures 4 and 5 have been prepared to illustrate this temperature loss at mid-point in the pavement course, eliminating the laydown temperature as a factor by plotting the temperature drop against time. These figures show that the range in time for the temperature to cool 100°F. ranges from 28 to 42 minutes for the 0.2' course and from 80 to 144 minutes for the 0.4' course.

These data suggest that to complete rolling above a specified temperature the 0.4' course would allow about twice the time as a 0.2' course, all other factors being equal. It also means that if rolling is done at the same time interval after laydown the 0.4' course is rolled at a much higher temperature than the 0.2' course.

The similarity in the shape of the temperature curves within Figures 4 and 5 indicates that higher laydown temperature can also extend rolling time if a specified temperature for completion of rolling is used. It is apparent that

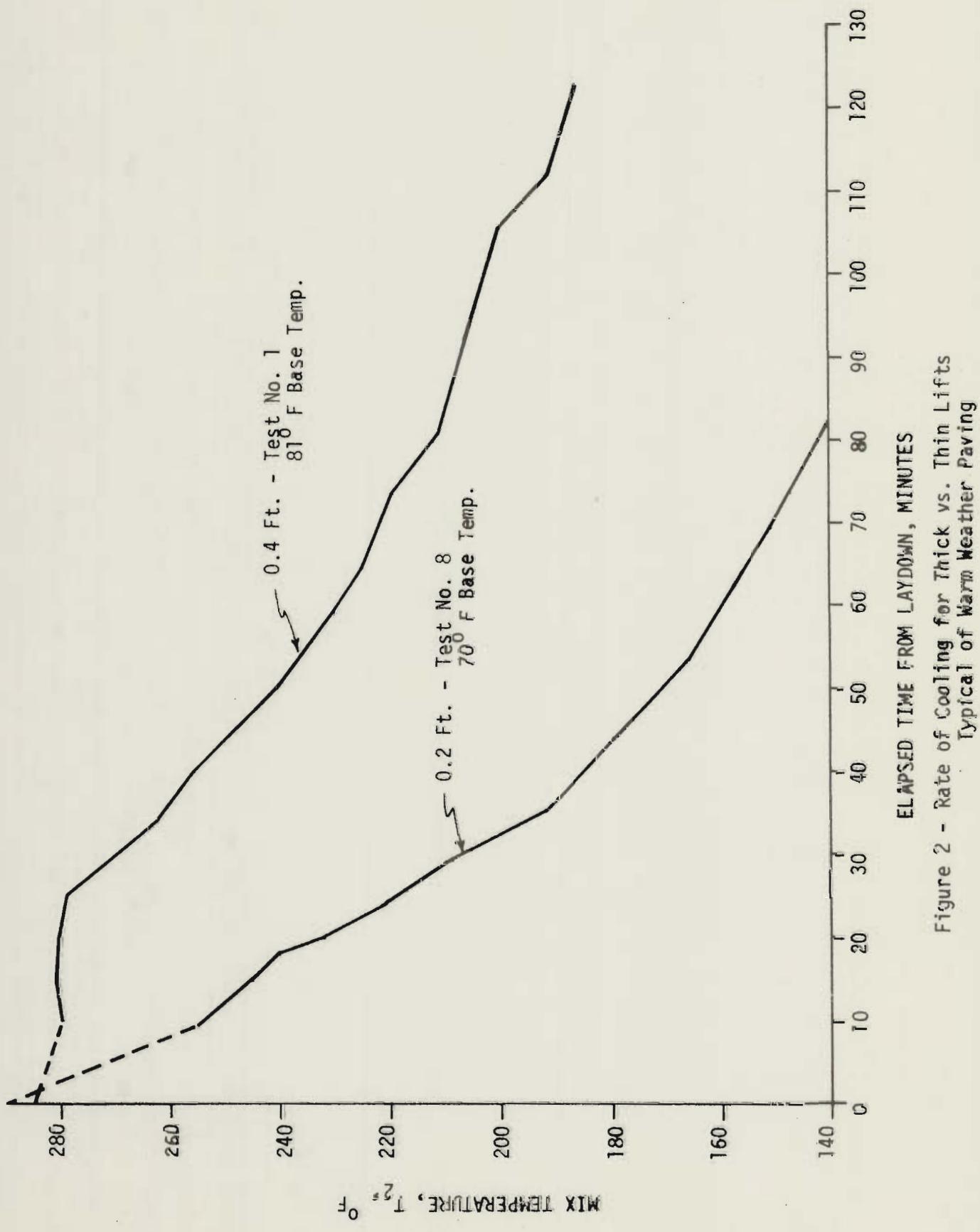


Figure 2 - Rate of Cooling for Thick vs. Thin Lifts
Typical of Warm Weather Paving

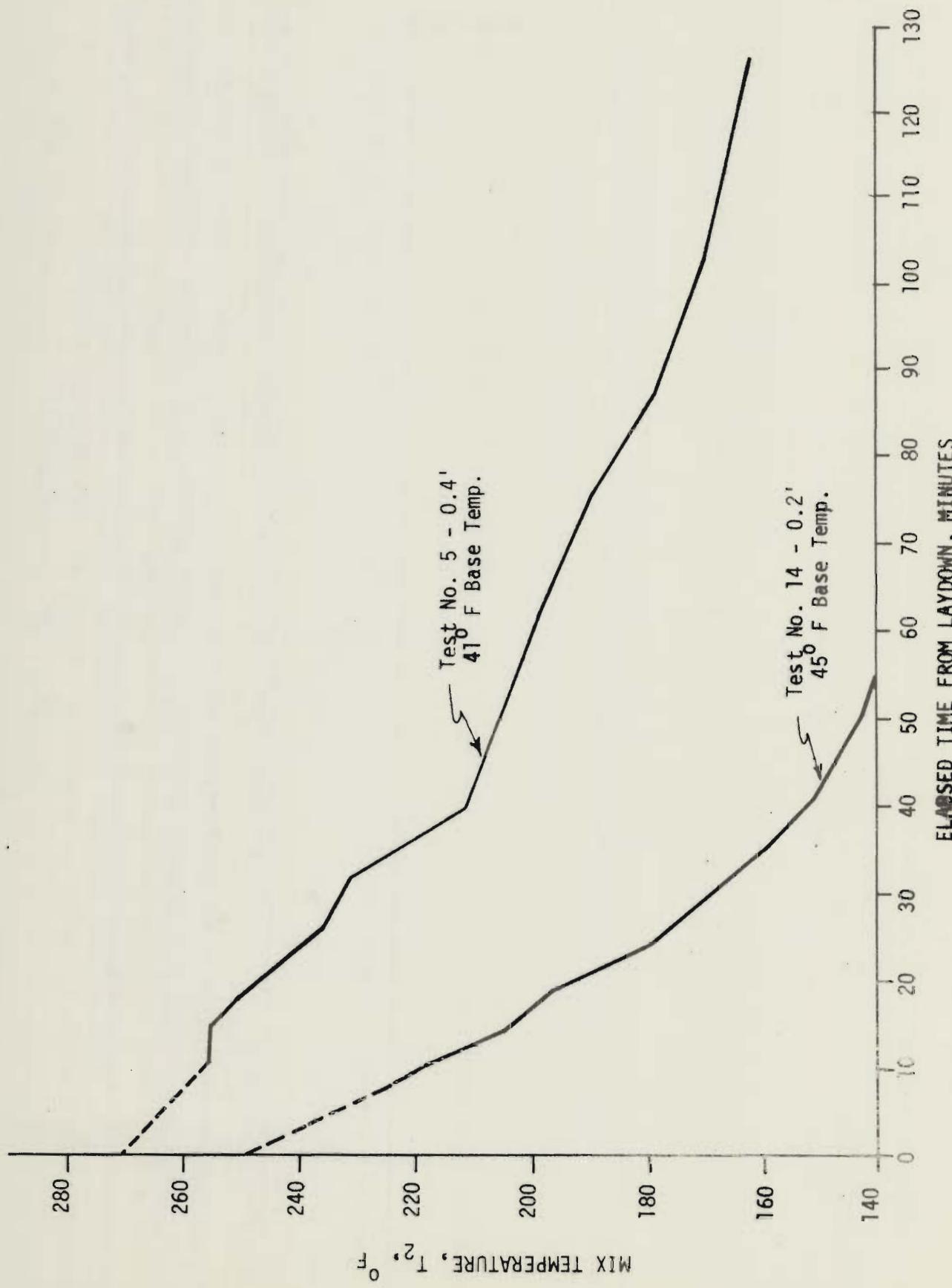


Figure 3 - Rate of Cooling - Thick vs. Thin Lifts
Typical of Cool Paving Weather

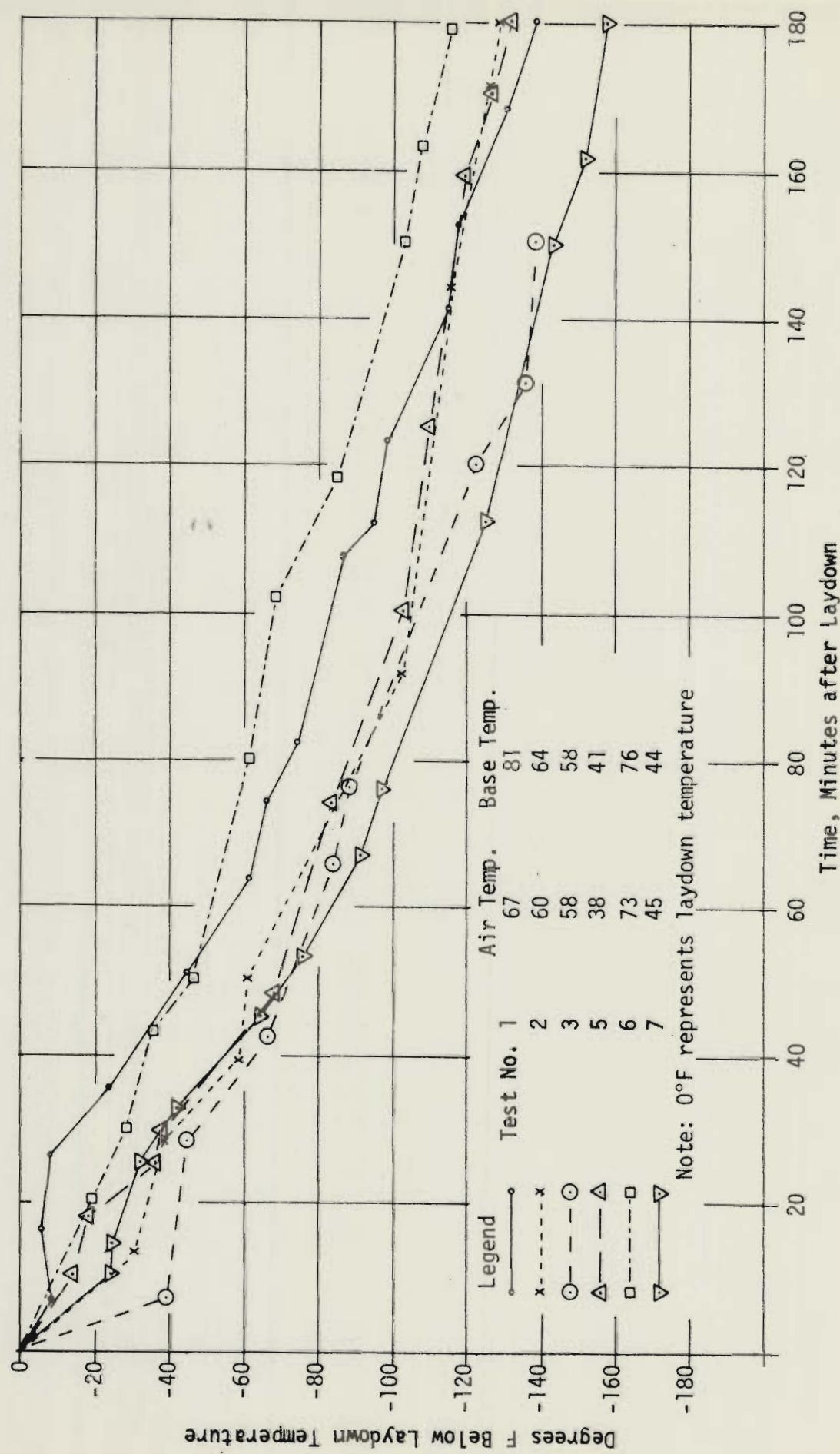


Figure 4 - Comparison of Cooling Rates of T₂ in 0.4' Plantmix Base

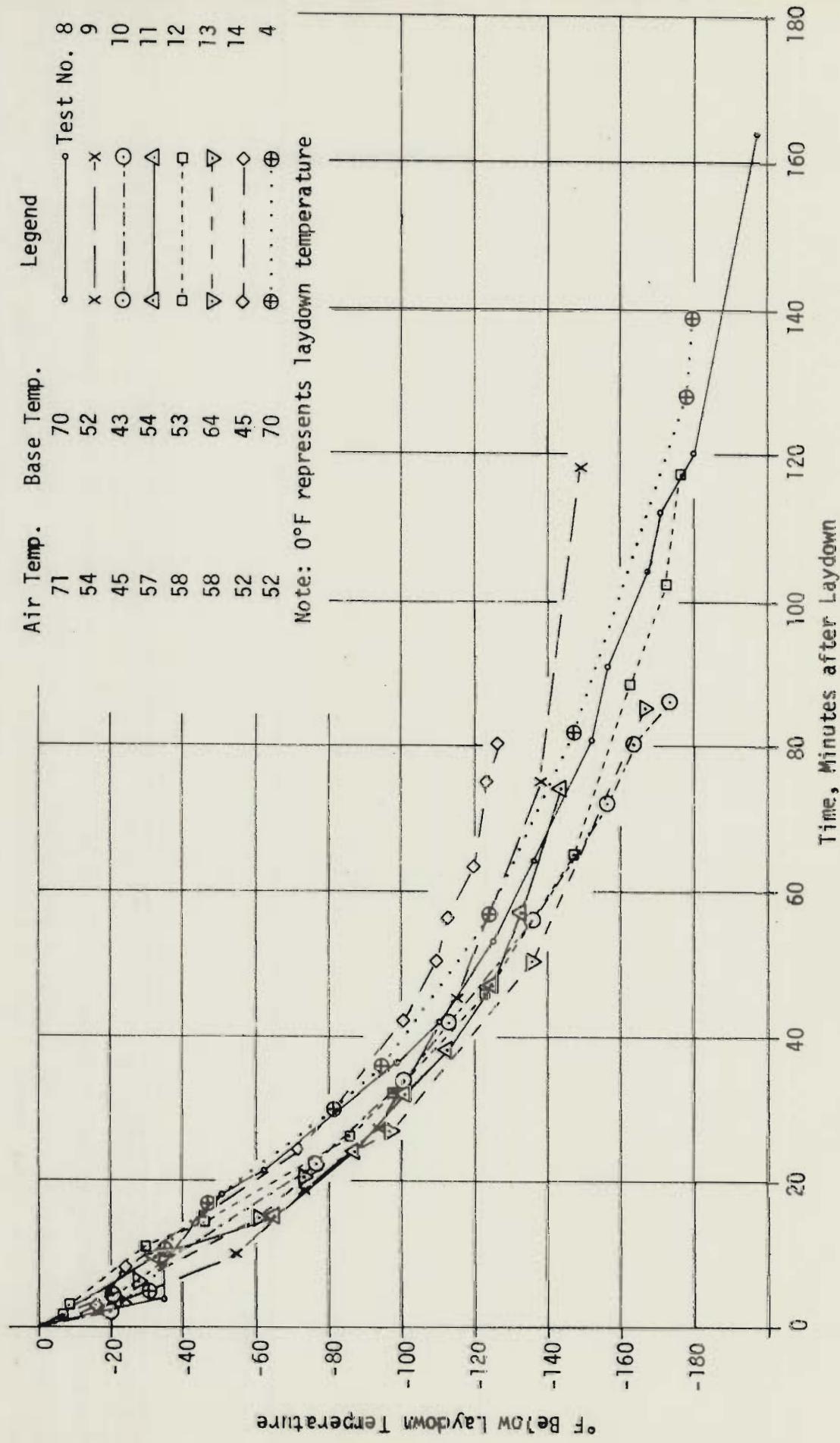


Figure 5 - Comparison of Cooling Rates of T2 in 0.2' Plantmix Surfacing

should laydown temperature be increased the effect is to raise the entire curve and thereby extend the time needed.

ROLLING PATTERN

The temperature-time figures also show the beginning and ending time for each type of rolling. A study of Appendix A figures illustrates that the completion of breakdown and intermediate rolling were accomplished above specification temperature minimums and in some instances as much as 50-60°F. above this minimum.

Even though this is the general pattern and the 0.2' course was rolled much earlier than the 0.4' course, the temperatures on completion of each type of rolling were higher for the 0.4' course than for the 0.2' course. Table 1 shows this relationship.

TABLE 1
TEMPERATURE AT COMPLETION OF ROLLING

	0.4' Course		0.2' Course	
	Range	Ave.	Range	Ave.
Breakdown	200 - 255°F.	221°F.	170 - 235°F.	208°F.
Intermediate	160 - 220°F.	195°F.	133 - 185°F.	165°F.
Finish	133 - 153°F.	144°F.	100 - 135°F.	118°F.

The time and distance from the pavement edge for each passage of a roller at the test section were recorded. Appendix A shows the rolling pattern across the roadway diagrammatically for each roller and also the accumulated roller passes for each 1/2 ft. increment of pavement width.

It is apparent that the largest number of passes occurred well within the lane and that the outer two feet were deficient in total coverages when compared to the remainder of the lane.

A careful study of these figures indicates that the breakdown and intermediate rolling patterns were not uniform across the lane whereas the finish rolling pattern appears more consistently uniform. It was observed that where the largest number of breakdown and intermediate passes occurred finish rolling could be accomplished at higher temperatures without "checking or hair line cracking".

DENSITY AND AIR VOIDS

Density and air void data for each test are given in Appendix B. These results are also shown graphically on the accumulated roller pattern chart of Appendix A. It is apparent that the highest densities and least air voids were obtained with the 0.4' course. Figure 6 gives the range of values and average for each location across the lane. Generally the 0.4' course has from 2.0 to 5.5 percent air voids with an average of about 4.0 percent. The 0.2' course has from 5 to 8.5 percent with an average of about 7 percent.

The 0.4' cores were cut into three sections corresponding to the top, middle and bottom thermocouples. Data given in Appendix B show a positive relationship between the density-air voids and temperature shown to exist during rolling, as illustrated in Appendix A. The temperature at the center of the lay is highest and densities are correspondingly high and air voids low. The bottom of the course consistently has the coldest temperatures and the lowest density and highest air voids. The top of the course lies in between as would be expected.

The 0.2' cores were considered too thin to be cut into three sections and were cut in half. No definite correlation was obtained. It is believed a similar relationship to the 0.4' course exists, although perhaps not so pronounced.

A relationship between density-air voids and temperatures at the time of rolling is indicated in Tables 2 and 3. These tables show that when the temperature at the middle of the course is lower before rolling is started the density

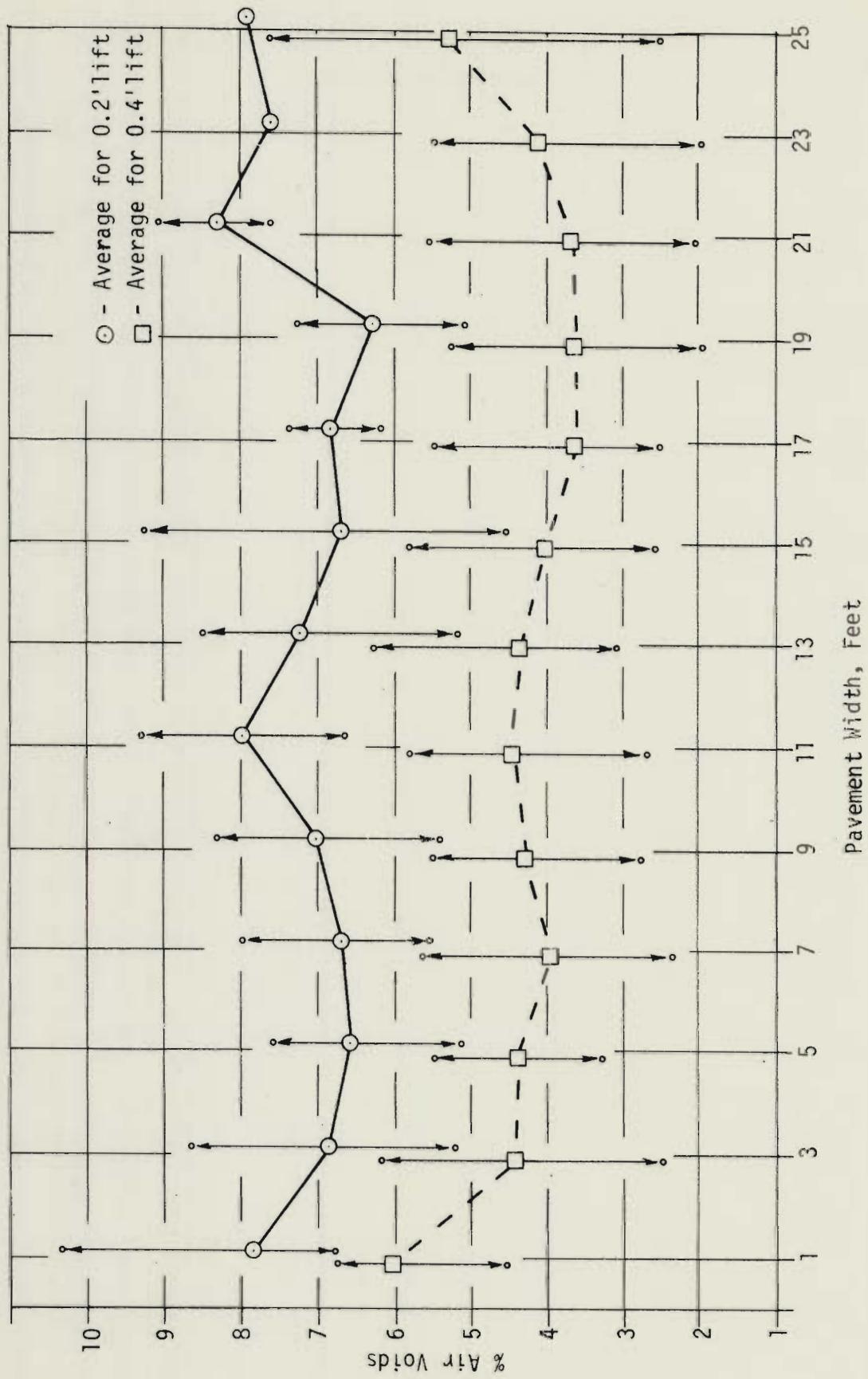


Figure 6 - Ranges in % Air Voids at 2-foot Intervals Across Pavement

TABLE 2
TEST RESULTS OF 0.4 FT. ATB

TEST No.	AVERAGE OF 2 AND 3 CORE DENSITY, PCF	AIR Voids, %	BASE TEMP., °F	PAVER TEMP., °F	TIME TO BEGIN BREAKDOWN ROLLING, MINUTES	TEMP. OF T ₂ WITH 1ST ROLLER PASS, °F	BREAKDOWN ROLLER PASSES	INTERM. ROLLER PASSES
1	141.6	2.9	81	285	21	278	4	7
7	140.6	4.0	44	295 +	25	262	5	2
2	140.2	4.2	64	275	17	243	4	7
3	139.2	5.0	58	275	27	230	3	10
6	139.1	4.6	76	255	27	226	5	4
5	137.8	5.8	41	270	22-34 *	240-222 *	5	5

* Only 1 Breakdown Roller Pass to Start With;
8 passes were made before Roller returned to the 3 to 5' Area.

TABLE 3
TEST RESULTS OF 0.2 FT. TOP COURSE

TEST No.	AVERAGE OF 2 AND 3 CORE DENSITY, PCF	BASE TEMP., °F	PAVER TEMP., °F	TIME TO BEGIN BREAKDOWN ROLLING, MINUTES	TEMP. OF T ₂ WITH 1ST ROLLER PASS OF ROLLING, °F	TEMP. OF T ₂ AT END OF BREAKDOWN ROLLING, °F	BREAKDOWN ROLLER PASSES	INTERM. ROLLER PASSES
11	137.2	5.2	54	275	9	241	222	6
8	136.5	6.2	70	290	17	241	220	2
10	135.8	6.7	43	300	10	265	252	6
12	135.4	6.7	53	285	4	272	255	8
14	134.8	6.9	45	250	3-10 *	233-226 *	205	6
13	134.8	7.3	64	278	6	251	234	6
9	133.6	8.2	52	245	26	184	176	2
								4

* One pass at three minutes;
10 passes were made before roller returned to 3-5' area.

is also reduced and air voids increased.

It is evident that rolling should be accomplished while the mixture is hot to reduce the voids to a minimum. The roller pattern should be uniform and the number of coverages adequate to obtain the desired density and air void range. Insufficient coverages or rolling at too low a temperature can cause the pavement to have lower densities and greater air voids than desirable.

NUCLEAR DENSITY MEASUREMENTS

Nuclear density data is given in Appendix C. The densities obtained from cores are plotted against the nuclear values. The nuclear values give the same trend to the density as the core value.

Nuclear values are only relative since it would have required calibration of the nuclear gage to determine actual densities. Relative density measurements can be used to control compaction. The Virginia Department of Highways requires a test rolling pattern to determine when no further densification is being obtained. This pattern is used to provide a standard density. All other sections of pavement on the roadway are required to be compacted to a minimum of 98 percent of this standard, using the nuclear density tests.

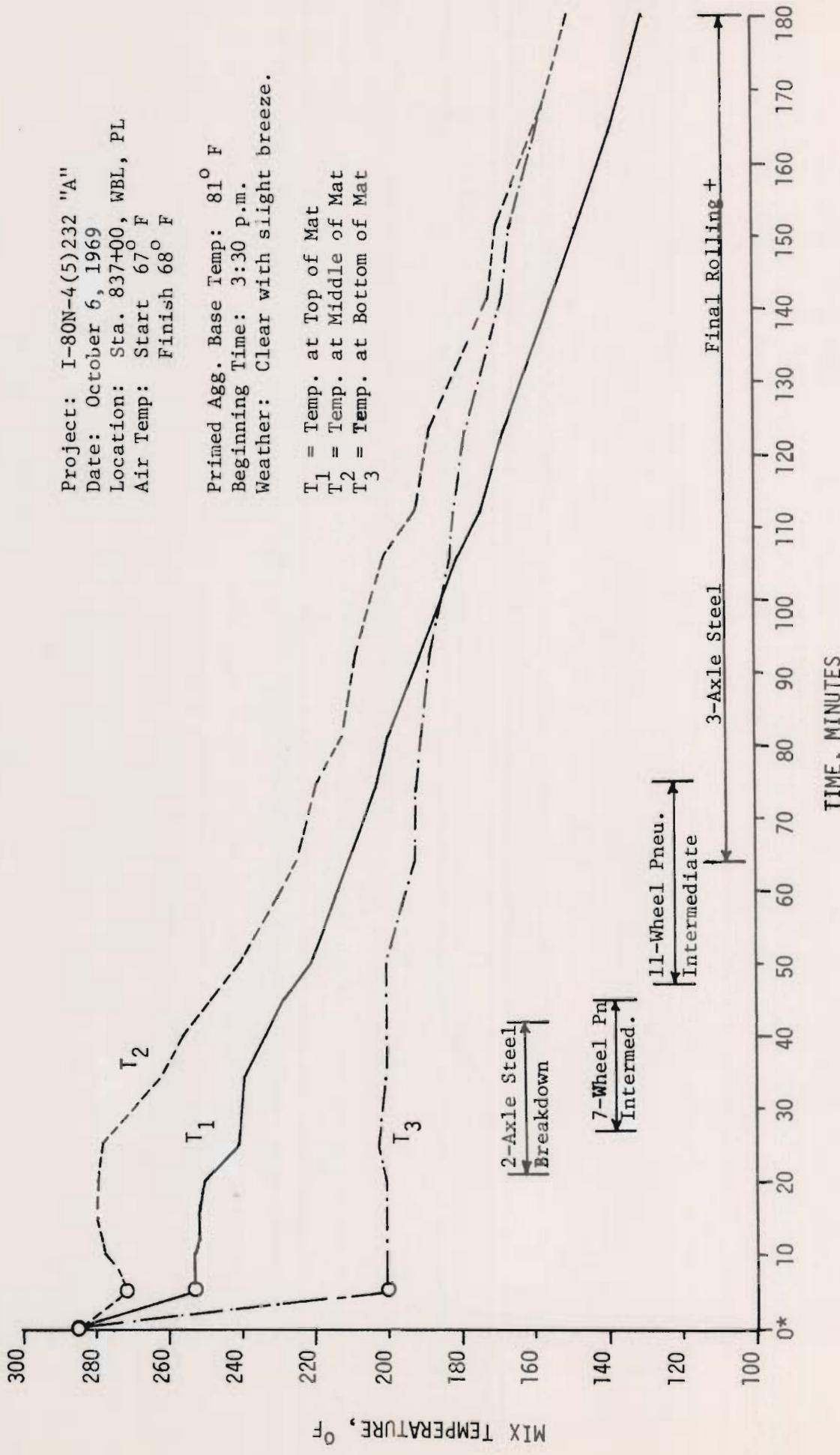
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1. Vaughn Marker, Wm. J. Jari, Chas S. Hughes and R. V. LeClerc; "Symposium on Compaction of Asphalt Concrete", Proceedings of the Association of Asphalt Paving Technologists, Vol. 36, February 1967.
2. J. S. Corlew and P. F. Dickson; "Methods for Calculating Temperature Profiles of Hot-Mix Asphalt Concrete as Related to the Construction of Asphalt Pavements", Proceedings of the Association of Asphalt Paving Technologists, Vol. 37, February 1968.
3. J. York Welborn; "Asphalt Hardening-Fact and Fallacy", Public Roads, Vol. 35, No. 12, February 1970.
4. H. J. Fromm; "The Compaction of Asphalt Concrete on the Road", Proceedings of the Association of Asphalt Paving Technologists, Vol. 33, February 1964.

