COMPACTION OF BITUMINOUS CONCRETE WITH SELF-PROPELLED PNEUMATIC TIRE ROLLERS IN LOUISIANA

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With the appearance of accelerated rutting of new asphaltic concrete pavement on primary routes, the Louisiana Department of Highways decided to undertake an investigation to provide means to minimize this situation.

The study was made during the overlaying of State Project 7-07-13 (FAP: F-172(12)), Prairieville-Sorrento Highway on US 61, which has a traffic volume of 11,000 vehicles per 24 hours. The original 20 feet wide concrete slab, 8-6-8 in. was widened to a 24 feet roadway with the addition of a 4 feet uniform concrete section 8 inches thick.

The project, contracted by Texas Bitulithic Company, was overlayed with 3-1/2 inches of asphaltic concrete, consisting of 2 inches of binder course and 1-1/2 inches of wearing course.

Scope

The main objective of this investigation was to study the possibilities of improving the density of asphaltic concrete pavements at the time of construction to approach the values obtained during the first year of

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traffic service, in order to eliminate excessive rutting (longitudinal grooves) resulting from additional densification by heavy loads. Furthermore, it was intended to determine the optimum requirements; such as, the required number of passes of roller, weight, tire pressure and approximate rolling temperatures.

It was also planned to use the measurement devices, installed during this work, in an extended temperature study of asphaltic concrete pavements to determine the maximum and minimum seasonal temperatures obtained in Louisiana.

Special Equipment and Personnel

Special equipment used on the project consisted of a Tampo SP-9S self-propelled 9 ton pneumatic tire roller (Figure 1). The general specifications for this roller are given in Table 1.

In this particular investigation, the Tampo SP-9S was used in all cases with a constant weight of 15,700 lb.

The personnel consisted of two crews; one at the plant, sampling the trucks and molding Marshall briquettes and another on the roadway, checking the temperatures and controlling the rolling operations throughout the test sections.