APPENDIX A

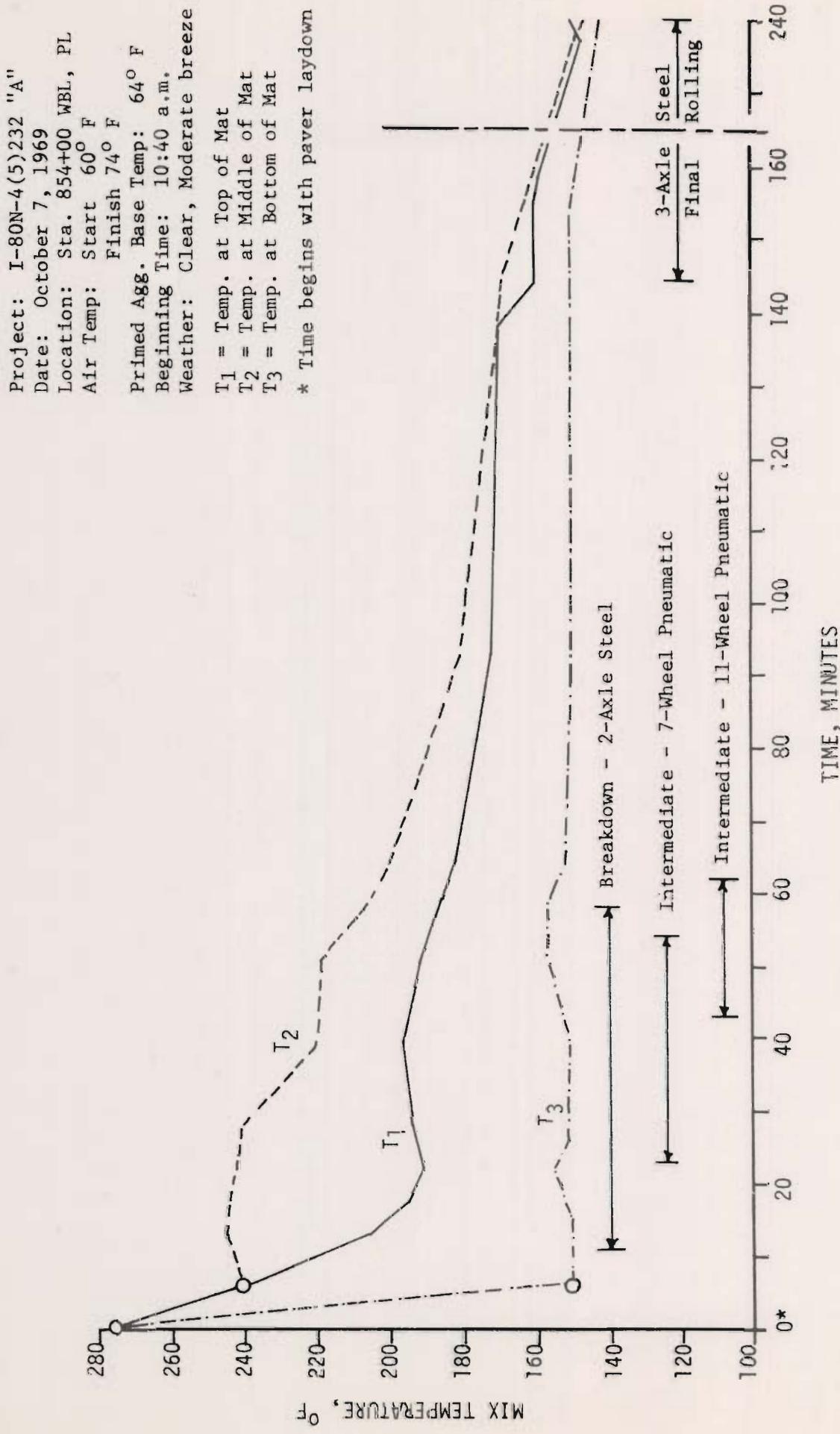
Temperature-Time, Rolling Pattern
and
Density-Air Voids Charts

TEMPERATURE VS. TIME
TEST NO. 1
0.4' ATB

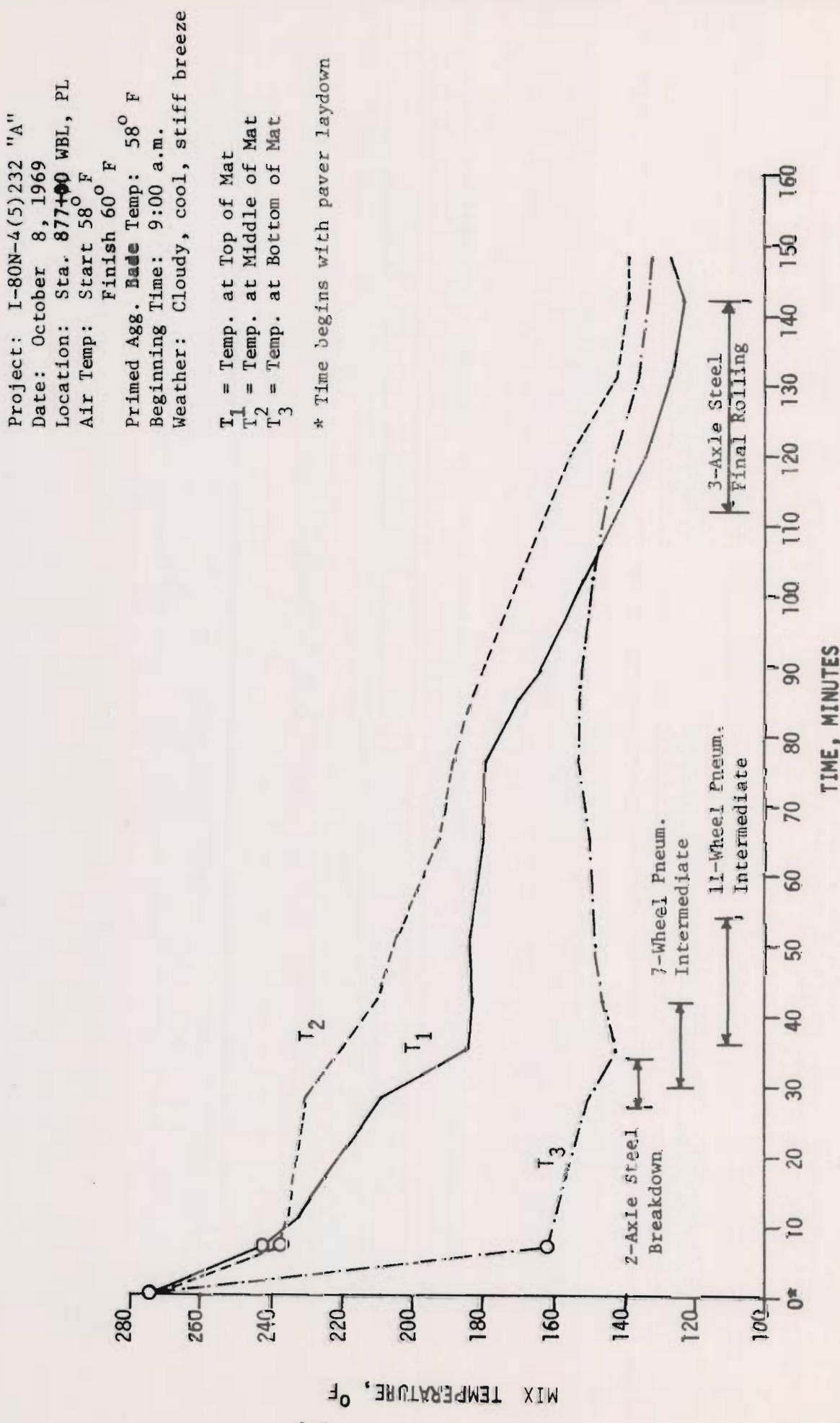


* Time begins with paver laydown.
+ One Cold Coverage beginning at 210 minutes

TEMPERATURE VS. TIME
TEST NO. 2
0.4' ATB



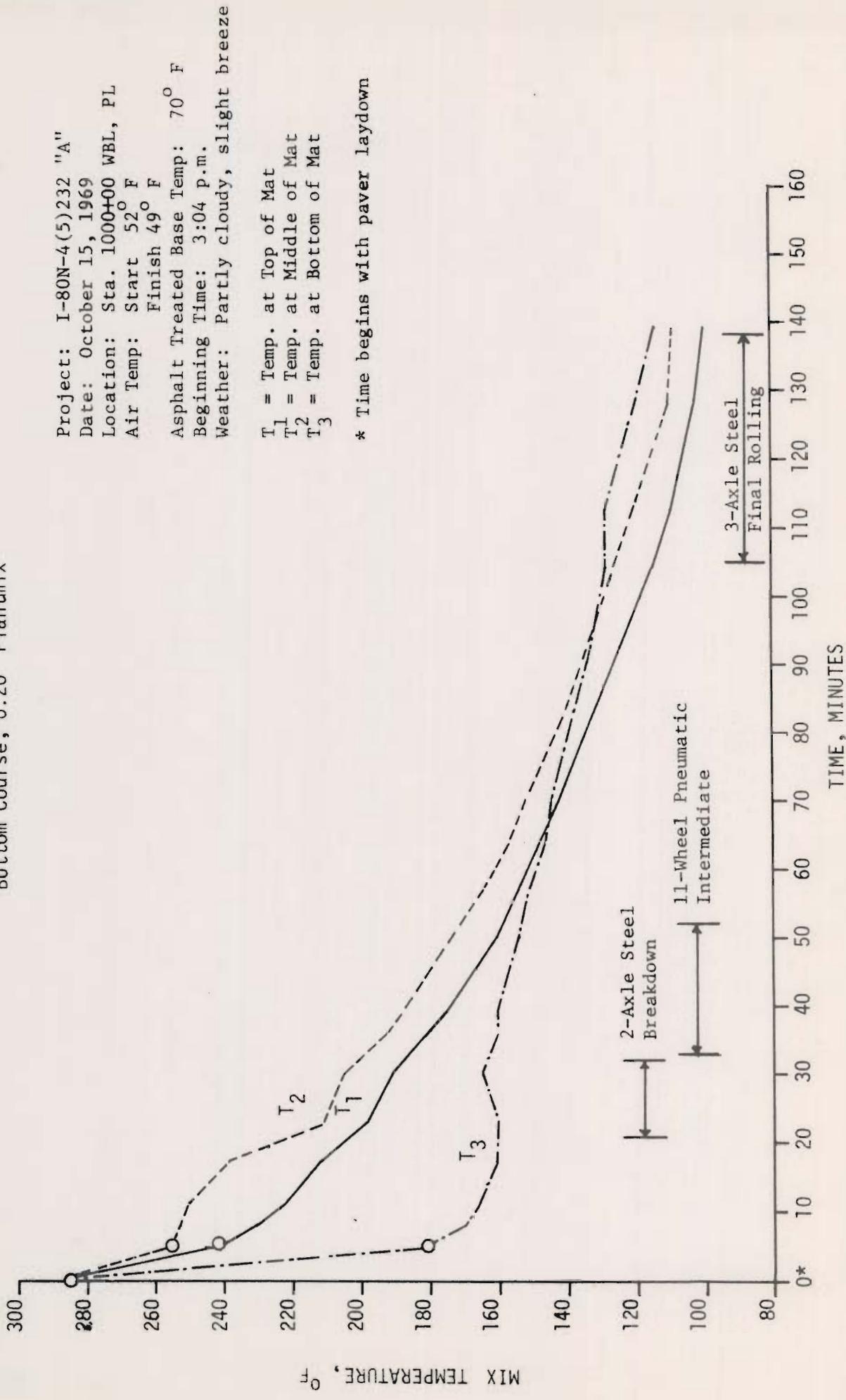
TEMPERATURE VS. TIME
Test No. 3
0.4' ATB



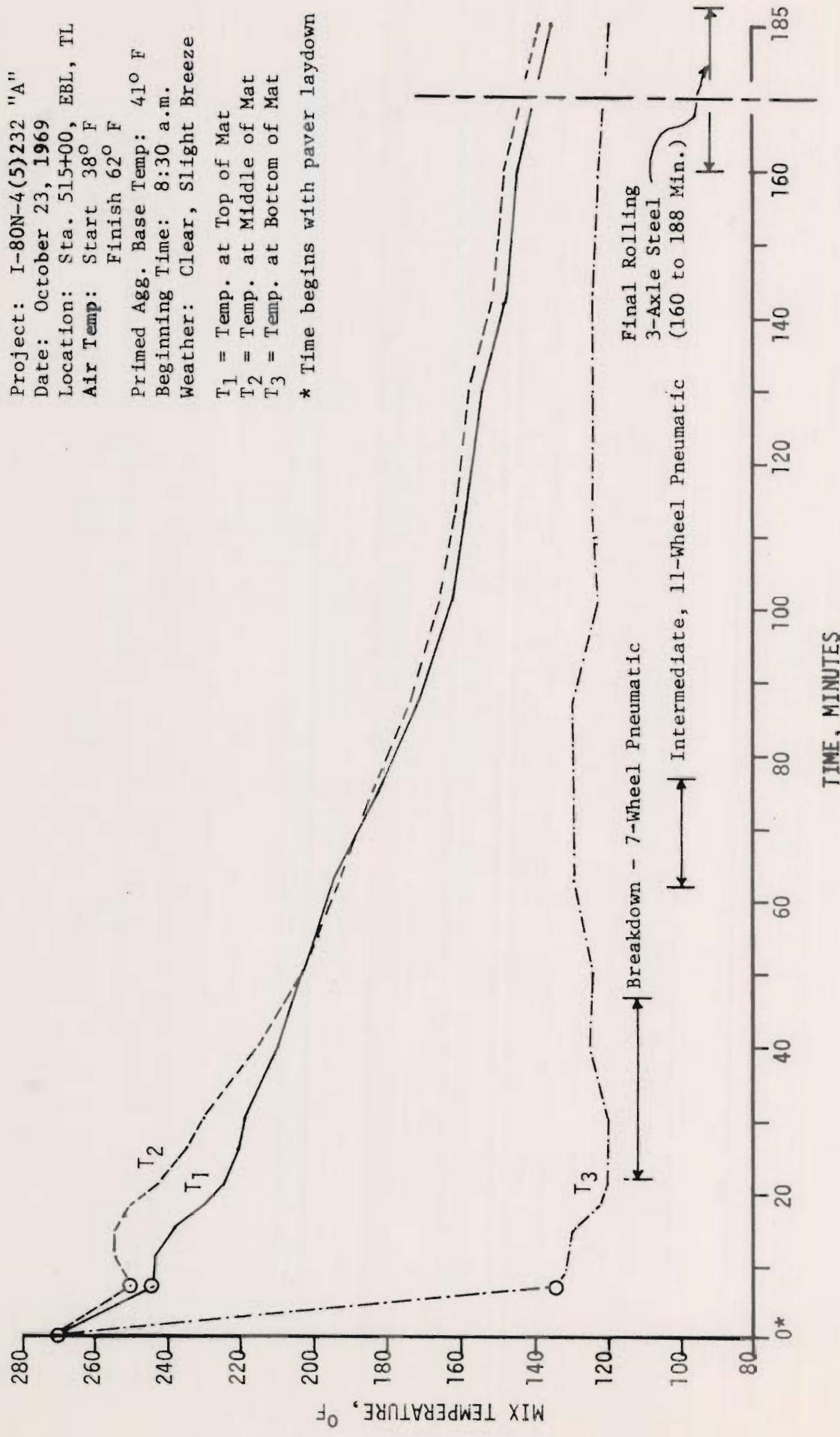
TEMPERATURE VS. TIME

Test No. 4

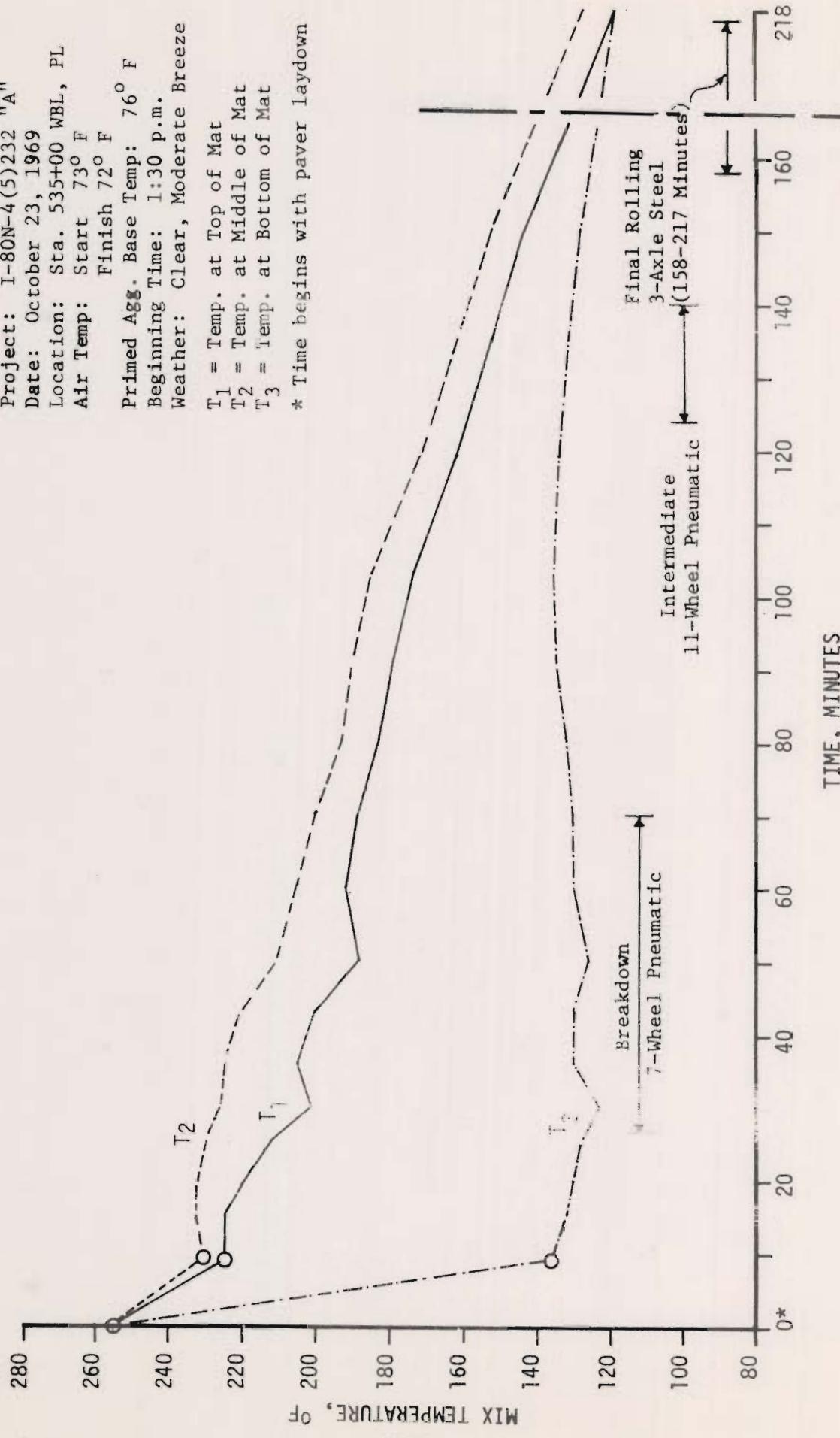
Bottom Course, 0.20' Plantmix



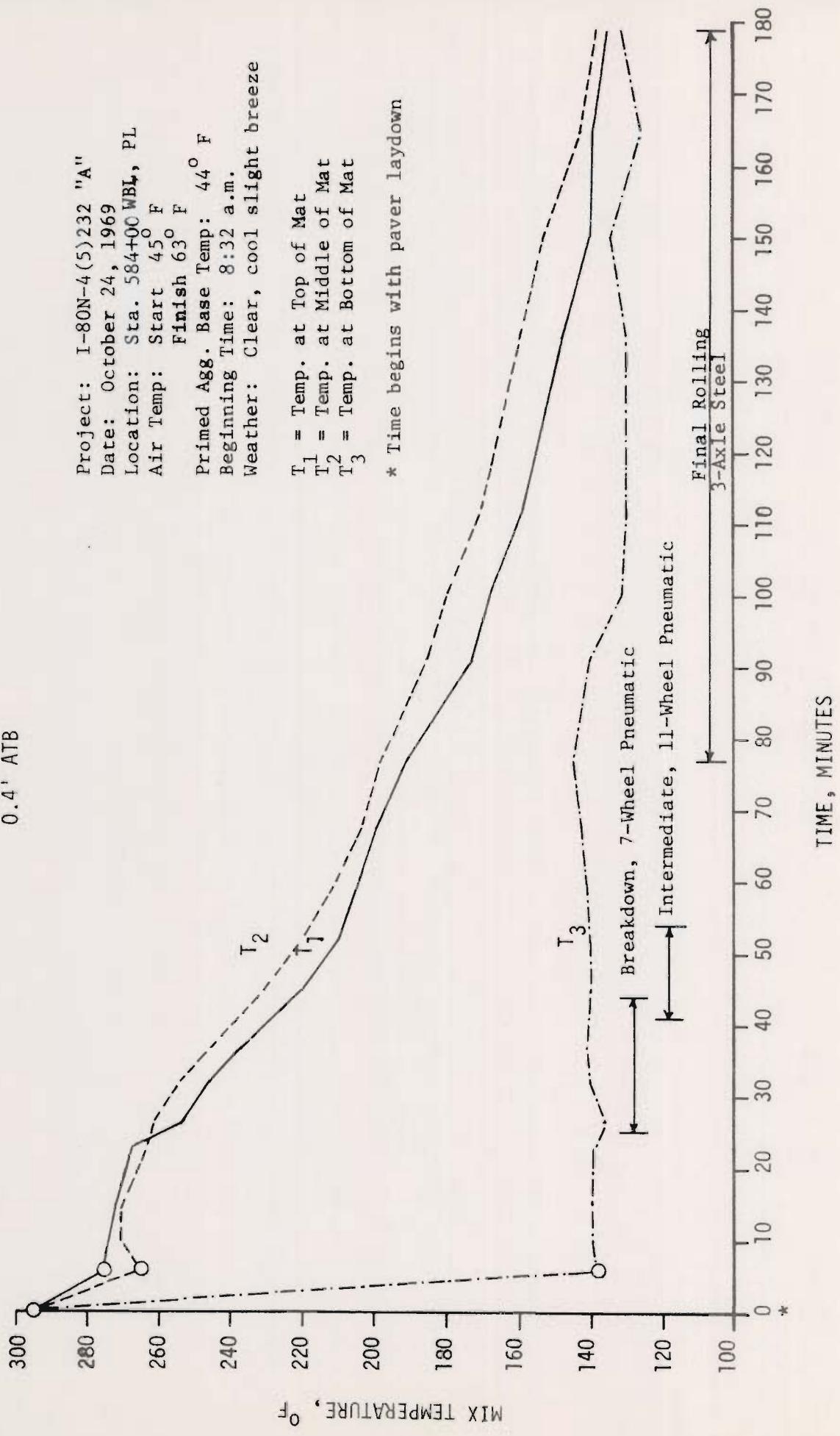
TEMPERATURE VS. TIME
TEST NO. 5
0.4' ATB



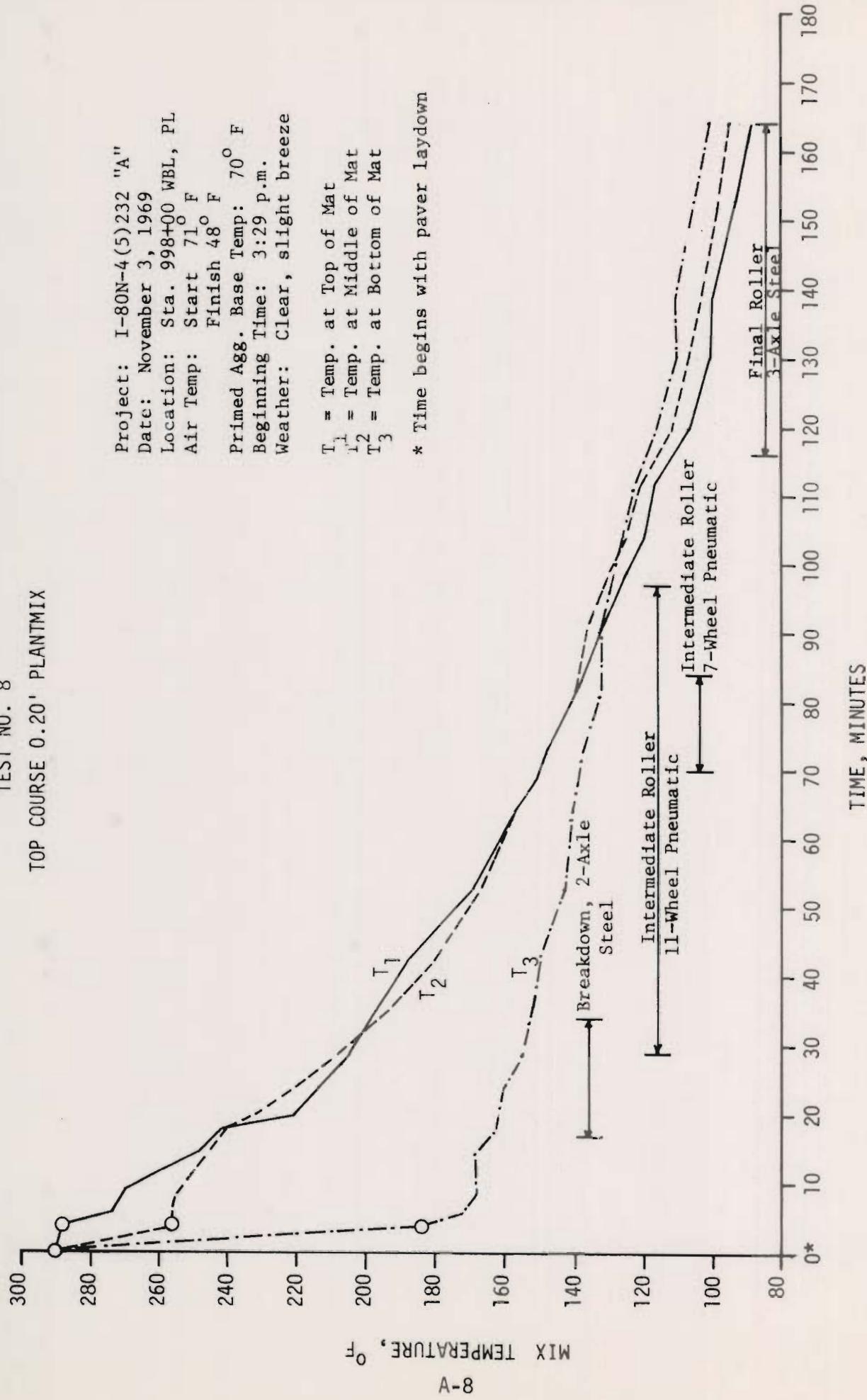
TEMPERATURE VS. TIME
TEST NO. 6
0.4' ATB



TEMPERATURE VS. TIME
TEST NO. 7
0.4' ATB



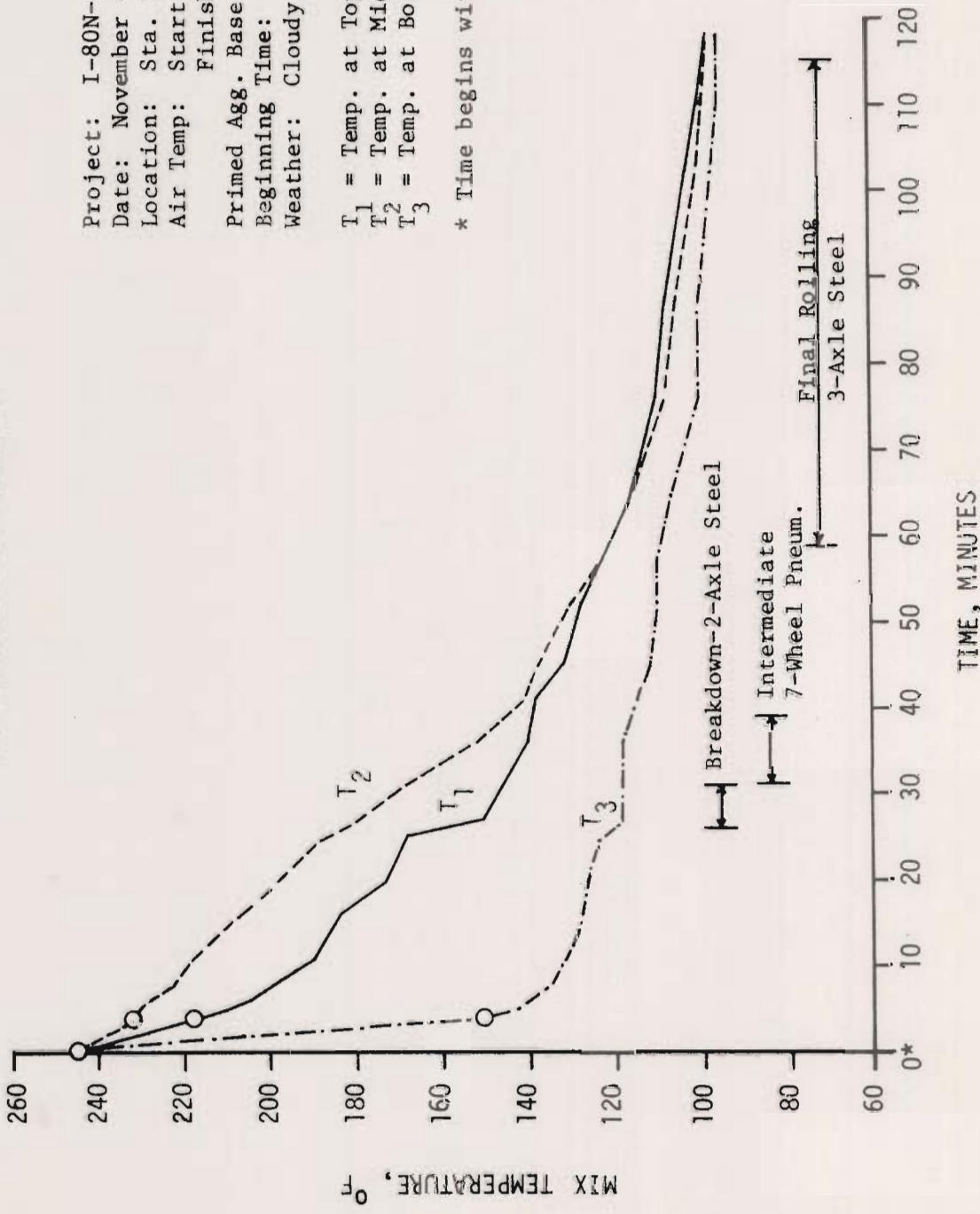
TEMPERATURE VS. TIME
TEST NO. 8
TOP COURSE 0.20' PLANTMIX



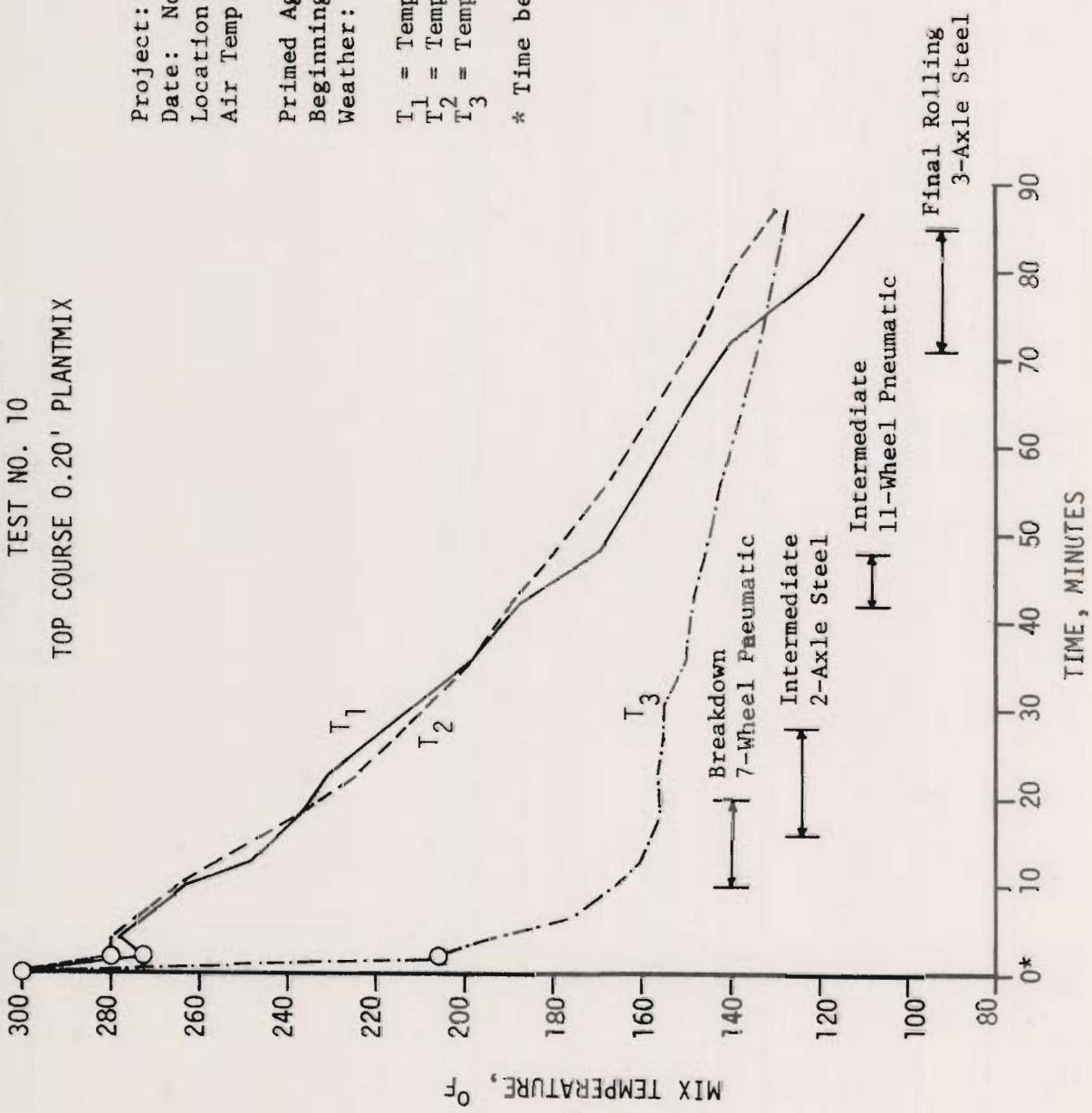
TEMPERATURE VS. TIME

TEST NO. 9

TOP COURSE 0.20' PLANTMIX



TEMPERATURE VS. TIME
TEST NO. 10
TOP COURSE 0.20' PLANTMIX





Project: I-80N-4(5)232 "A"
Date: November 13, 1969
Location: Sta. 806+00 WBL, PL
Air Temp: Start 57° F
Finish 58° F
Primed Agg. Base Temp: 54° F
Beginning Time: 10:32 a.m.
Weather: Hazy and windy

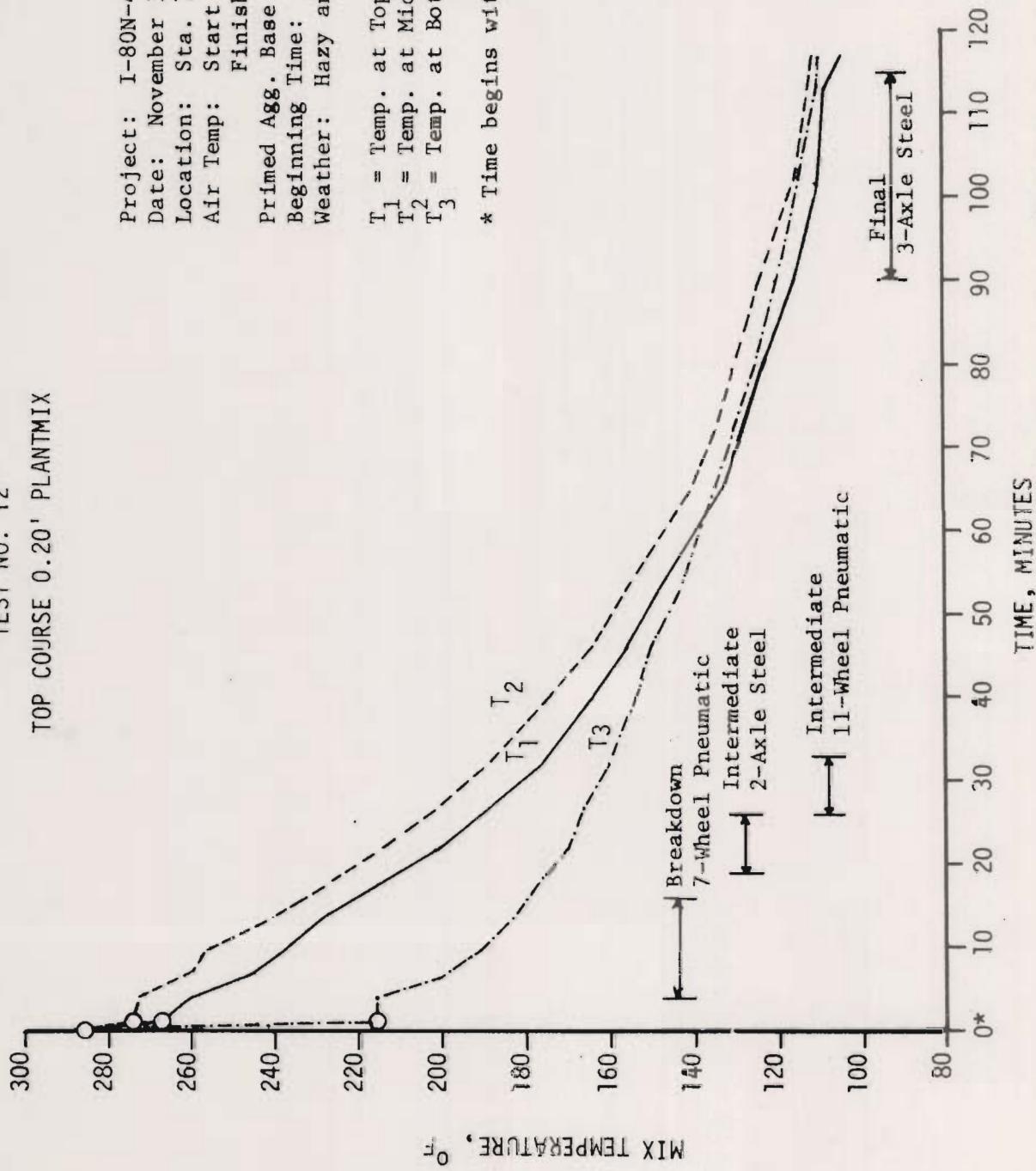
T_1 = Temp. at Top of Mat
 T_2 = Temp. at Middle of Mat
 T_3 = Temp. at Bottom of Mat

* Time begins with paver laydown

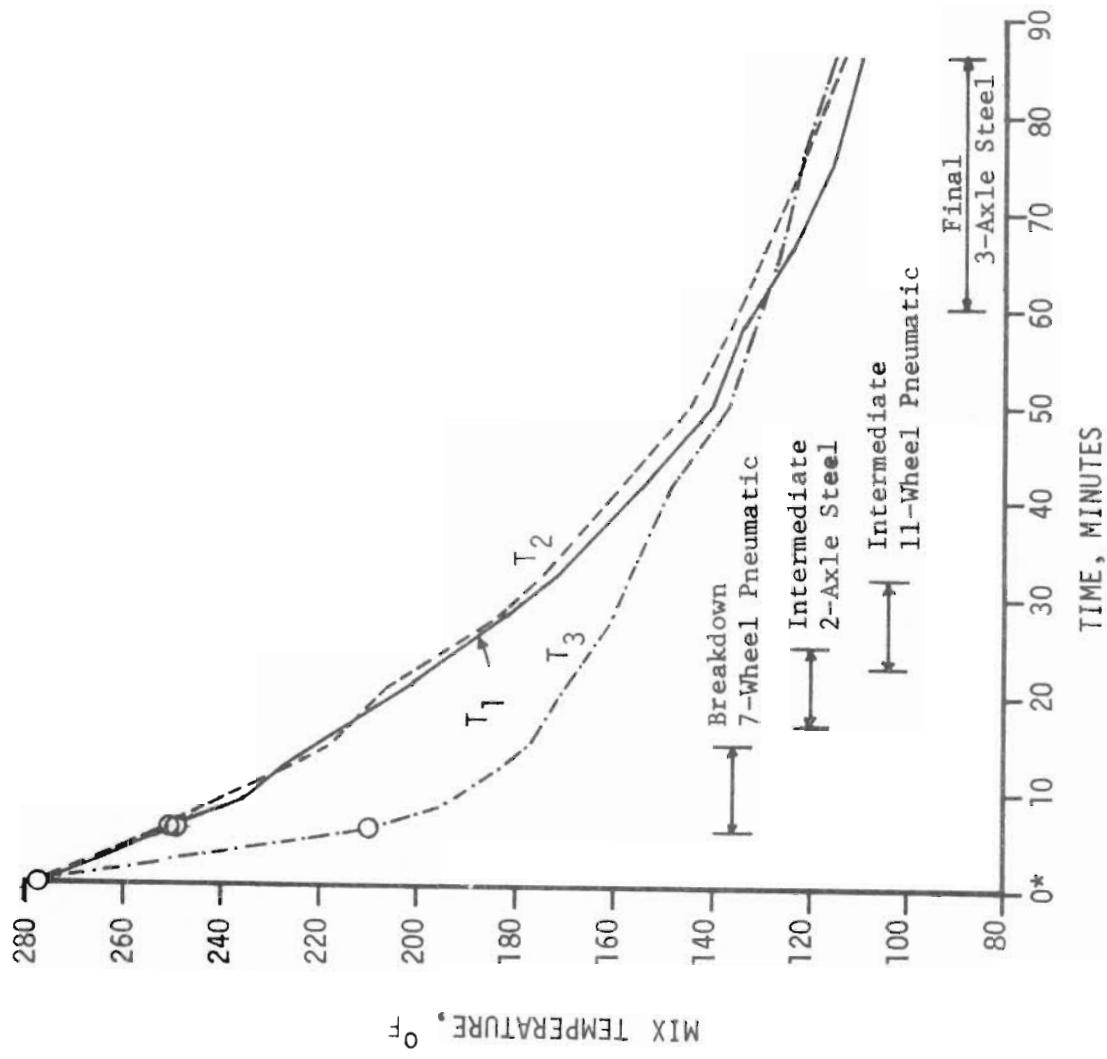
TEMPERATURE VS. TIME

TEST NO. 12

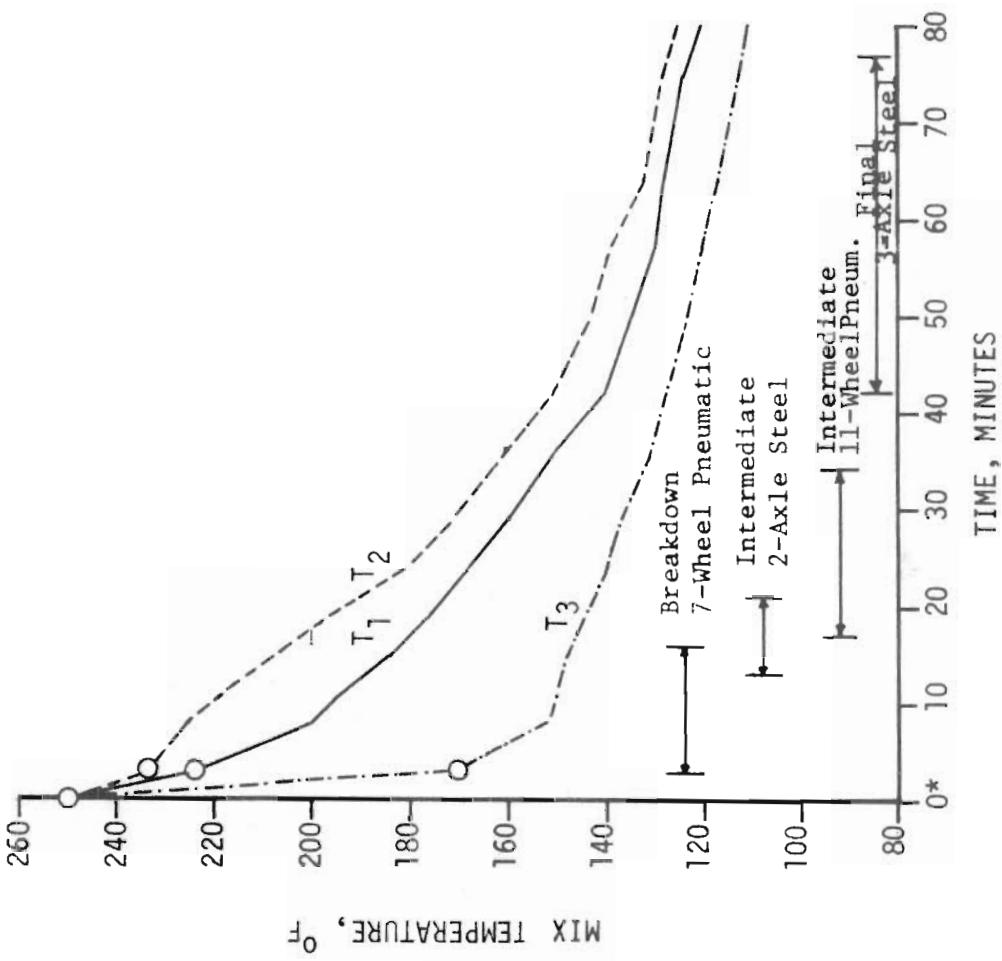
TOP COURSE 0.20' PLANTMIX



TEMPERATURE VS. TIME
TEST NO. 13
TOP COURSE 0.20' PLANTMIX



TEMPERATURE VS. TIME
TEST NO. 14
0.20' PLANTMIX ON DETOUR



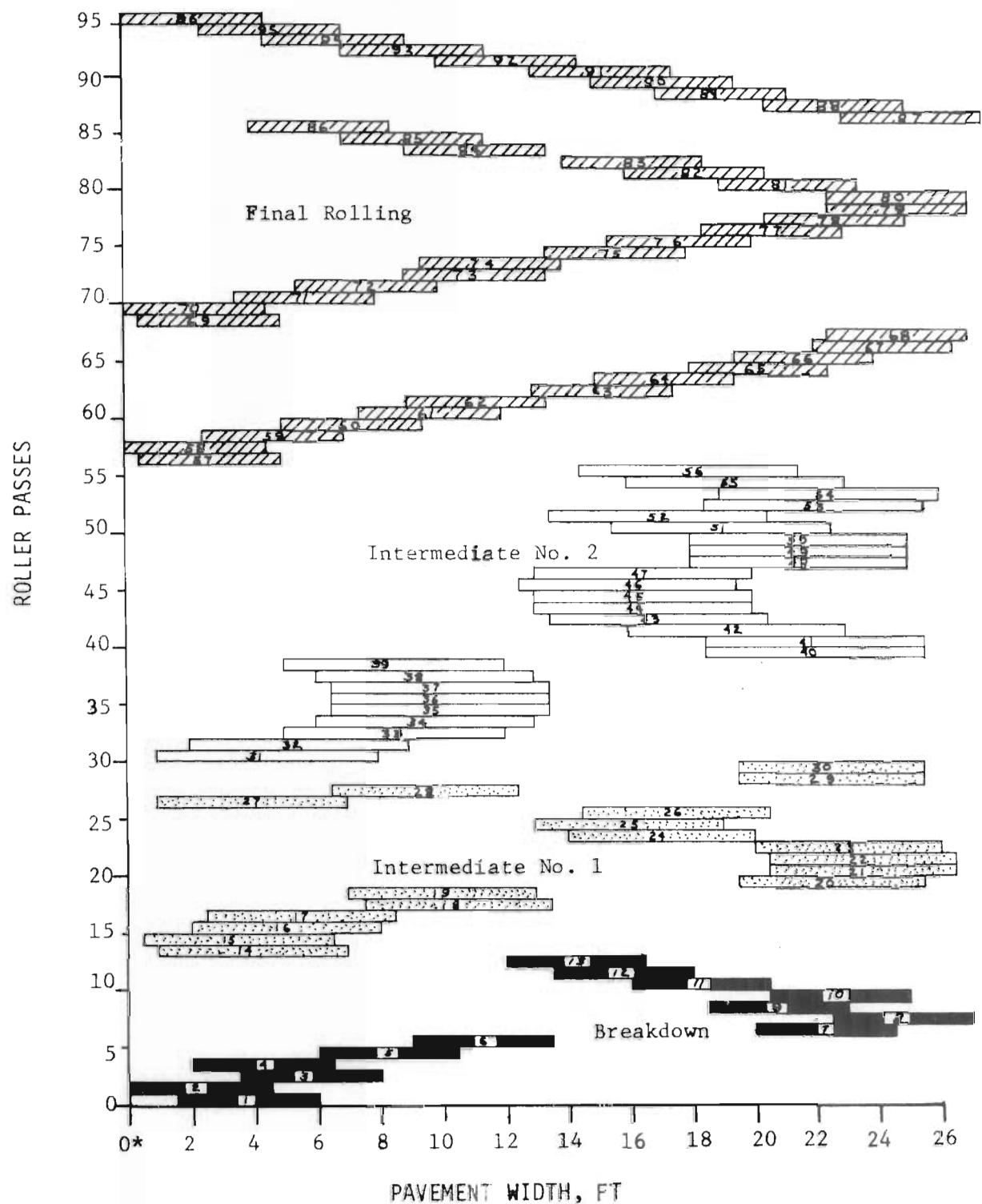
Project: I-80N-4(5)232 "A"
Date: November 14, 1969
Location: Sta. 922+00, Detour Section
Air Temp: Start 52° F
Finish 60° F
Primed Agg. Base Temp: 45° F
Beginning Time: 10:43 A.M.
Weather: Clear, slight breeze

T_1 = Temp. at Top of Mat
 T_2 = Temp. at Middle of Mat
 T_3 = Temp. at Bottom of Mat
* Time begins with paver laydown

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 1

0.4' ATB

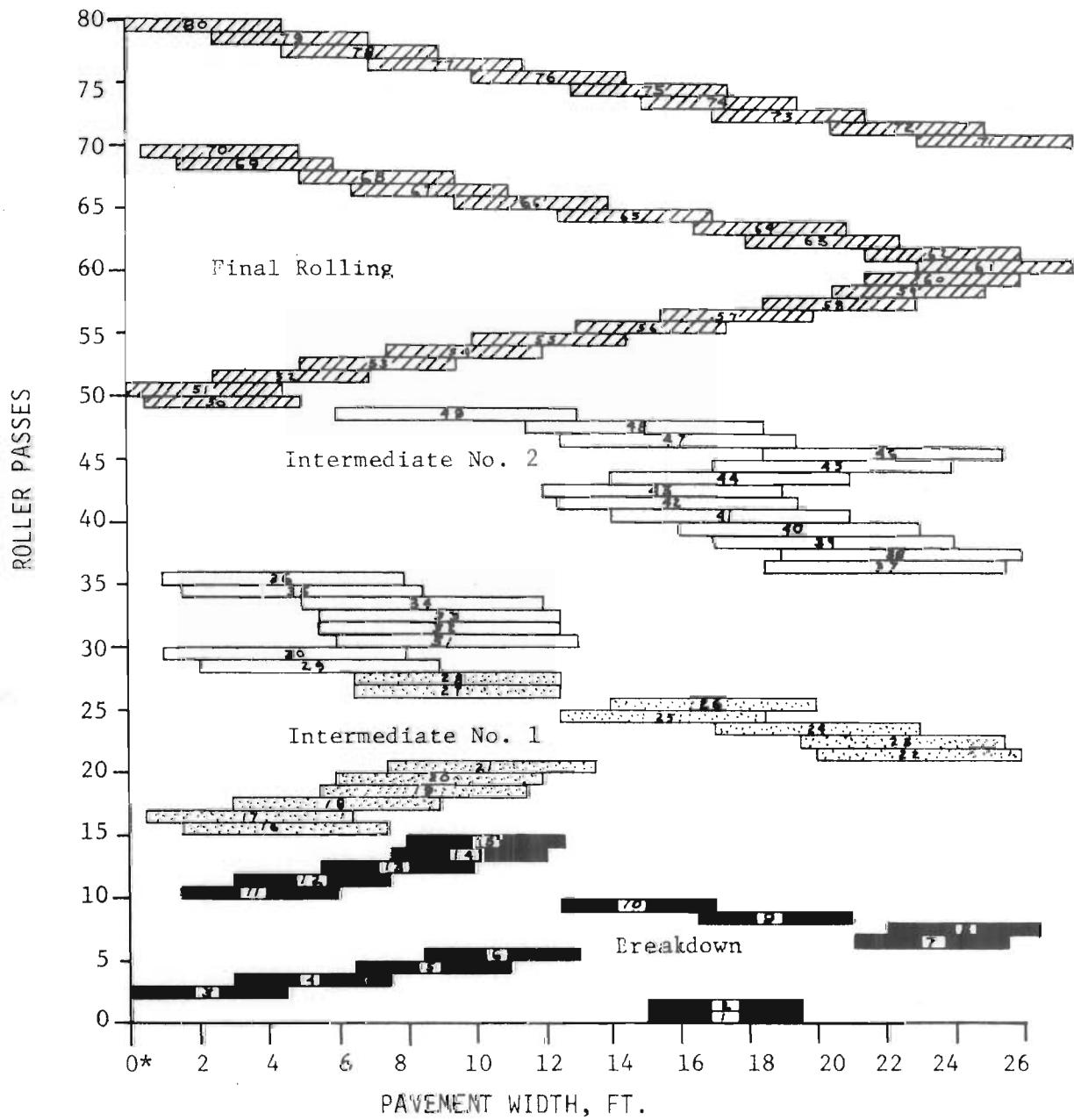


*Edge of lay, WBL, PL

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 2

0.4' ATB

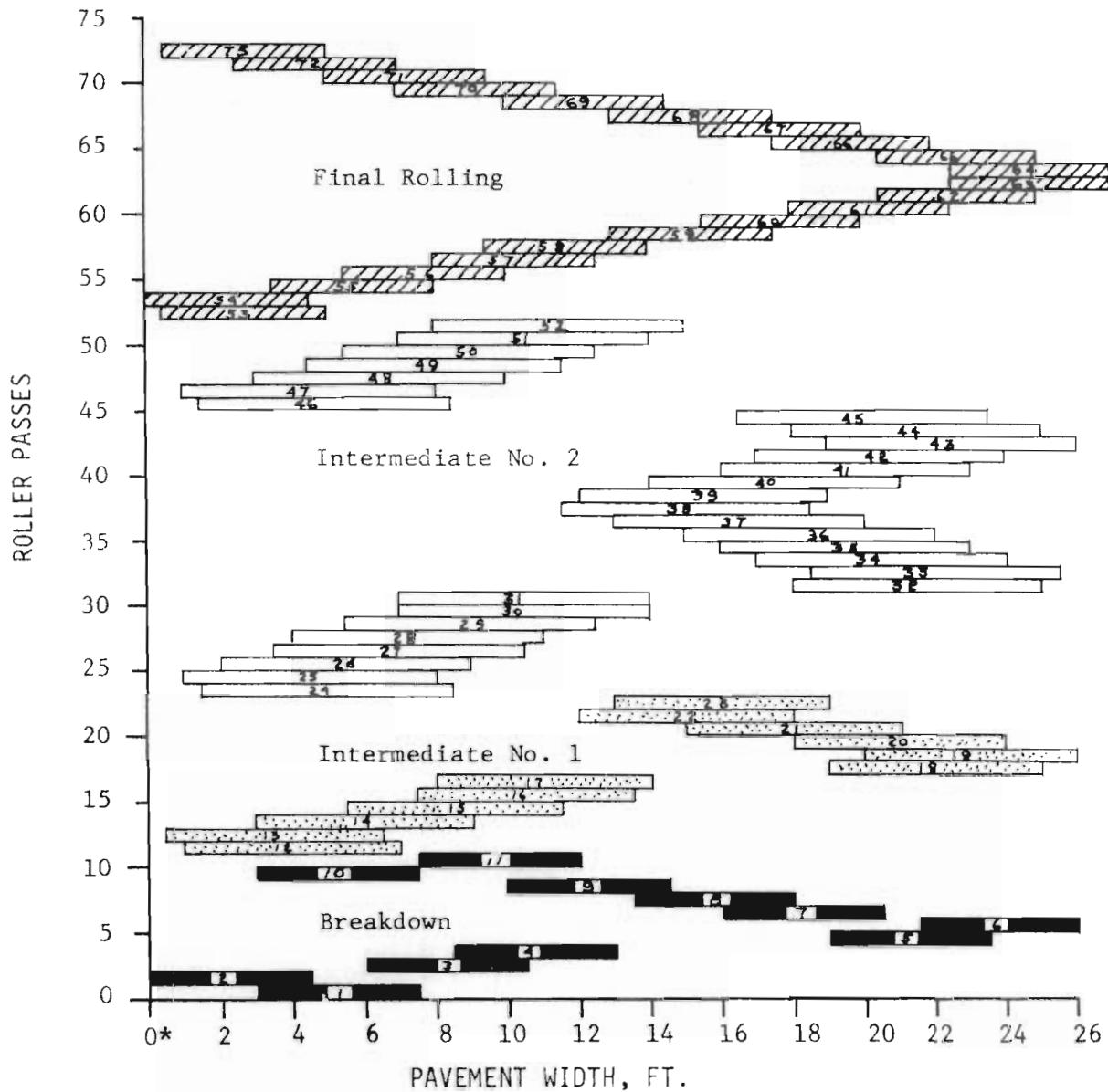


* Edge of lay, WBL, PL

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 3

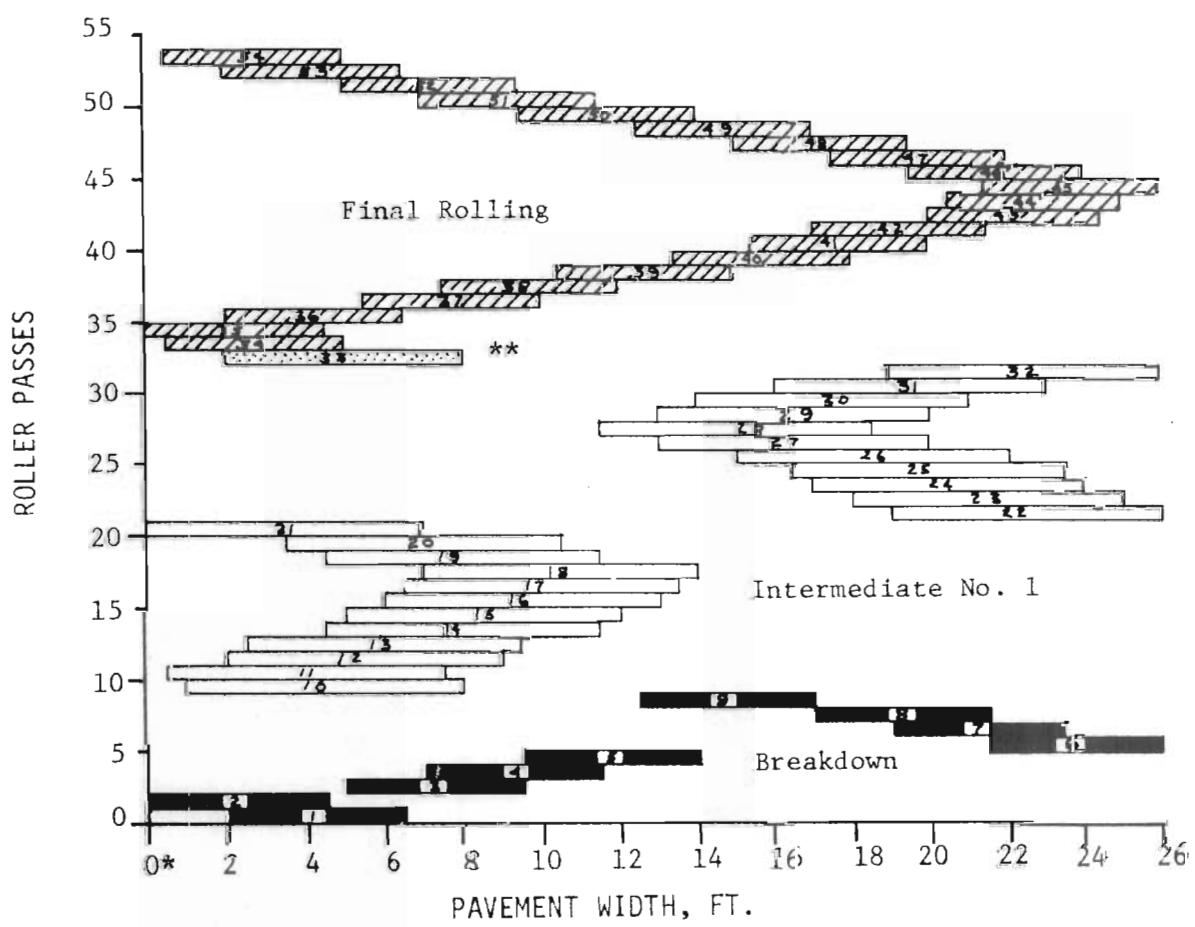
0.4' ATB



ROLLING PATTERN ACROSS ROADWAY

TEST NO. 4

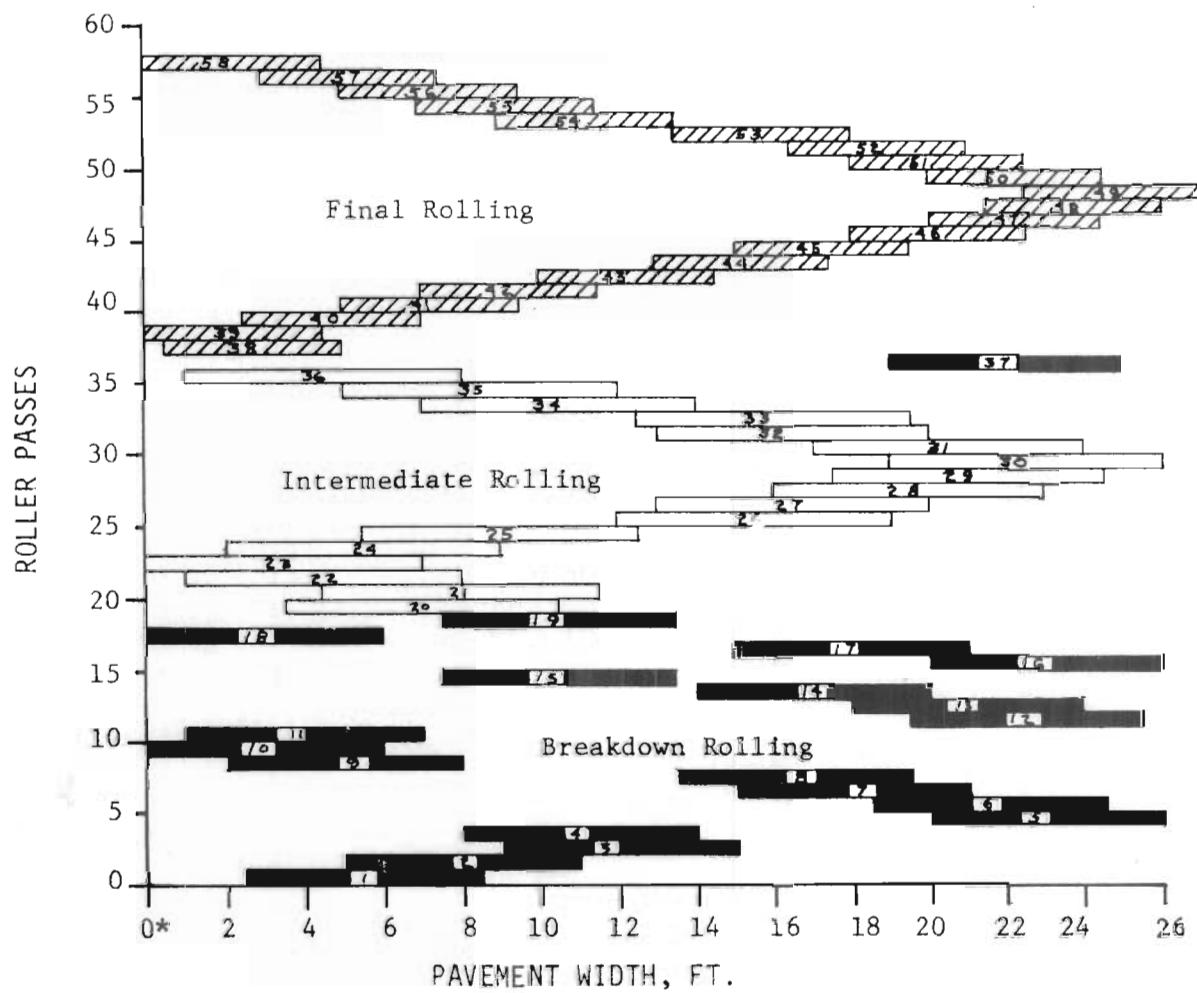
BOTTOM COURSE 0.20' PLANTMIX



ROLLING PATTERN ACROSS ROADWAY

TEST NO. 5

0.4' ATB

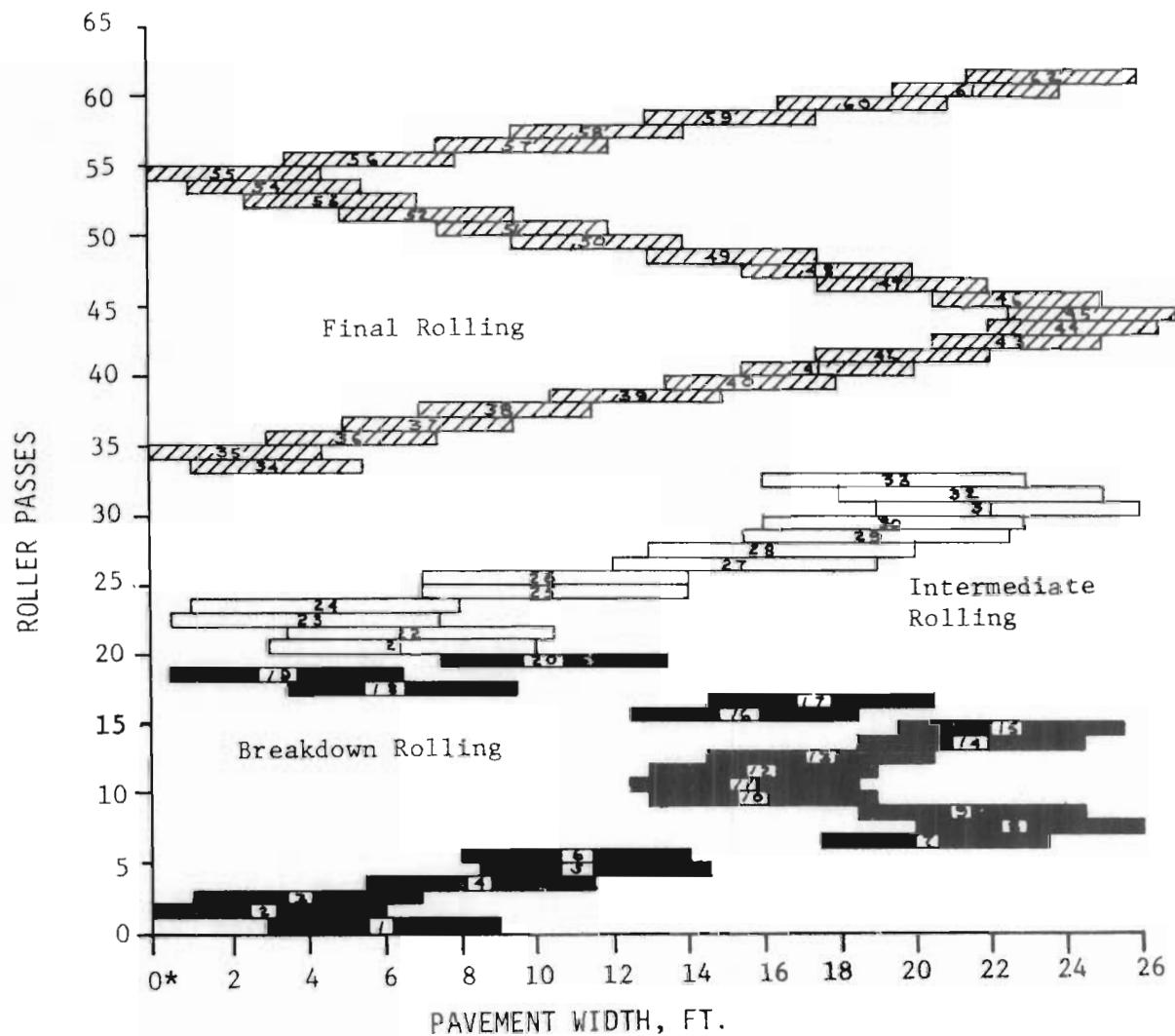


* Edge of lay, WBL, PL

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 6

0.4' ATB

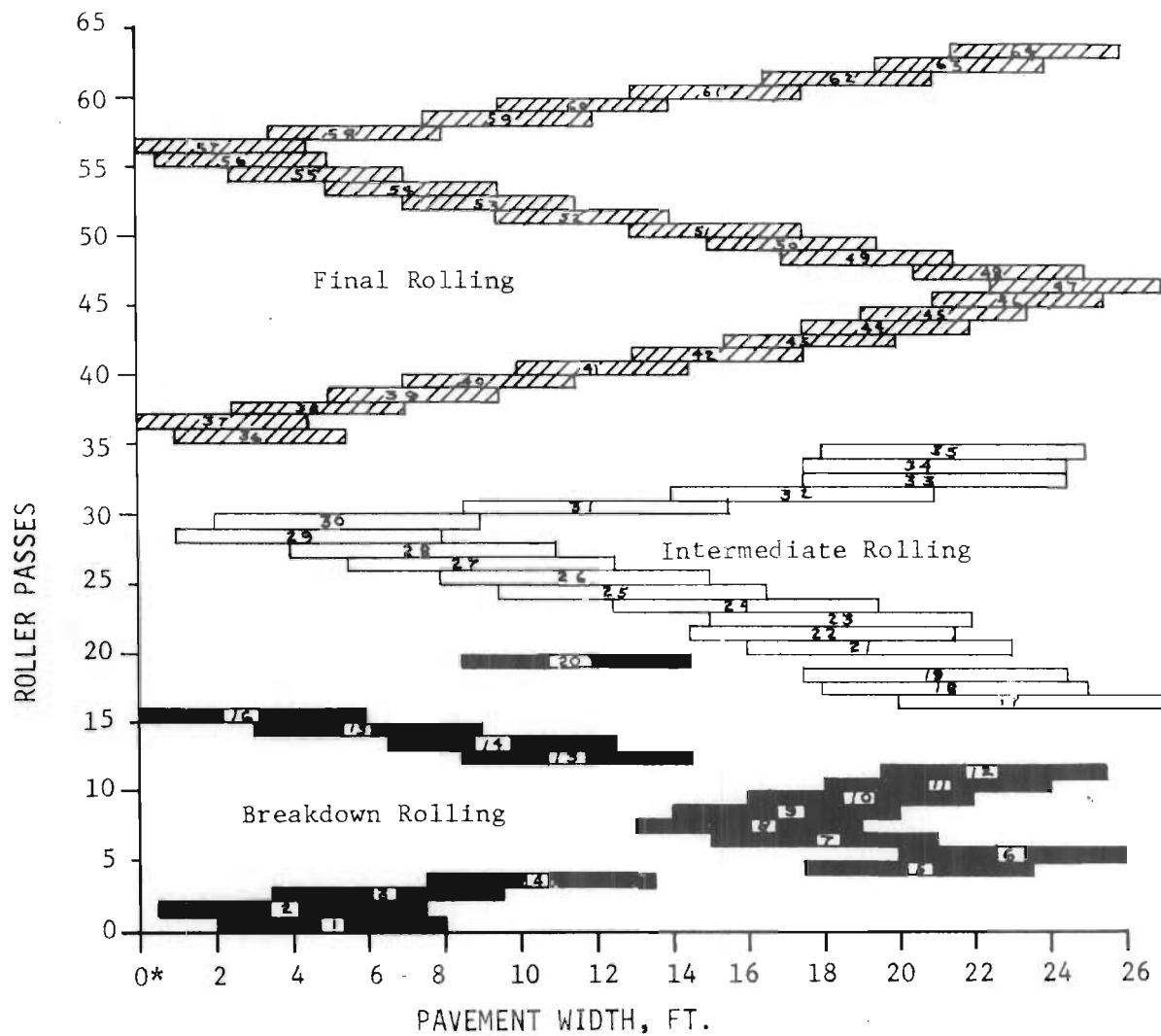


* Edge of lay, WBL, PL

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 7

0.4' ATB

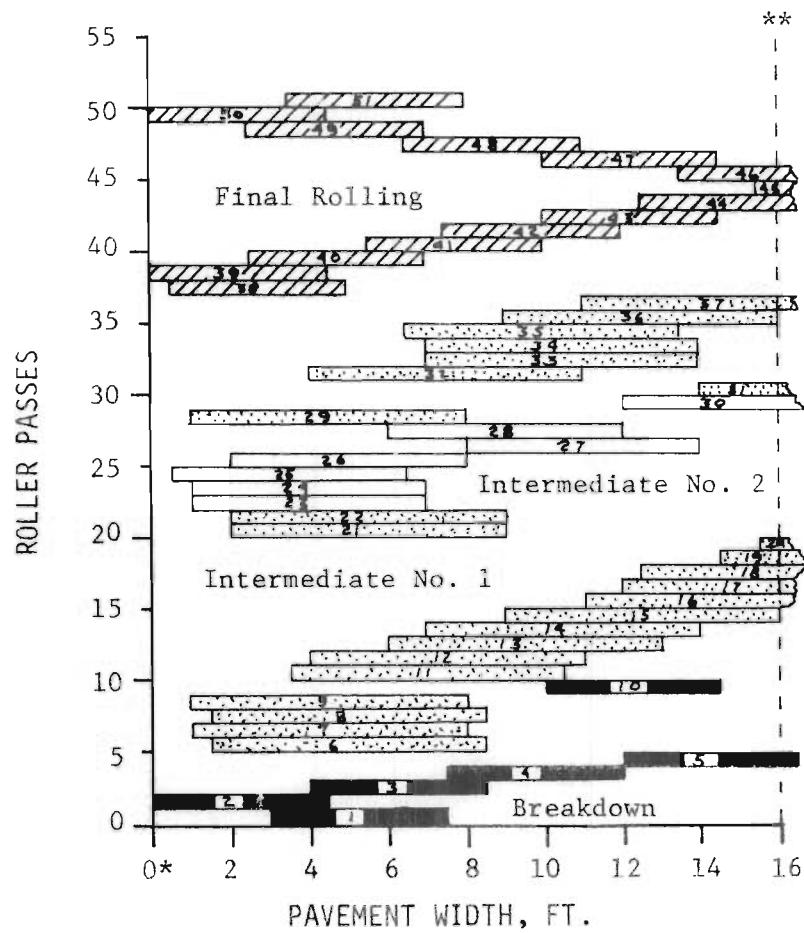


* Edge of lay, WBL, PL

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 8

TOP COURSE 0.20' PLANTMIX



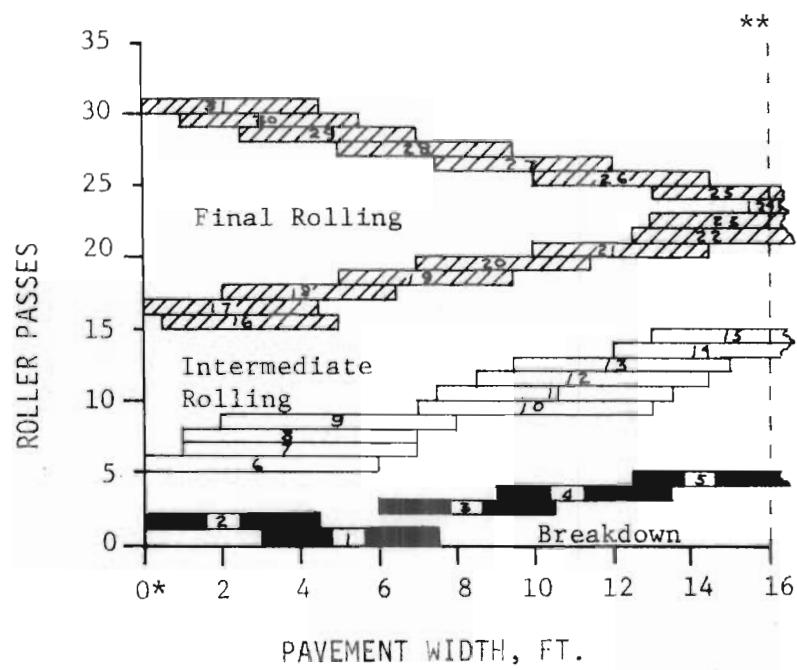
* Edge of lay, WBL, PL

** One Paver Width

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 9

TOP COURSE 0.20' PLANTMIX



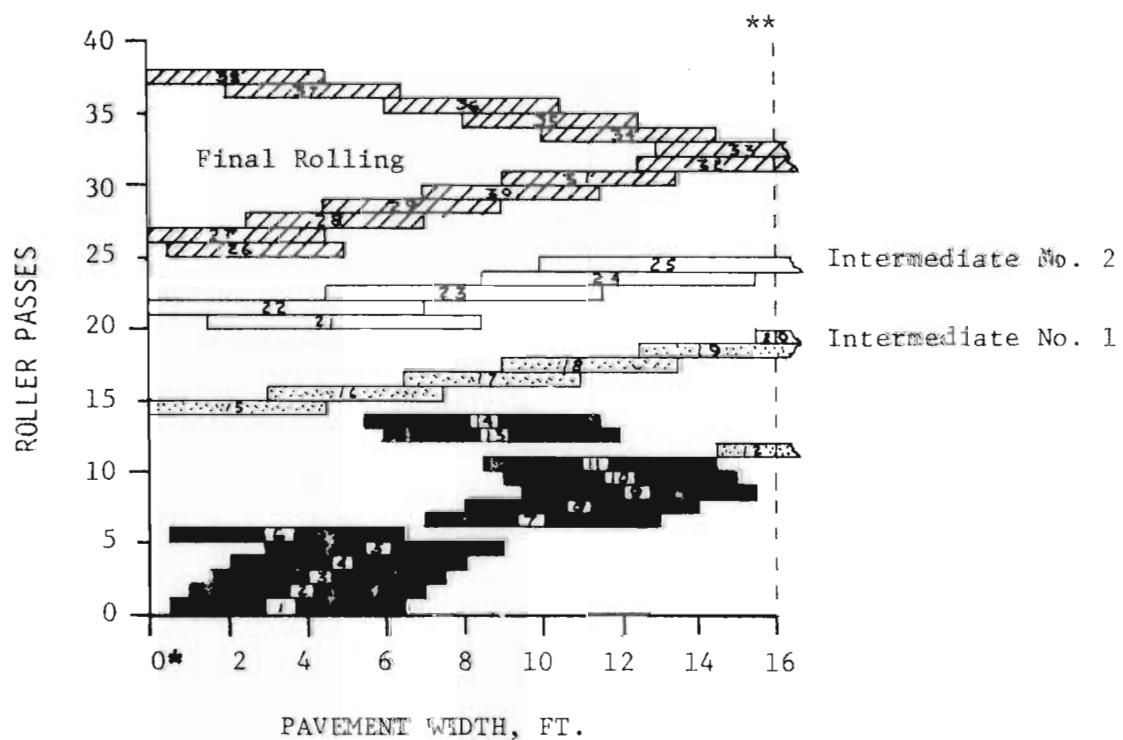
* Edge of lay, WBL, PL

** One Paver Width

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 10

TOP COURSE 0.20' PLANTMIX



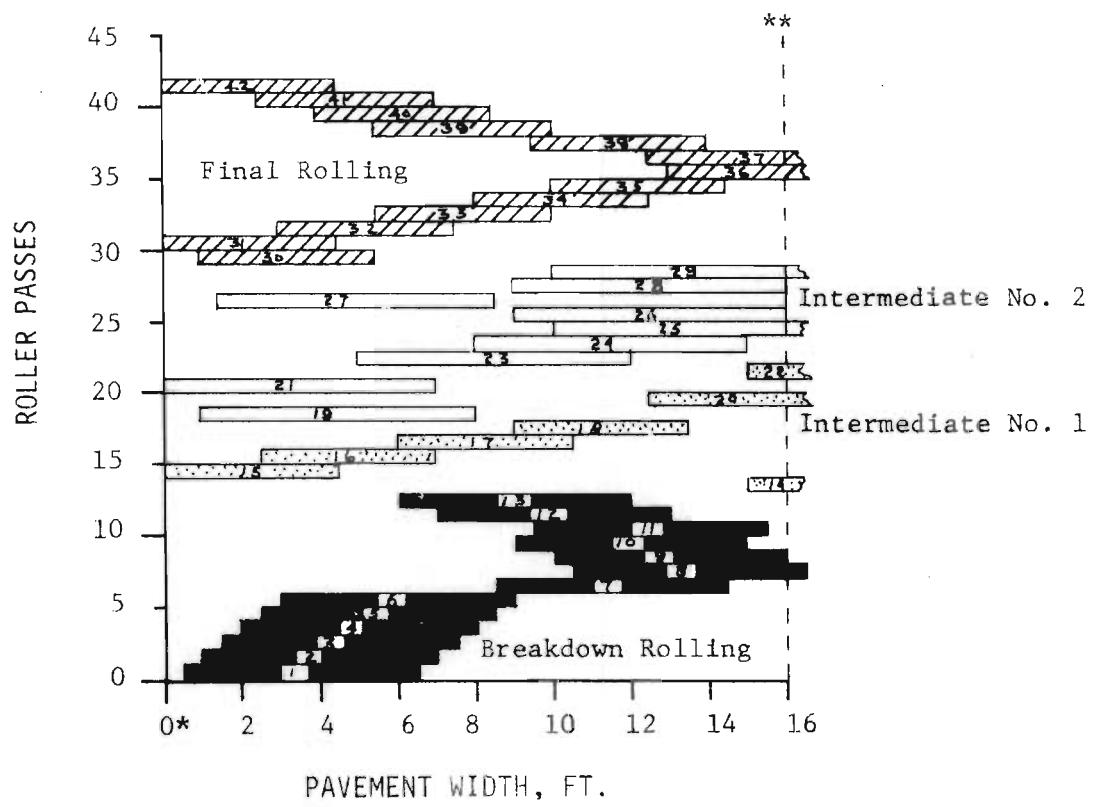
* Edge of lay, WBL, PL

** One Paver Width

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 11

TOP COURSE 0.20' PLANTMIX

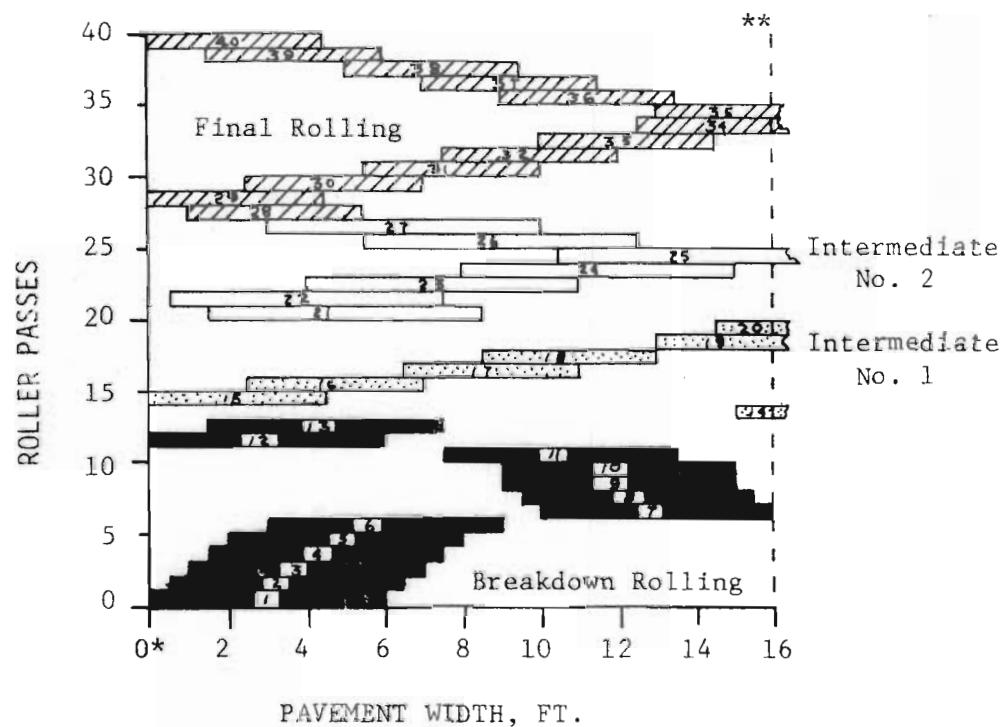


* Edge of lay, WBL, PL
** One Paver Width

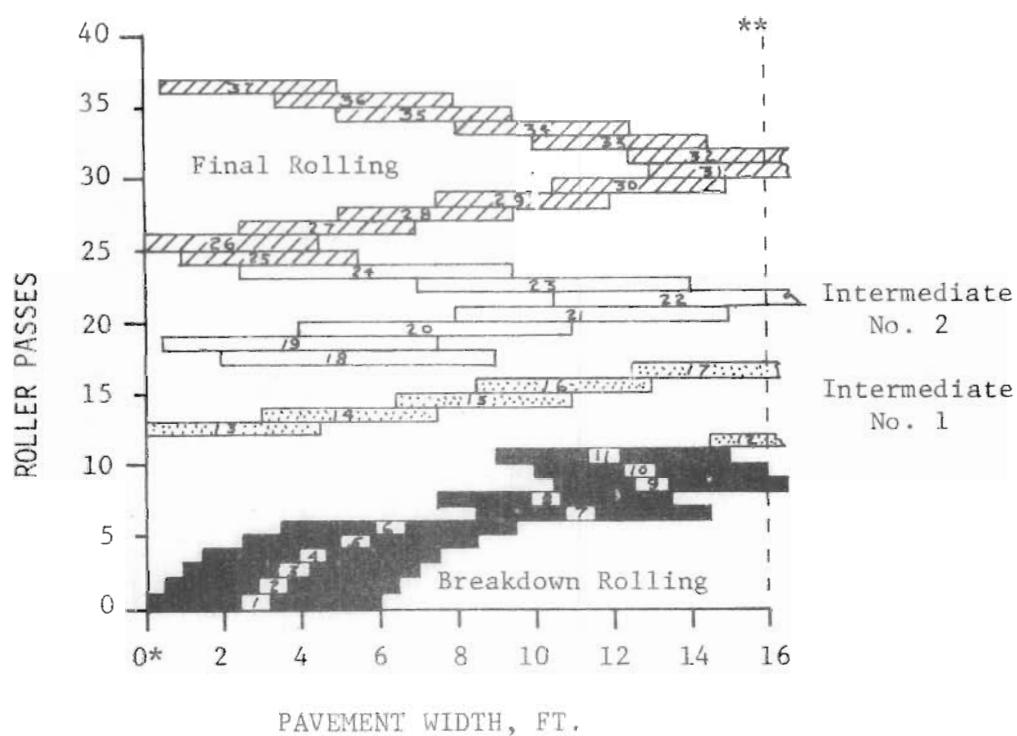
ROLLING PATTERN ACROSS ROADWAY

TEST NO. 12

TOP COURSE 0.20' PLANTMIX



ROLLING PATTERN ACROSS ROADWAY
TEST NO. 13
TOP COURSE 0.20' PLANTMIX

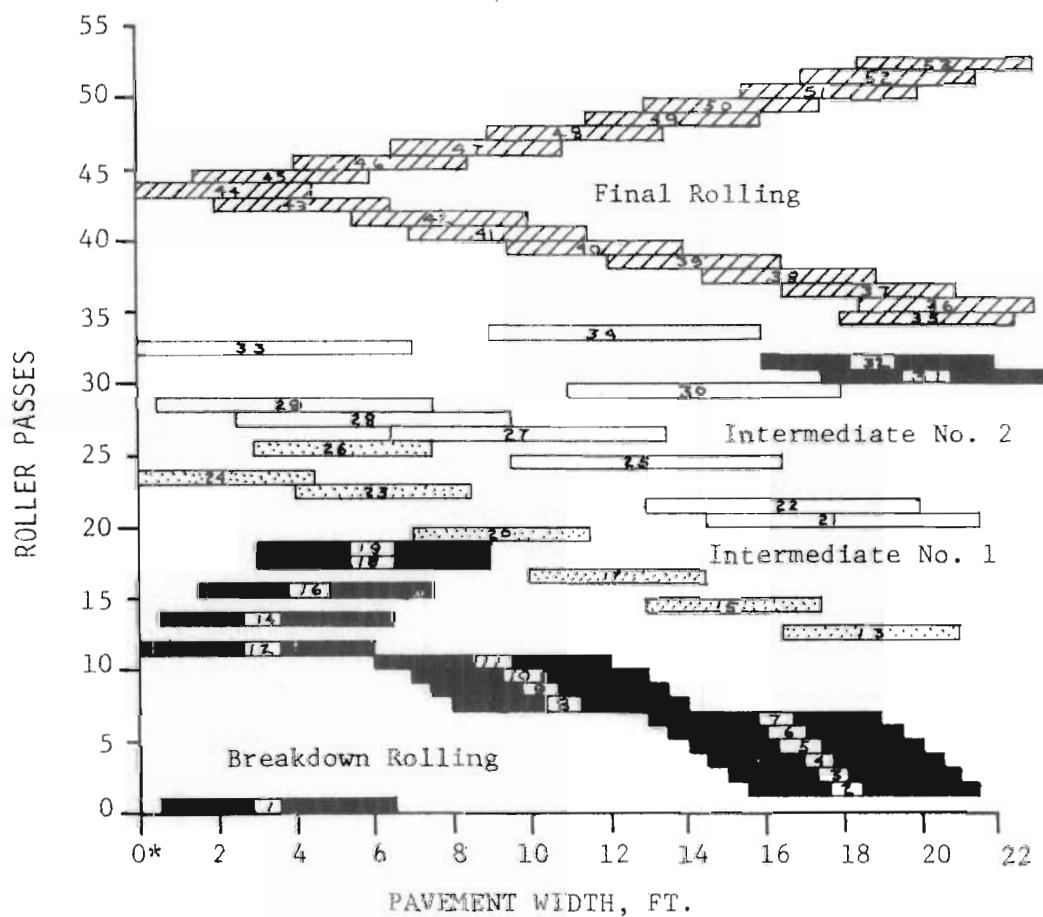


* Edge of lay, WBL, PL
** One Paver Width

ROLLING PATTERN ACROSS ROADWAY

TEST NO. 14

0.20' PLANTMIX ON DETOUR

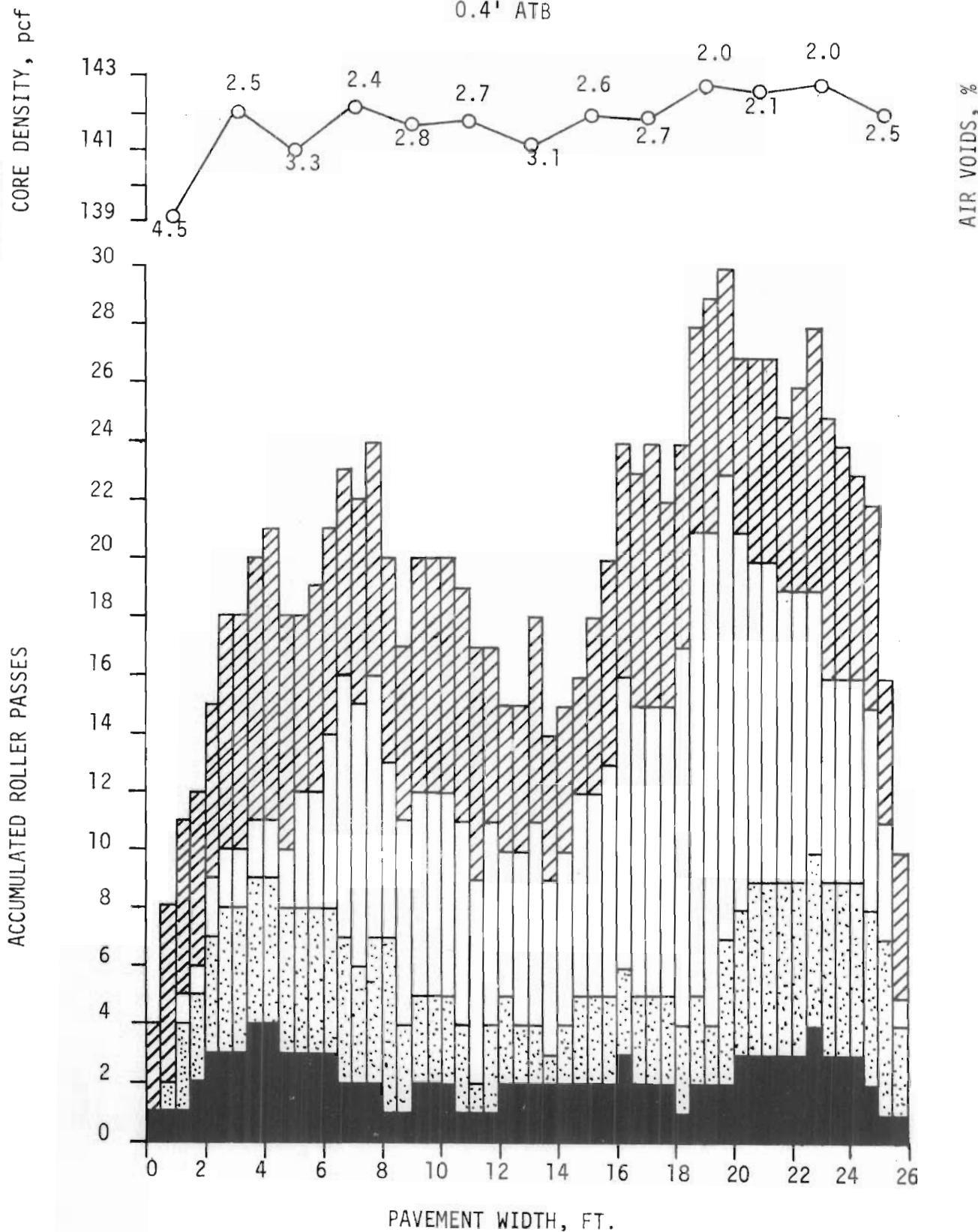


* Edge of lay, WBL, PL

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

TEST NO. 1

0.4' ATB

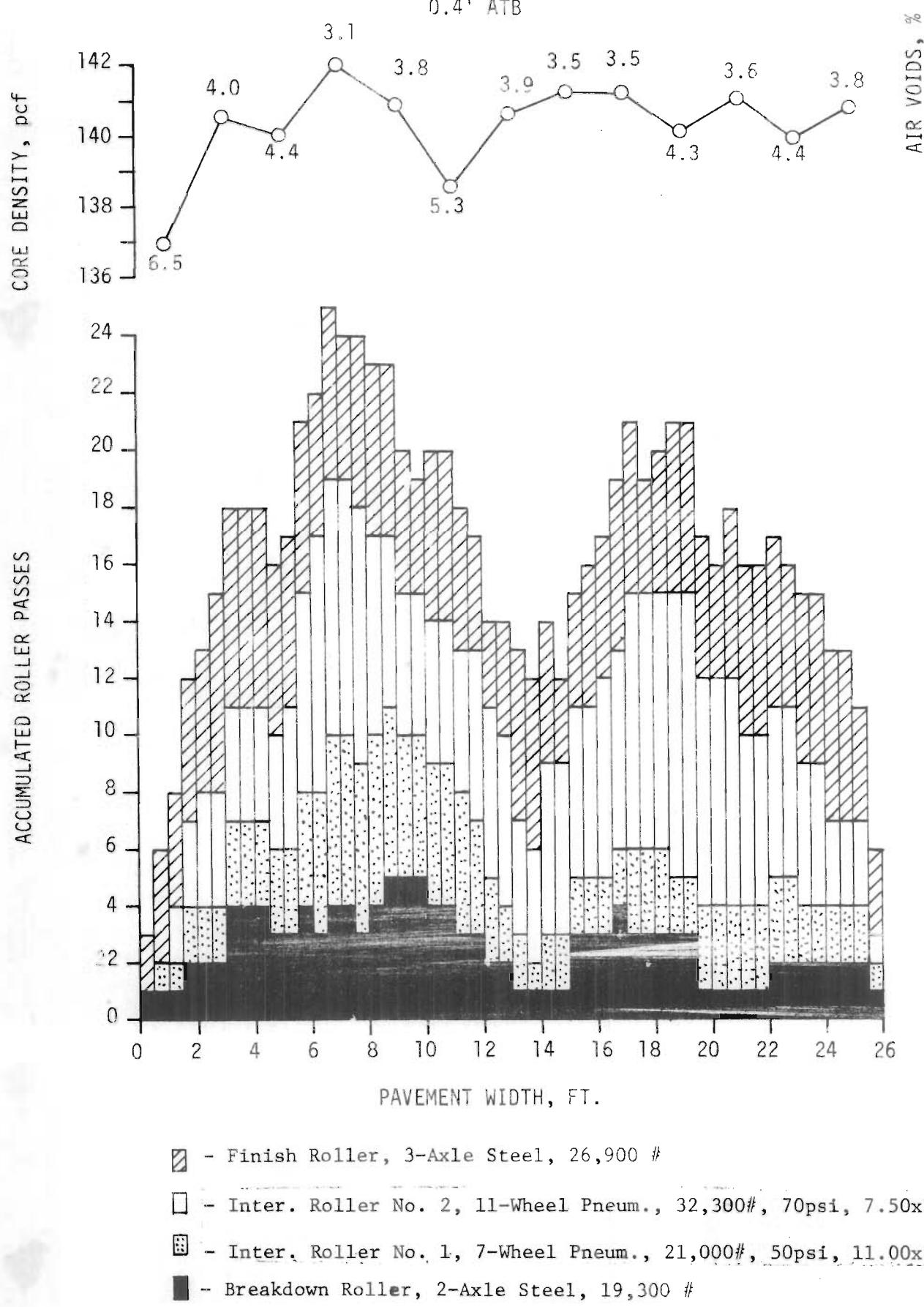


- ▨ - Finish Roller, 3-Axle Steel, 26,900 #
- - Inter. Roller No. 2, 11-Wheel Pneum., 32,300#, 70psi, 7.50x15
- ▨ - Inter. Roller No. 1, 7-Wheel Pneum., 21,000#, 50psi, 11.00x20
- - Breakdown Roller, 2-Axle Steel, 19,300 #

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

TEST NO. 2

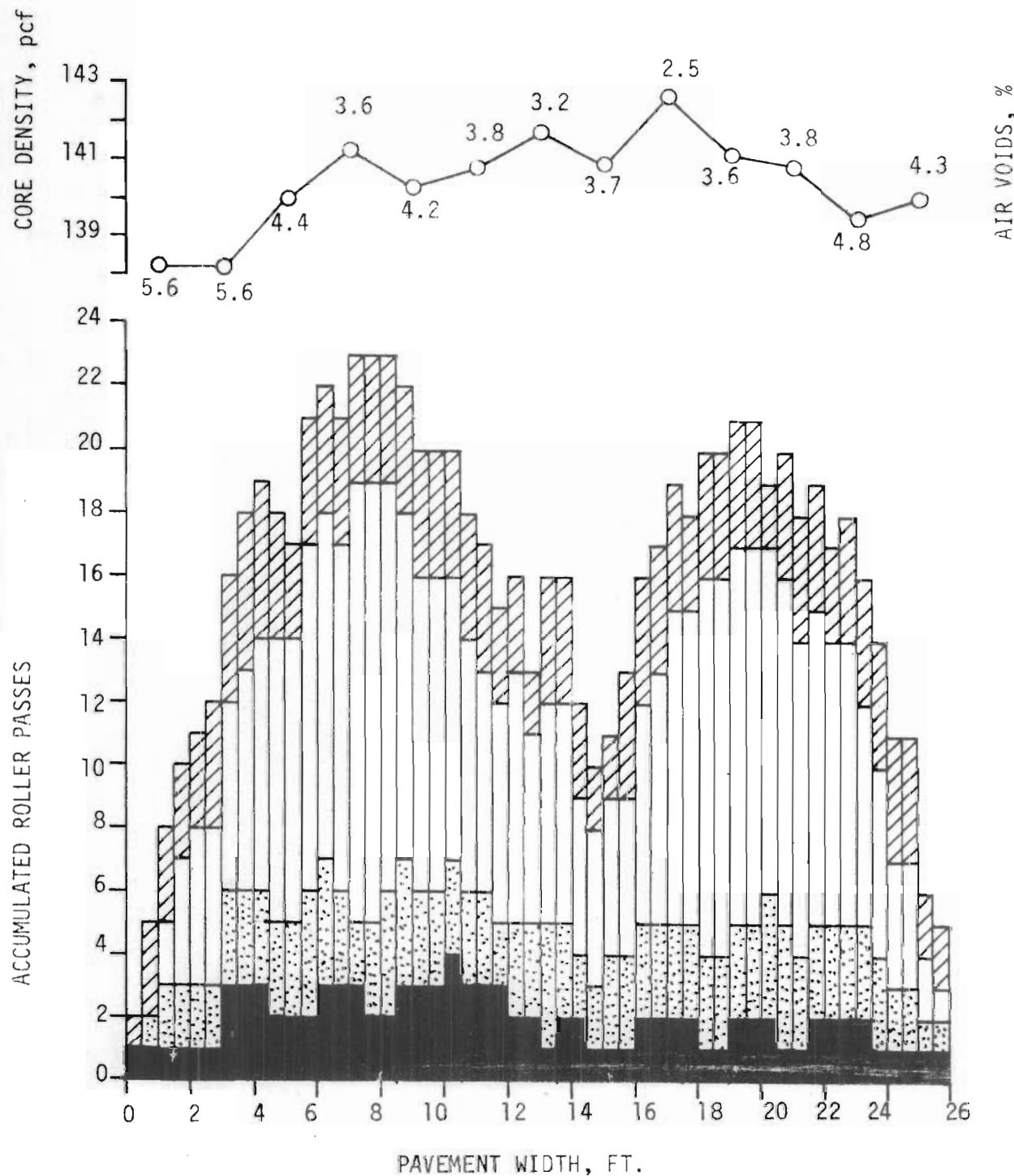
0.4' ATB



ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

Test No. 3

0.4' ATB



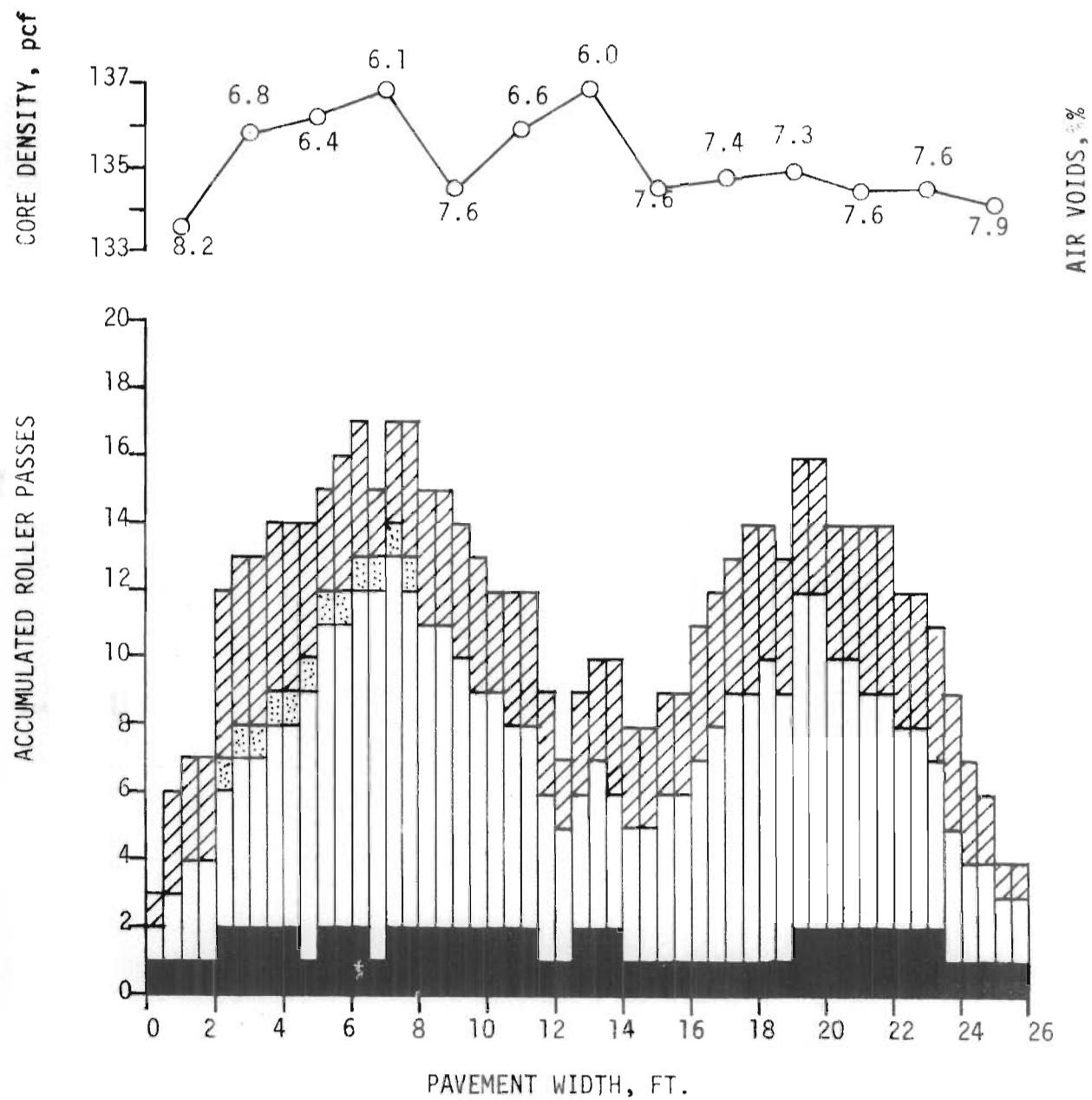
▨ = Finish Roller, 3-Axle Steel, 26,900 #

□ = Inter. Roller No. 2, 11-Wheel Pneum., 32,300#, 70psi, 7.50x15

▨ = Inter. Roller No. 1, 7-Wheel Pneum., 21,000#, 50psi, 11.00x20

■ = Breakdown Roller, 2-Axle Steel, 19,300 #

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS
 TEST NO. 4
 BOTTOM COURSE, 0.20' PLANTMIX

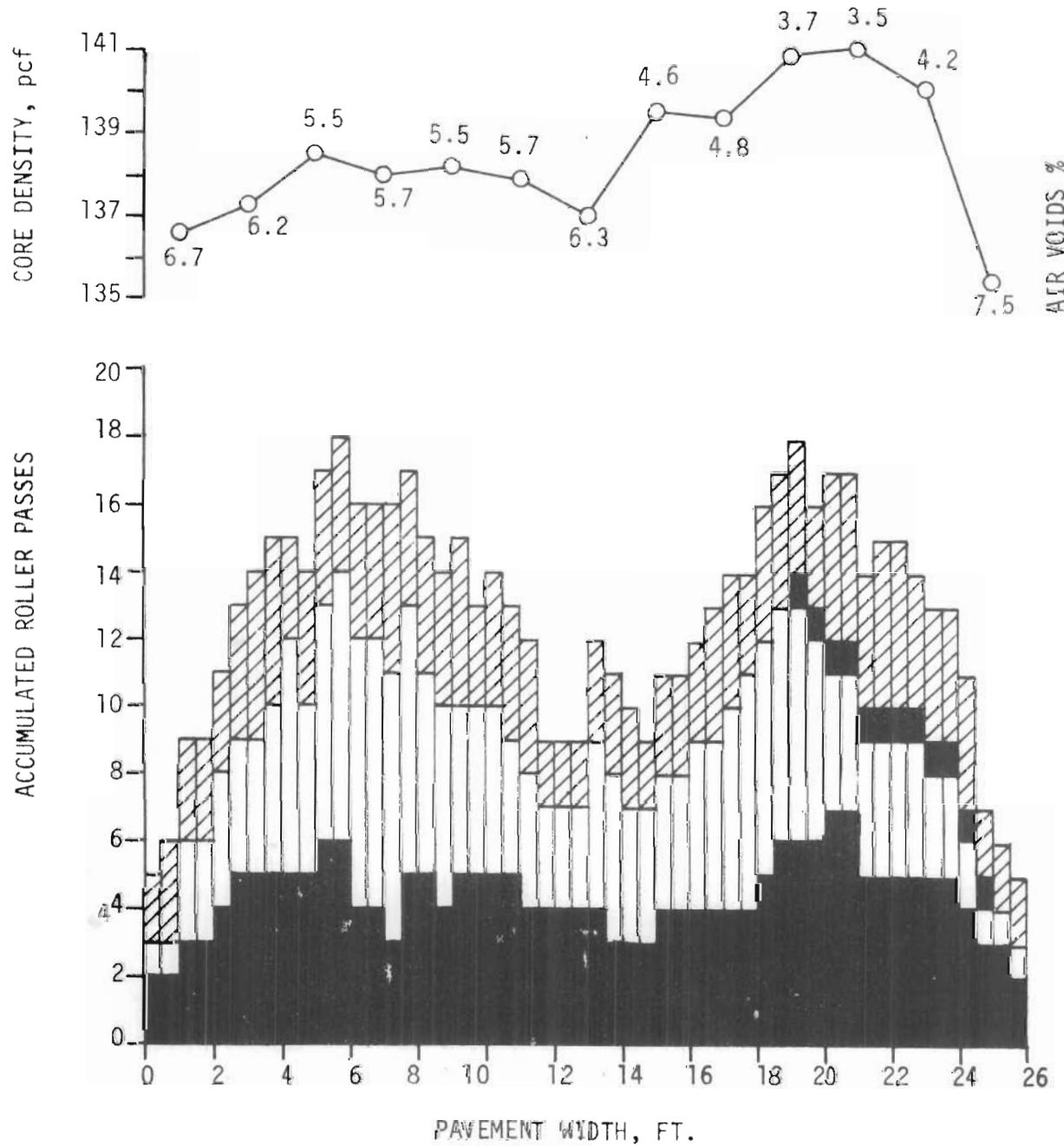


- - Finish Roller, 3-Axle Steel, 26,900 #
- - Inter. Roller No. 1, 11-Wheel Pneum., 32,300#, 55psi, 7150x15
- - Breakdown Roller, 2-Axle Steel, 19,300 #

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

TEST NO. 5

0.4° ATB



■ - Finish Roller, 3-Axle Steel, 26,900#

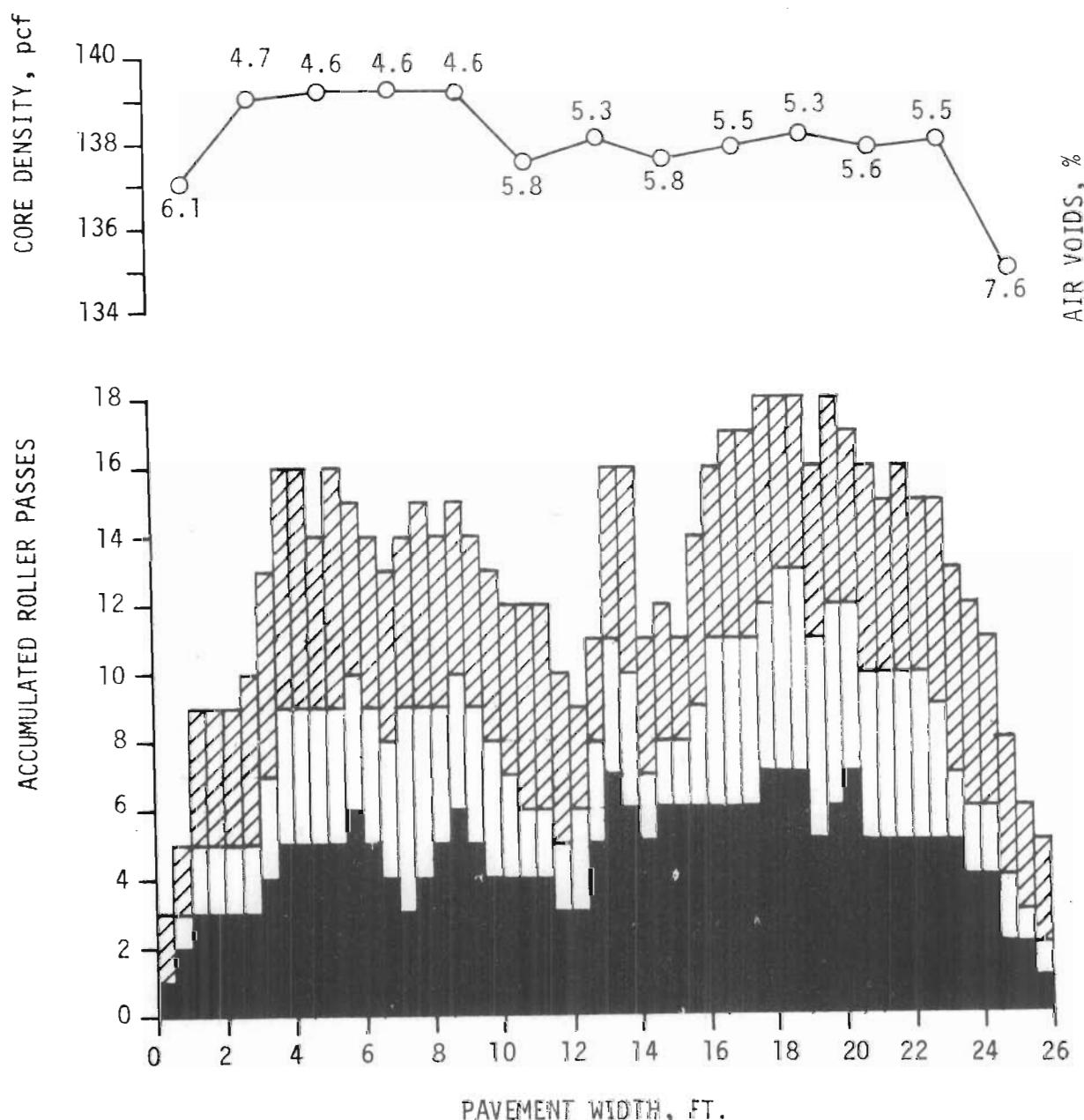
□ - Inter. Roller, 11-Wheel Pneum., 32,300#, 55psi, 7.50x15

■ - B. Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00x20

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

TEST NO. 6

0.4' ATB



▨ - Finish Roller, 3-Axle Steel, 26,900#

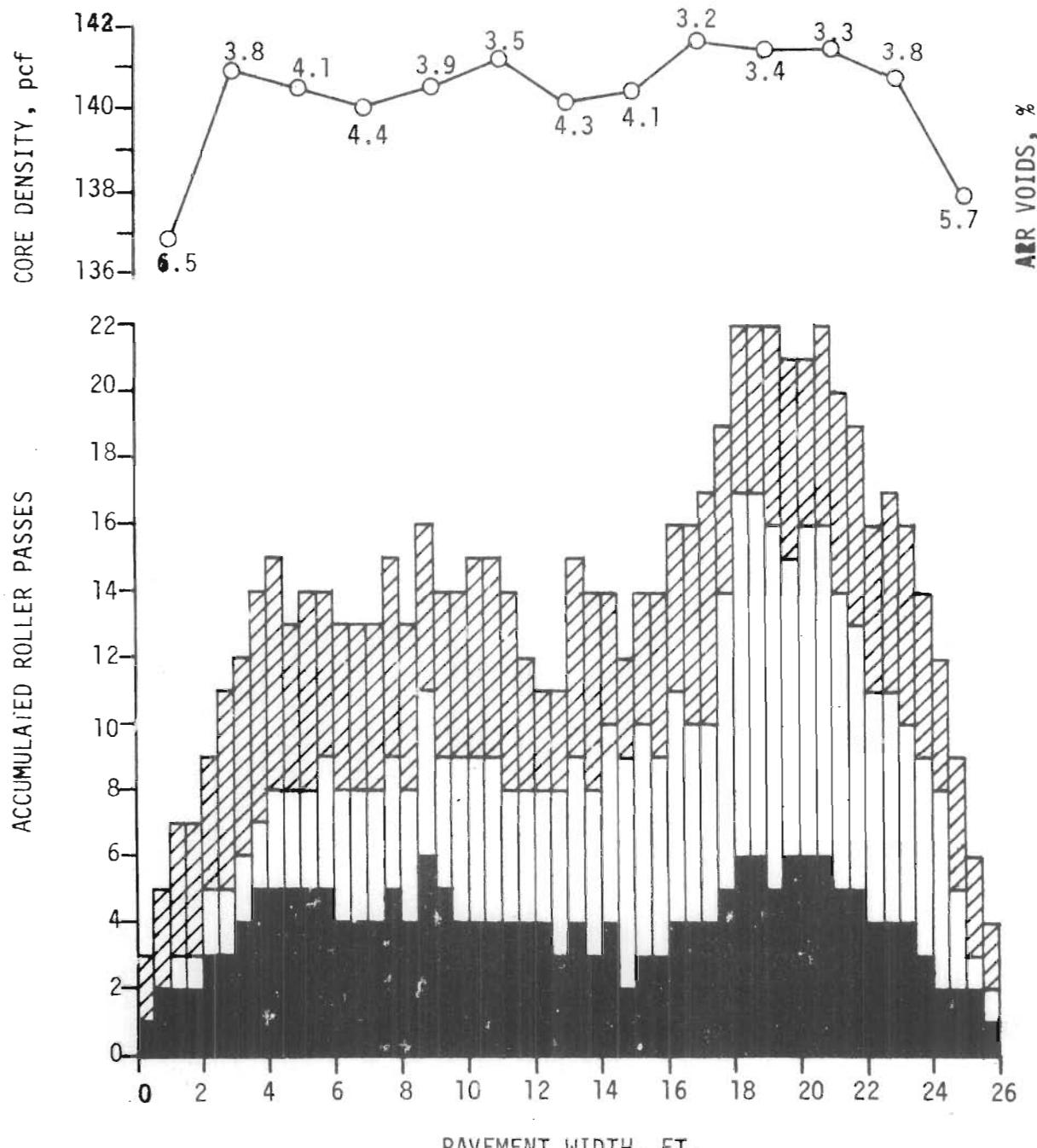
□ - Inter. Roller, 11-Wheel Pneum., 32,300#, 55psi, 7.50x15

■ - B, Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00x20

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

TEST NO. 7

0.4' ATB

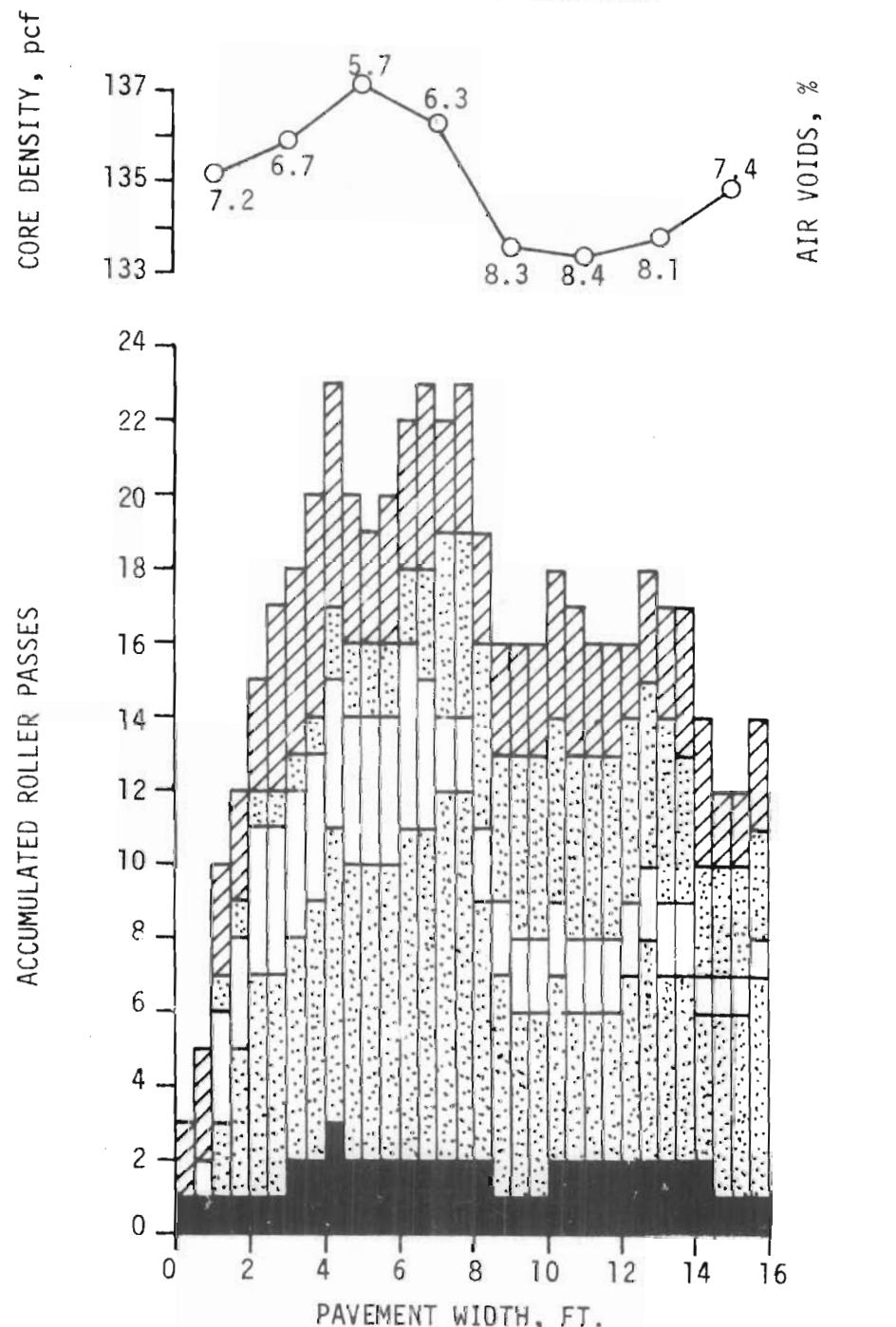


▨ - Finish Roller, 3-Axle Steel, 26,900#

□ - Inter. Roller, 11-Wheel Pneum., 32,300#, 55psi, 7.50 x 15

█ - B. Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00 x 20

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS
 TEST NO. 8
 TOP COURSE, 0.20' PLANTMIX

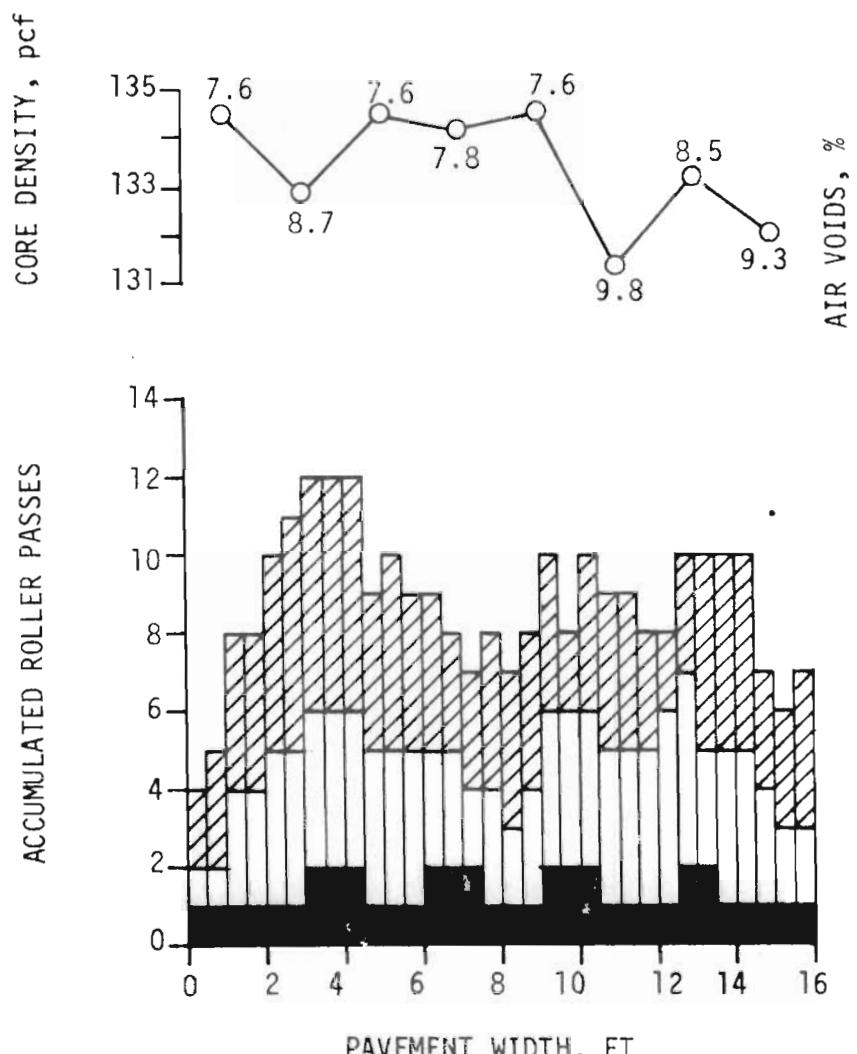


- ▨ - Finish Roller, 3-Axle Steel, 26,900#
- - Inter. Roller No. 2, 7-Wheel Pneum., 21,000#, 50psi, 11.00x20
- ▨ - Inter. Roller No. 1, 11-Wheel Pneum., 32,300#, 60psi, 7.50x15
- - Breakdown Roller, 2-Axle Steel, 19,300#

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

TEST NO. 9

TOP COURSE, 0.20' PLANTMIX



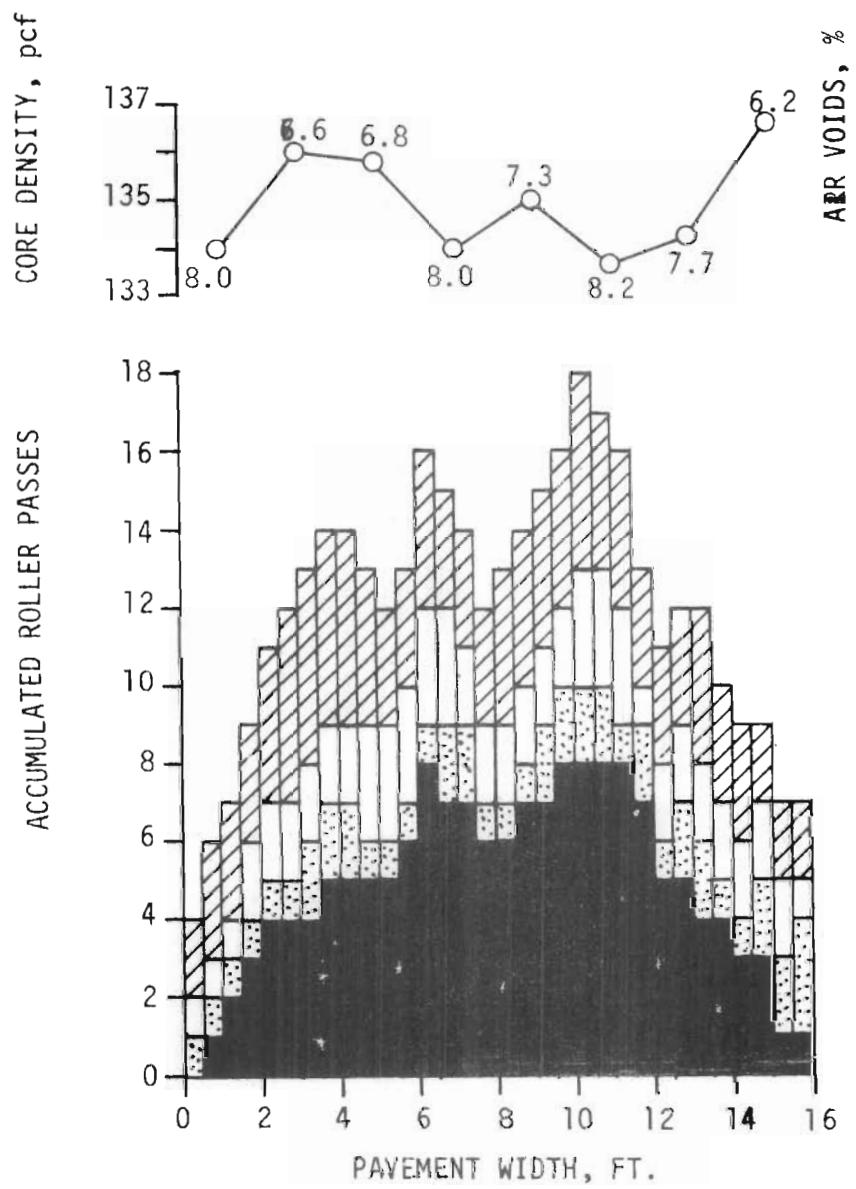
◻ - Finish Roller, 3-Axle Steel, 26,900#

◻ - Inter. Roller, 7-Wheel Pneum., 21,000#, 50psi. 11.00x20

■ - B. Roller, 2-Axle Steel, 19,300#

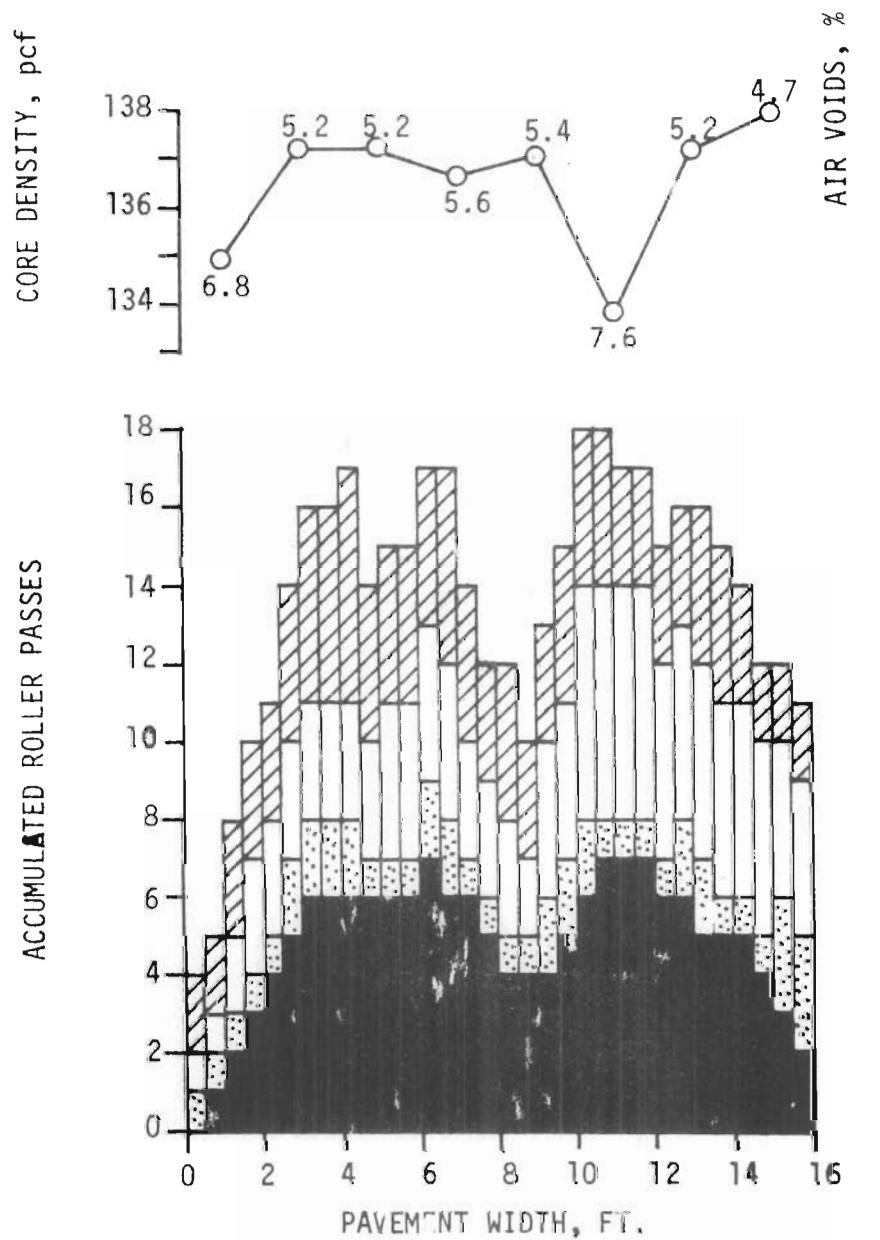
ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS
TEST NO. 10

TOP COURSE 0.20' PLANTMIX



- ▨ - Finish Roller, 3-Axle Steel, 26,900#
- - Inter. Roller No. 2, 11-Wheel Pneum., 32,300#, 60psi, 7.50x15
- ▨ - Inter. Roller No. 1, 2-Axle Steel, 19,300#
- - B. Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00 x 20

ROLLING PATTERN VS. FINAL DENSITY AND AIR Voids
 TEST NO. 11
 TOP COURSE 0.20' PLANTMIX

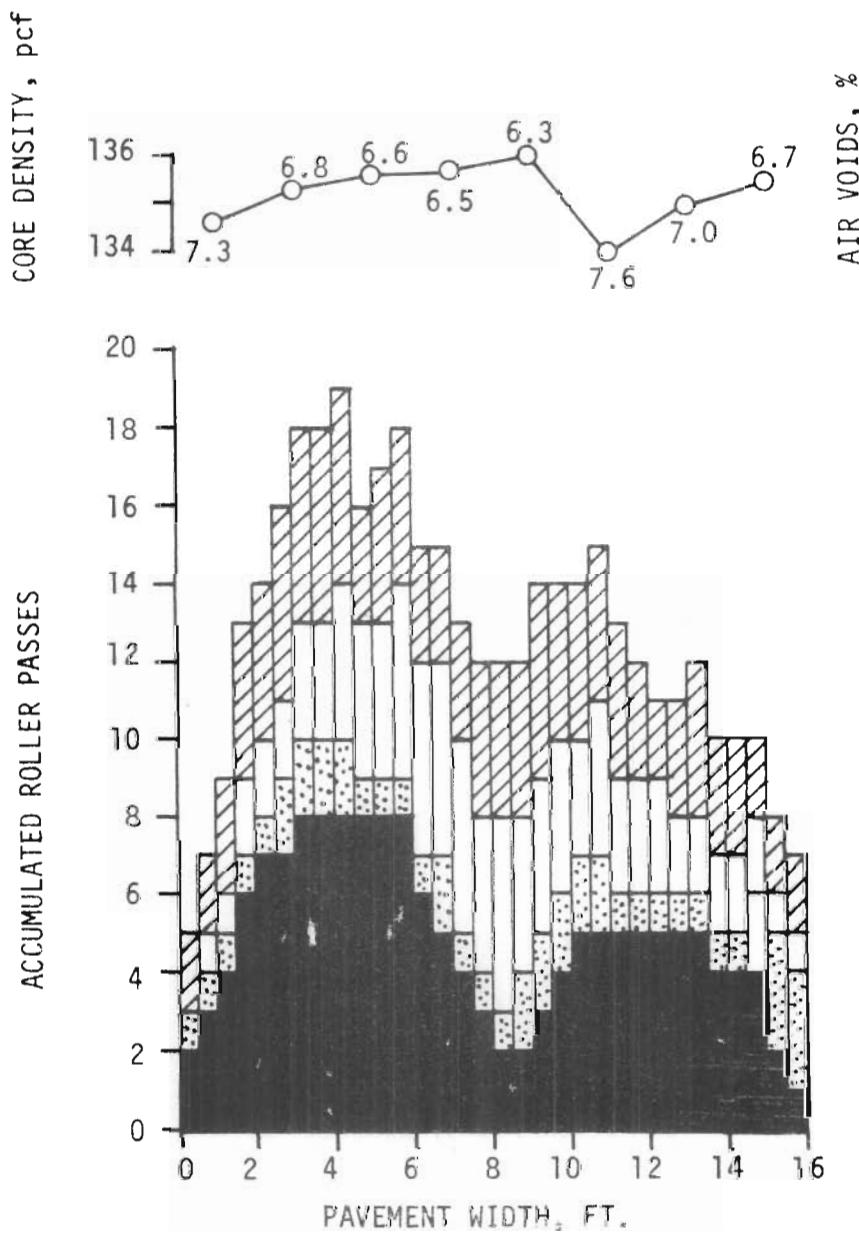


- ▨ - Finish Roller, 3-Axle Steel, 26,900#
- - Inter. Roller No. 2, 11-Wheel Pneum., 32,300#, 60psi, 7.50x15
- ▨ - Inter. Roller No. 1, 2-Axle Steel, 19,300#
- - B. Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00 x 20

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS

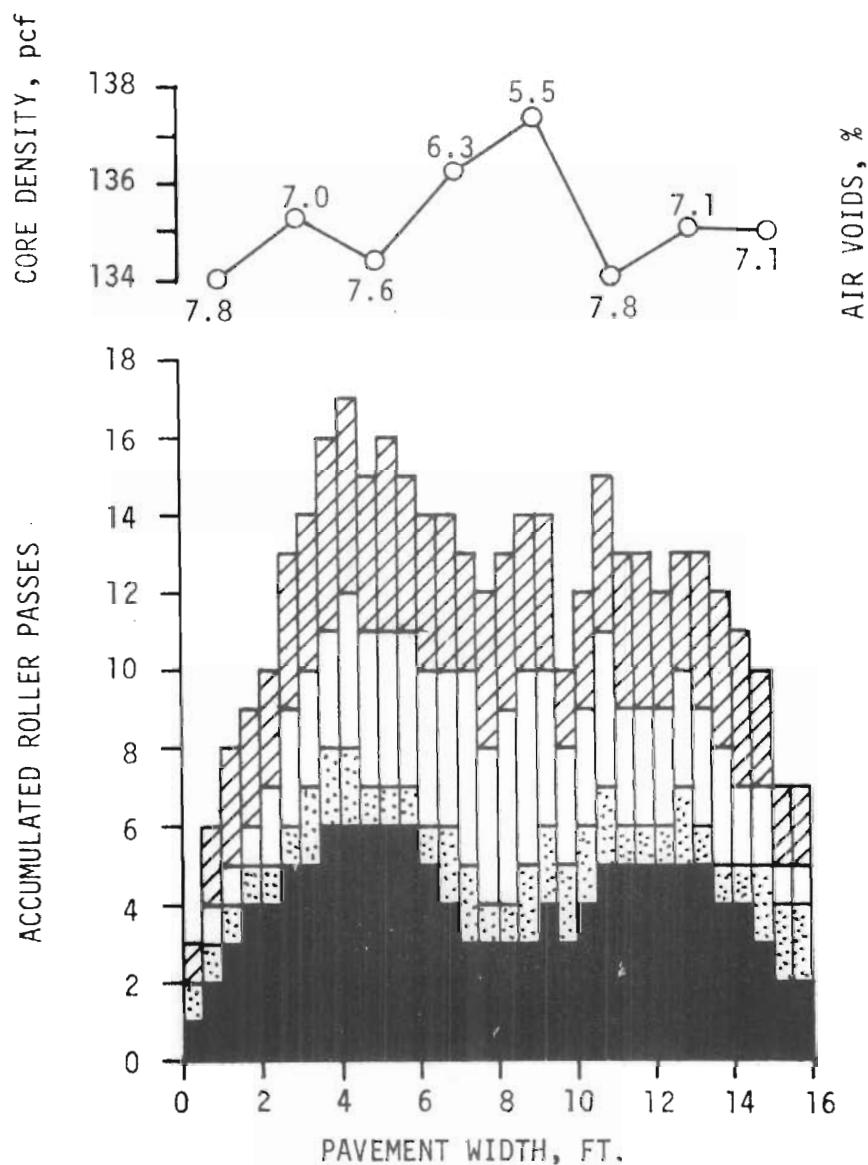
TEST NO. 12

TOP COURSE 0.20' PLANTMIX

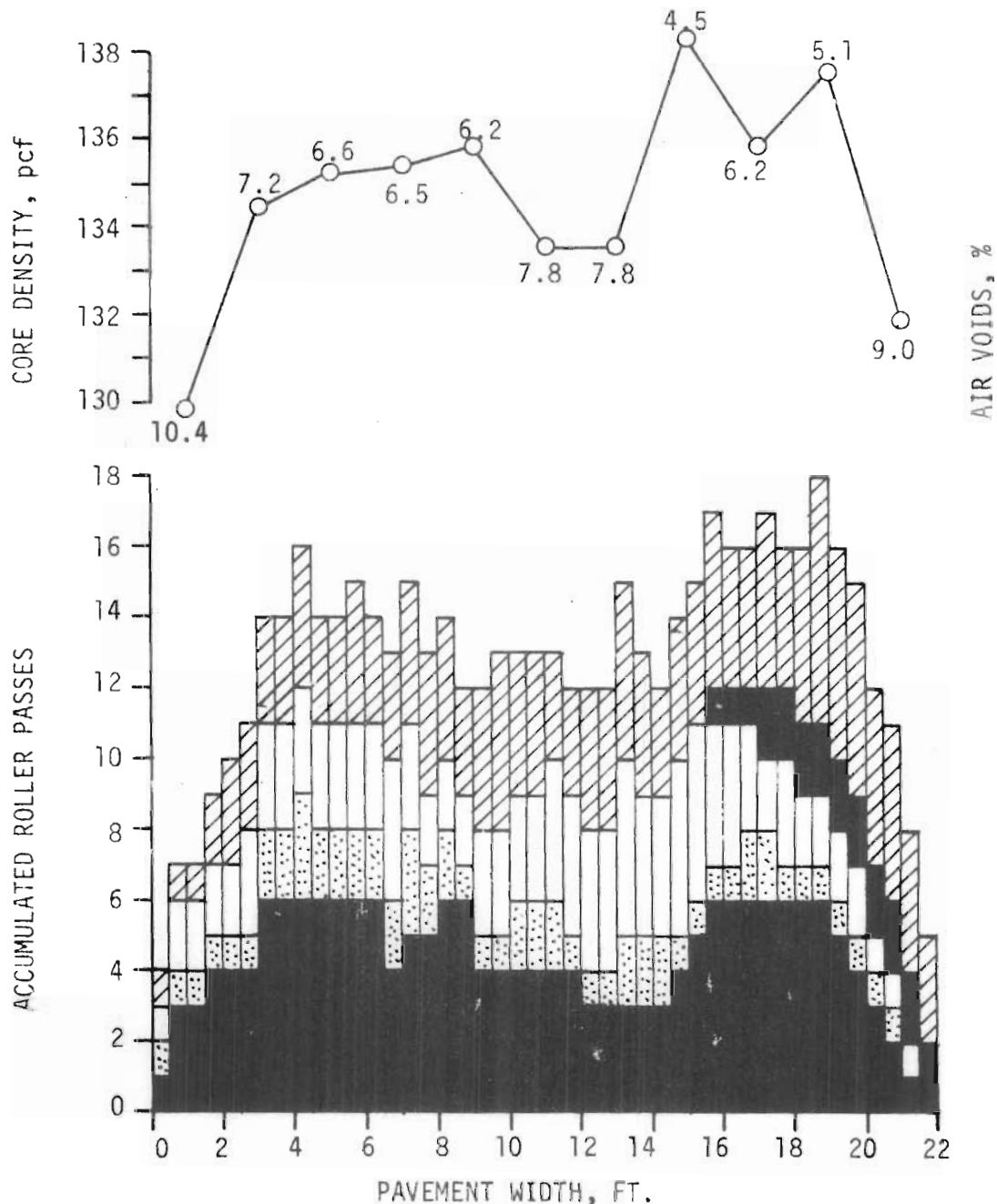


- ◻ - Finish Roller, 3-Axle Steel, 26,900#
- - Inter. Roller No. 2, 11-Wheel Pneum., 32,300#, 60psi, 7.50x15
- ▨ - Inter. Roller No. 1, 2-Axle Steel, 19,300#
- - B. Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00 x 20

ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS
 TEST NO. 13
 TOP COURSE 0.20' PLANTMIX



ROLLING PATTERN VS. FINAL DENSITY AND AIR VOIDS
 TEST NO. 14
 0.20¹ PLANTMIX ON DETOUR



- ◻ -- Finish Roller, 3-Axle Steel, 26,900#
- -- Inter. Roller No. 2, 11-Wheel Pneum., 32,300#, 60psi, 7.50x15
- ▨ -- Inter. Roller No. 1, 2-Axle Steel, 19,300#
- -- B. Roller, 7-Wheel Pneum., 21,000#, 50psi, 11.00 x 20

APPENDIX B
Density-Air Voids Tables

DENSITY AND AIR Voids
TEST NO. 1

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	139.2	4.5	137.1	5.9	140.2	3.8	138.4	5.1
2-4	142.1	2.5	141.9	2.7	143.6	1.5	141.5	2.9
4-6	141.0	3.3	140.8	3.4	143.3	1.7	139.2	4.5
6-8	142.3	2.4	142.4	2.3	143.6	1.5	140.9	3.3
8-10	141.7	2.8	141.7	2.8	141.9	2.7	139.7	4.2
10-12	141.9	2.7	141.3	3.1	142.7	2.1	138.2	5.2
12-14	141.2	3.1	140.1	3.9	142.0	2.6	139.7	4.2
14-16	142.0	2.6	141.7	2.8	142.2	2.4	141.5	2.9
16-18	141.9	2.7	141.6	2.9	142.4	2.3	140.8	3.4
18-20	142.9	2.0	142.7	2.1	143.8	1.4	141.7	2.8
20-22	142.7	2.1	141.6	2.9	144.1	1.1	141.4	3.0
22-24	142.9	2.0	142.0	2.6	143.8	1.3	142.1	2.5
24-26	142.2	2.5	142.4	2.3	142.3	2.4	141.5	2.9
Average, excluding 0-2' Section (inadequate rolling).	142.1	2.6	141.7	2.8	143.0	1.9	140.7	3.5

DENSITY AND AIR VOIDS
TEST NO. 2

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	136.9	6.5	134.8	7.9	137.8	5.9	134.8	7.9
2-4	140.5	4.0	140.4	4.1	141.6	3.3	137.8	5.9
4-6	140.0	4.4	139.5	4.7	140.3	4.2	137.4	6.2
6-8	141.9	3.1	141.7	3.2	142.5	2.7	140.0	4.4
8-10	140.9	3.8	140.9	3.8	141.8	3.1	139.1	5.0
10-12	138.6	5.3	137.1	6.4	139.7	4.6	137.6	6.0
12-14	140.7	3.9	140.5	4.0	142.3	2.8	138.8	5.2
14-16	141.3	3.5	141.7	3.2	141.9	3.1	140.7	3.9
16-18	141.3	3.5	140.6	4.0	142.6	2.6	140.2	4.2
18-20	140.1	4.3	139.1	5.0	140.1	4.3	138.7	5.3
20-22	141.1	3.6	140.8	3.8	141.7	3.2	138.6	5.3
22-24	139.9	4.4	138.4	5.5	140.8	3.8	138.1	5.7
24-26	140.8	3.8	140.9	3.8	141.1	3.6	139.1	5.0
Average, excluding 0-2, section (inadequate rolling).	140.6	4.0	140.1	4.3	141.4	3.4	138.8	5.2

DENSITY AND AIR Voids
TEST NO. 3

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	138.2	5.6	136.8	6.6	138.7	5.3	136.1	7.0
2-4	138.3	5.6	135.9	7.2	139.6	4.6	139.4	4.8
4-6	140.0	4.4	139.2	4.9	141.6	3.3	138.2	5.6
6-8	141.2	3.6	141.6	3.3	142.7	2.5	139.0	5.0
8-10	140.3	4.2	142.4	2.7	140.9	3.8	138.4	5.5
10-12	140.8	3.8	140.6	4.0	142.5	2.7	138.9	5.1
12-14	141.7	3.2	140.6	4.0	142.6	2.6	141.1	3.6
14-16	141.0	3.7	139.9	4.4	142.1	2.9	139.9	4.4
16-18	142.7	2.5	140.9	3.8	145.5	0.6	140.8	3.8
18-20	141.1	3.6	141.1	3.6	142.0	3.0	139.4	4.8
20-22	140.9	3.8	140.1	4.3	141.9	3.1	138.7	5.3
22-24	139.4	4.8	137.8	5.9	140.2	4.2	139.0	5.0
24-26	140.1	4.3	140.1	4.3	142.4	2.7	138.4	5.5
Average, excluding 0-2' section (in- adequate rolling).	140.6	4.0	140.0	4.4	142.0	3.0	139.3	4.9

DENSITY AND AIR Voids
TEST NO. 4

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	133.6	8.2	135.2	7.2			132.6	9.0
2-4	135.8	6.8	136.8	6.1			135.2	7.2
4-6	136.3	6.4	136.0	6.6			137.2	5.8
6-8	136.8	6.1	137.0	5.9			137.1	5.9
8-10	134.6	7.6	134.0	8.0			134.9	7.4
10-12	136.0	6.6	135.5	7.0			136.3	6.4
12-14	136.9	6.0	136.8	6.1			136.9	6.0
14-16	134.5	7.6	134.7	7.5			134.8	7.4
16-18	134.8	7.4	135.7	6.8			135.4	7.0
18-20	135.0	7.3	135.1	7.2			135.6	6.9
20-22	134.5	7.6	134.8	7.4			133.5	8.3
22-24	134.6	7.6	134.3	7.8			135.0	7.3
24-26	134.2	7.9	133.6	8.3			134.7	7.5
Average, excluding 1st & last section	135.4	7.0	135.5	6.9			135.6	6.9

DENSITY AND AIR Voids
TEST NO. 5

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	136.5	6.7	136.9	6.4	137.4	6.1	134.4	8.1
2-4	137.2	6.2	137.2	6.2	138.3	5.4	135.3	7.5
4-6	138.4	5.5	139.0	5.0	138.6	5.2	135.3	7.5
6-8	138.0	5.7	138.6	5.2	138.7	5.2	133.9	8.5
8-10	138.2	5.5	137.9	5.7	137.9	5.7	136.3	6.8
10-12	137.9	5.7	137.9	5.7	139.2	4.8	136.6	6.6
12-14	137.0	6.3	136.6	6.6	138.3	5.4	135.8	7.2
14-16	139.5	4.6	138.7	5.2	141.4	3.3	138.0	5.7
16-18	139.3	4.8	139.6	4.6	140.2	4.2	139.8	4.4
18-20	140.9	3.7	138.5	5.3	143.8	1.7	140.8	3.7
20-22	141.1	3.5	139.3	4.8	144.1	1.5	139.8	4.4
22-24	140.1	4.2	137.3	6.1	143.4	2.0	138.3	5.4
24-26	135.3	7.5	132.8	9.2	136.3	6.8	136.0	7.0
Average, excluding 1st & last section	138.9	5.1	138.2	5.5	140.4	4.0	137.3	6.2

DENSITY AND AIR Voids
TEST NO. 6

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	137.0	6.1	138.1	5.3	138.3	5.2	134.9	7.5
2-4	139.0	4.7	140.1	4.0	140.7	3.6	137.0	6.1
4-6	139.2	4.6	139.5	4.4	140.7	3.6	137.9	5.5
6-8	139.2	4.6	140.7	3.6	141.0	3.4	135.5	7.1
8-10	139.2	4.6	140.1	4.0	140.8	3.5	137.3	5.9
10-12	137.5	5.8	138.4	5.1	139.0	4.7	135.2	7.3
12-14	138.1	5.3	139.0	4.7	140.3	3.8	136.4	6.5
14-16	137.5	5.8	138.7	4.9	139.1	4.7	136.0	6.8
16-18	137.8	5.5	139.1	4.7	140.1	4.0	135.5	7.1
18-20	138.2	5.3	139.4	4.4	139.9	4.1	137.2	6.0
20-22	137.7	5.6	137.9	5.5	139.6	4.3	136.8	6.2
22-24	137.9	5.5	137.6	5.7	139.1	4.7	137.5	5.8
24-26	134.8	7.6	135.8	6.9	136.7	6.3	133.6	8.4
Average, (excluding 1st and last section.)	138.3	5.2	139.1	4.6	140.0	4.0	136.6	6.4

DENSITY AND AIR Voids

TEST NO. 7

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	136.8	6.5	136.5	6.7	138.3	5.5	135.1	7.6
2-4	140.8	3.8	141.4	3.4	142.1	2.9	138.6	5.3
4-6	140.4	4.1	140.8	3.8	141.8	3.1	138.4	5.4
6-8	139.9	4.4	141.6	3.2	140.8	3.8	136.9	6.5
8-10	140.6	3.9	141.4	3.4	141.5	3.3	138.2	5.6
10-12	141.2	3.5	141.5	3.3	141.8	3.1	138.5	5.3
12-14	140.1	4.3	140.5	4.0	141.5	3.3	136.6	6.6
14-16	140.4	4.1	140.5	4.0	140.8	3.8	137.8	5.8
16-18	141.7	3.2	141.3	3.4	142.5	2.6	141.2	3.5
18-20	141.4	3.4	142.2	2.8	142.3	2.8	138.8	5.1
20-22	141.5	3.3	142.2	2.8	142.1	2.9	139.6	4.6
22-24	140.7	3.8	142.1	2.9	140.7	3.8	139.0	5.0
24-26	138.0	5.7	136.8	6.5	139.0	5.0	136.6	6.7
Average (less 1st and last sections.)	140.8	3.8	141.4	3.4	141.6	3.2	138.5	5.3

DENSITY AND AIR Voids
TEST NO. 8

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	135.1	7.2	134.8	7.4			135.1	7.2
2-4	135.8	6.7	135.8	6.7			135.9	6.6
4-6	137.2	5.7	137.1	5.8			137.7	5.4
6-8	136.3	6.3	135.5	6.9			136.7	6.1
8-10	133.5	8.3	133.1	8.5			133.5	8.3
10-12	133.3	8.4	133.5	8.3			134.3	7.7
12-14	133.7	8.1	133.9	8.0			133.9	8.0
14-16	134.8	7.4	135.0	7.2			134.4	7.6
16-18								
18-20								
20-22								
22-24								
24-26								
Average	135.0	7.3	134.8	7.4			135.2	7.1

DENSITY AND AIR Voids

TEST NO. 9

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	134.4	7.6	133.9	8.0			134.6	7.5
2-4	132.8	8.7	--	--			--	--
4-6	134.4	7.6	133.3	8.4			135.3	7.0
6-8	134.1	7.8	133.6	8.2			134.0	7.9
8-10	134.5	7.6	134.0	7.9			134.4	7.6
10-12	131.3	9.8	--	--			--	--
12-14	133.2	8.5	130.8	10.1			134.3	7.7
14-16	132.0	9.3	129.7	10.9			133.1	8.5
16-18								
18-20								
20-22								
22-24								
24-26								
Average	133.3	8.4	132.6	8.9			134.2	7.7

DENSITY AND AIR Voids
TEST NO. 10

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	134.0	8.0	133.9	8.0			134.6	7.5
2-4	136.0	6.6	136.6	6.2			135.6	6.9
4-6	135.7	6.8	136.4	6.3			135.6	6.9
6-8	134.0	8.0	134.7	7.5			134.6	7.5
8-10	135.0	7.3	135.3	7.1			135.1	7.2
10-12	133.6	8.2	134.3	7.7			132.7	8.8
12-14	134.3	7.7	133.8	8.1			134.8	7.4
14-16	136.5	6.2	136.2	6.4			137.0	5.9
16-18								
18-20								
20-22								
22-24								
24-26								
Average	134.9	7.4	135.2	7.2			135.0	7.3

DENSITY AND AIR Voids
TEST NO. 11

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	134.9	6.8	135.0	6.7			133.8	7.6
2-4	137.2	5.2	138.0	4.7			136.9	5.4
4-6	137.3	5.2	137.8	4.8			137.2	5.2
6-8	136.6	5.6	136.4	5.8			136.7	5.6
8-10	137.0	5.4	137.4	5.1			136.0	6.1
10-12	133.8	7.6	134.7	7.0			132.9	8.2
12-14	137.2	5.2	137.8	4.8			136.4	5.8
14-16	137.9	4.7	137.6	5.0			138.1	4.6
16-18								
18-20								
20-22								
22-24								
24-26								
Average	136.5	5.7	136.8	5.5			136.0	6.1

DENSITY AND AIR Voids
TEST NO. 12

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	134.5	7.3	134.8	7.1			135.1	6.9
2-4	135.2	6.8	136.5	5.9			134.8	7.1
4-6	135.5	6.6	136.4	6.0			134.8	7.1
6-8	135.6	6.5	135.5	6.6			134.7	7.2
8-10	136.0	6.3	135.7	6.5			136.4	6.0
10-12	134.0	7.6	134.5	7.5			134.1	7.6
12-14	134.9	7.0	135.1	6.9			134.8	7.1
14-16	135.4	6.7	134.9	7.0			135.5	6.6
16-18								
18-20								
20-22								
22-24								
24-26								
Average	135.1	6.8	135.4	6.7			135.0	7.0

DENSITY AND AIR Voids
TEST NO. 13

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	134.0	7.8	134.9	7.2	-	-	134.3	7.6
2-4	135.2	7.0	135.6	6.7	-	-	134.7	7.4
4-6	134.3	7.6	135.3	6.9	-	-	133.9	7.9
6-8	136.2	6.3	136.4	6.2	-	-	136.2	6.3
8-10	137.4	5.5	136.6	6.0	-	-	137.5	5.4
10-12	134.1	7.8	134.7	7.4	-	-	133.3	8.3
12-14	135.1	7.1	135.1	7.1	-	-	134.9	7.2
14-16	135.0	7.1	134.3	7.6	-	-	135.3	6.9
16-18	-	-	-	-	-	-	-	-
18-20	-	-	-	-	-	-	-	-
20-22	-	-	-	-	-	-	-	-
22-24	-	-	-	-	-	-	-	-
24-26	-	-	-	-	-	-	-	-
Average	135.2	7.0	135.4	6.9	-	-	135.0	7.1

DENSITY AND AIR Voids
TEST NO. 14

Distance from edge of lay, ft.	Total Core, pcf	Voids, %	Top 1/3 of core, pcf	Voids, %	Middle 1/3 of core, pcf	Voids, %	Bottom 1/3 of core, pcf	Voids, %
0-2	129.8	10.4	130.1	10.2			128.2	11.5
2-4	134.4	7.2	135.3	6.6			133.4	7.9
4-6	135.2	6.6	135.0	6.8			134.6	7.1
6-8	135.4	6.5	136.2	6.0			134.7	7.0
8-10	135.8	6.2	136.2	6.0			134.8	6.9
10-12	133.5	7.8	134.8	6.9			131.7	9.1
12-14	133.5	7.8	134.6	7.1			131.7	9.1
14-16	138.3	4.5	138.4	4.4			137.0	5.4
16-18	135.8	6.2	135.8	6.2			135.4	6.5
18-20	137.5	5.1	138.0	4.7			135.2	6.6
20-22	131.8	9.0	132.5	8.5			130.8	9.7
22-24								
24-26								
Average, excluding (1st & last Sections)	135.5	6.4	136.0	6.1			134.3	7.3

NUCLEAR DENSITY, PCF*

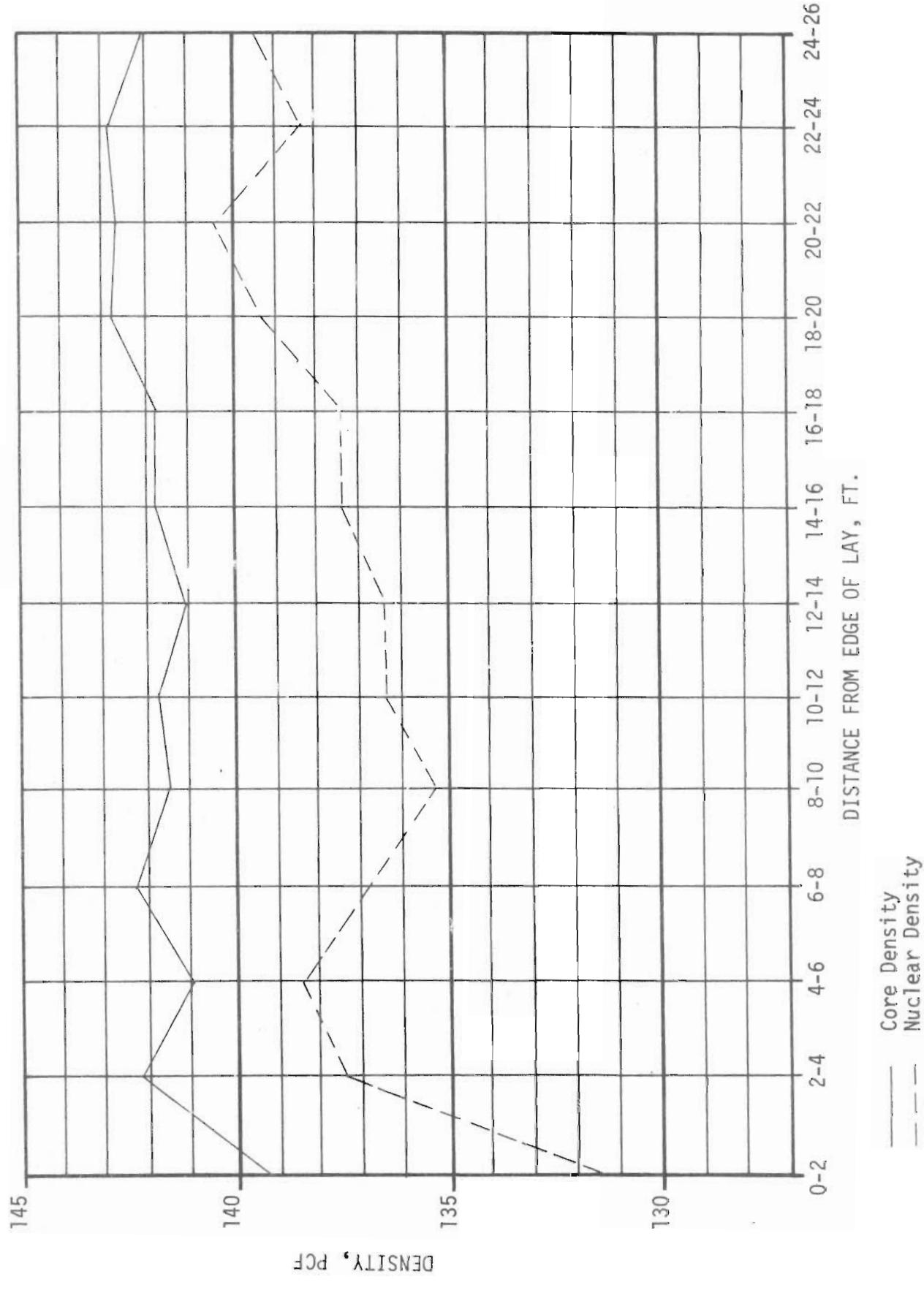
Distance from edge of lay, ft.	Test No. 1	Test No. 2	Test No. 3	Test No. 4	Test No. 5	Test No. 6	Test No. 7	Test No. 8	Test No. 9	Test No. 10	Test No. 11	Test No. 12	Test No. 13	Test No. 14
0-2	131.5 ⁺	131.0	127.5	138.5	135.5	136.5	136.5 ⁺			133.0	136.5	135.5		136.5
2-4	137.5	134.0	131.5	135.5	136.5	137.5	140.5			138.5	139.5	135.5		138.5
4-6	138.5	135.5	136.5	138.5	139.5	139.5	141.5			135.5	136.5	134.0		139.5
6-8	140.5	136.5	136.5	138.5	140.5	140.5	139.5			132.0	137.5	136.5		136.5
8-10	135.5	132.0	134.0	135.5	136.5	139.5	139.5			134.0	139.5	135.5		137.5
10-12	136.5	134.0	134.0	135.5	138.5	138.5	141.5			134.0	135.5	136.5		134.0
12-14	136.5	132.0	135.5	136.5	137.5	137.5	140.5			131.5	135.5	134.0		133.0
14-16	137.5	133.0	135.5	132.0	138.5	137.5	143.5			135.5	138.5	135.5		137.5
16-18	137.5	131.0	134.0	135.5	140.5	137.5	142.5							141.5
18-20	139.5	134.0	136.5	137.5	138.5	141.5	143.5							138.5
20-22	140.5	135.5	136.5	134.0	139.5	139.5	142.5							134.0
22-24	138.5	131.0	133.0	136.5	138.5	136.5	142.5							
24-26	139.5	131.0	129.5 ⁺	133.0	136.5	134.0 ⁺	138.5 ⁺							
AVERAGE (+ = Value Omitted)	138.2	133.1	134.9	135.9	138.4	138.5	141.6			134.2	137.4	135.4		137.0

* These are relative densities, not corrected to actual field densities.

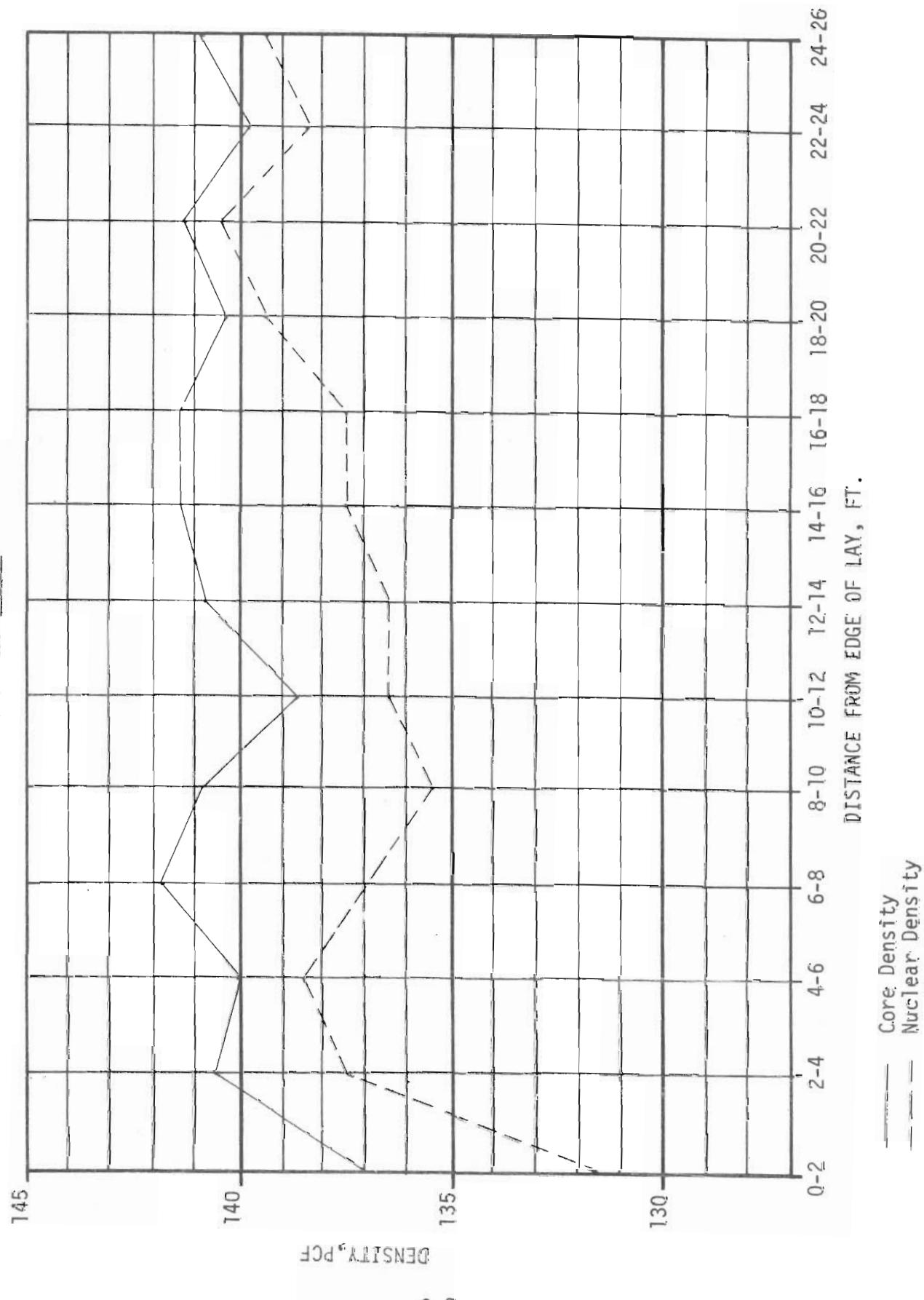
APPENDIX C

Nuclear Density and Core Density
vs.
Distance from Pavement Edge

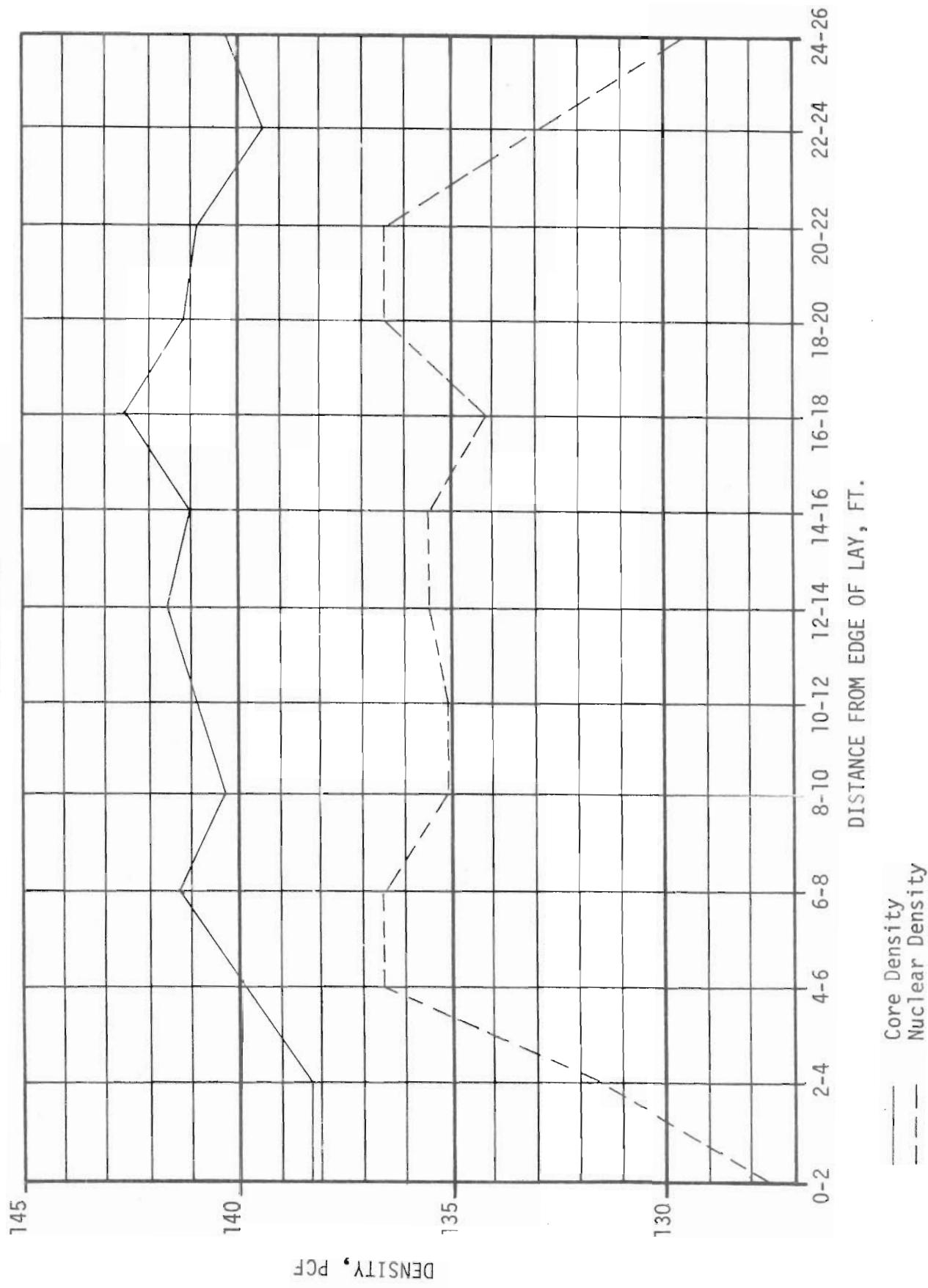
TREND OF CORE VS. NUCLEAR DENSITY
TEST No. — 1



TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 2

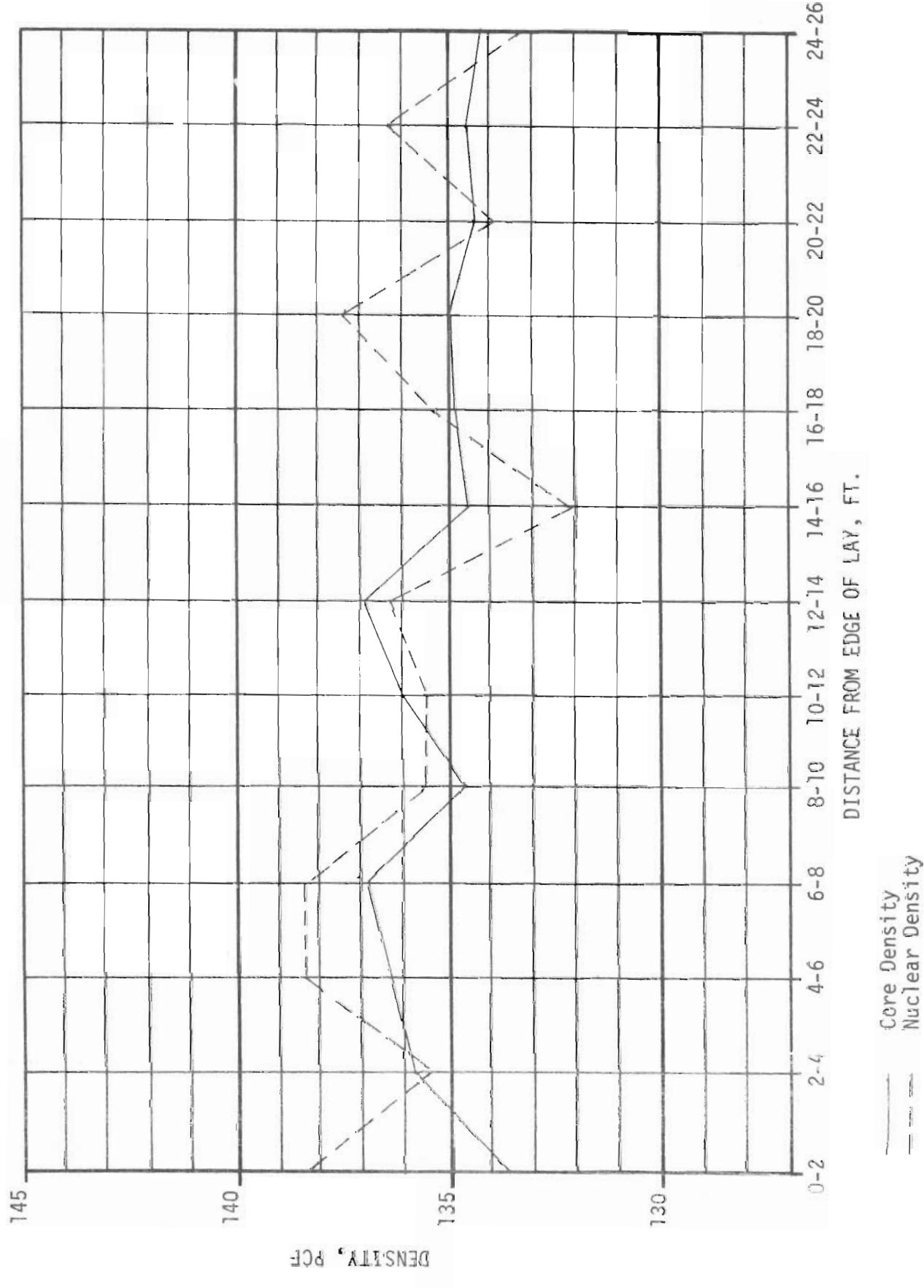


TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 3

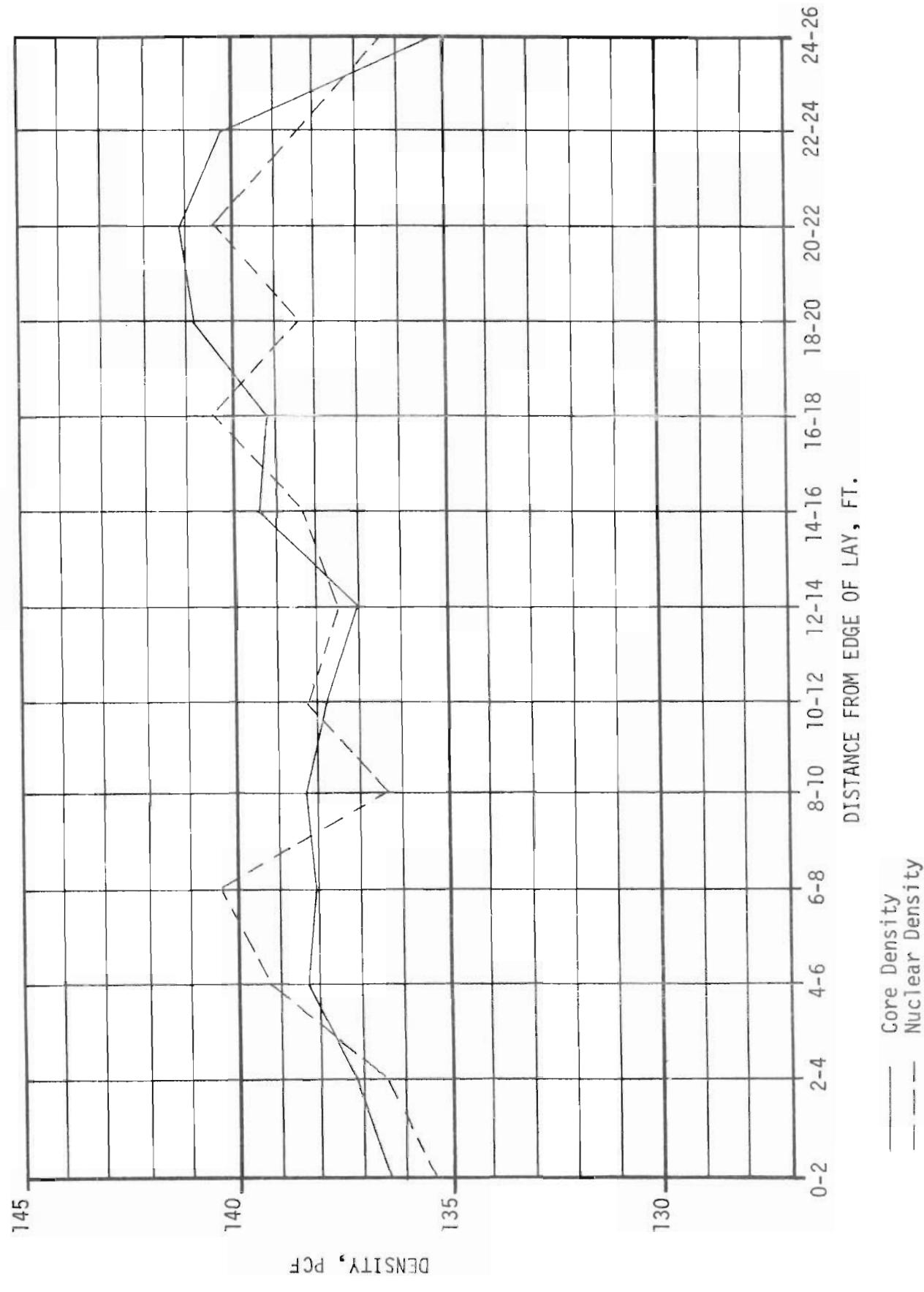


C-3

TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 4



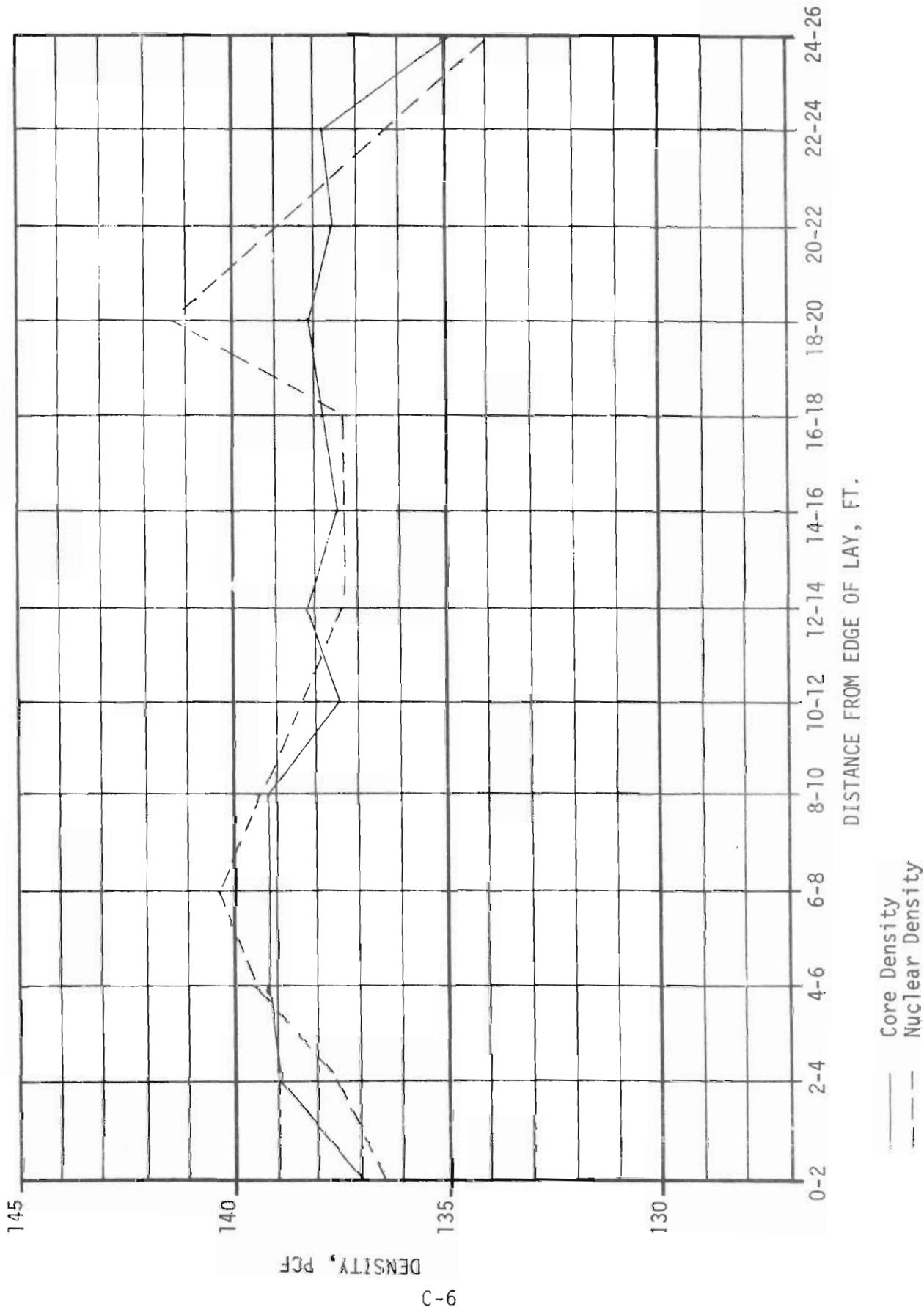
TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 5



DENSITY, PCF

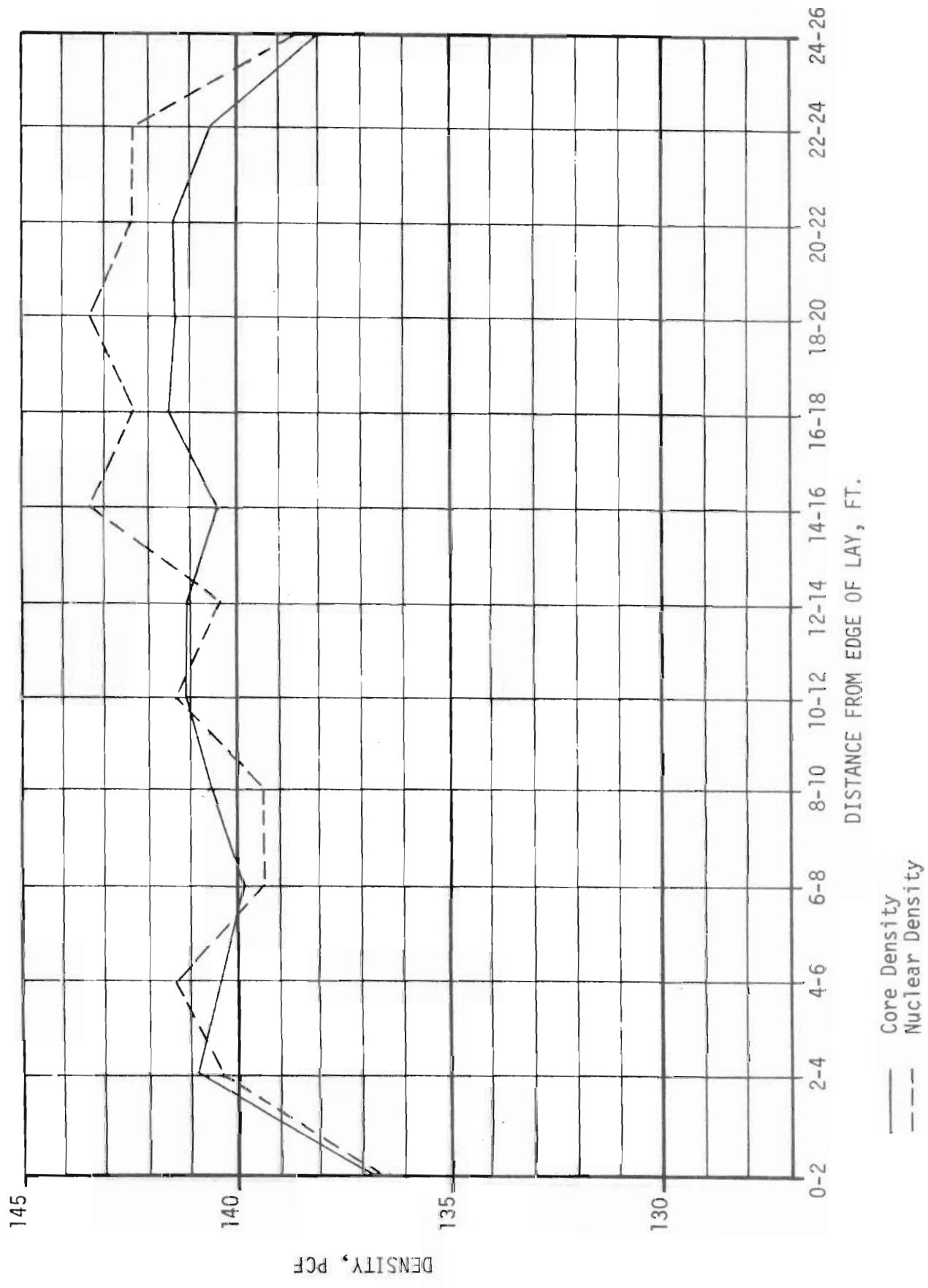
C-5

TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 6



TREND OF CORE VS. NUCLEAR DENSITY

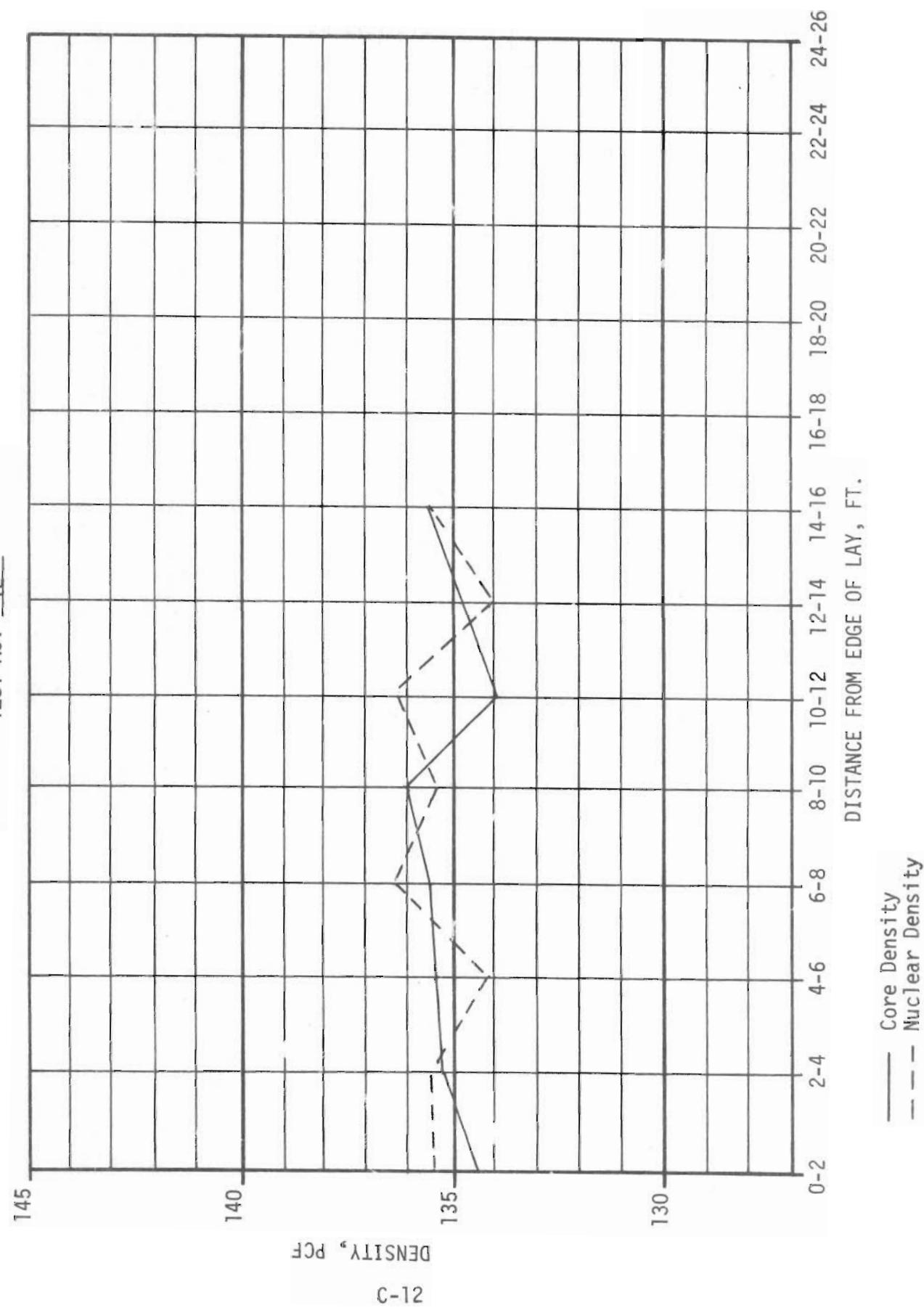
TEST No. 7



DENSITY, PCF

C-6

TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 12



TREND OF CORE VS. NUCLEAR DENSITY
TEST No. 14

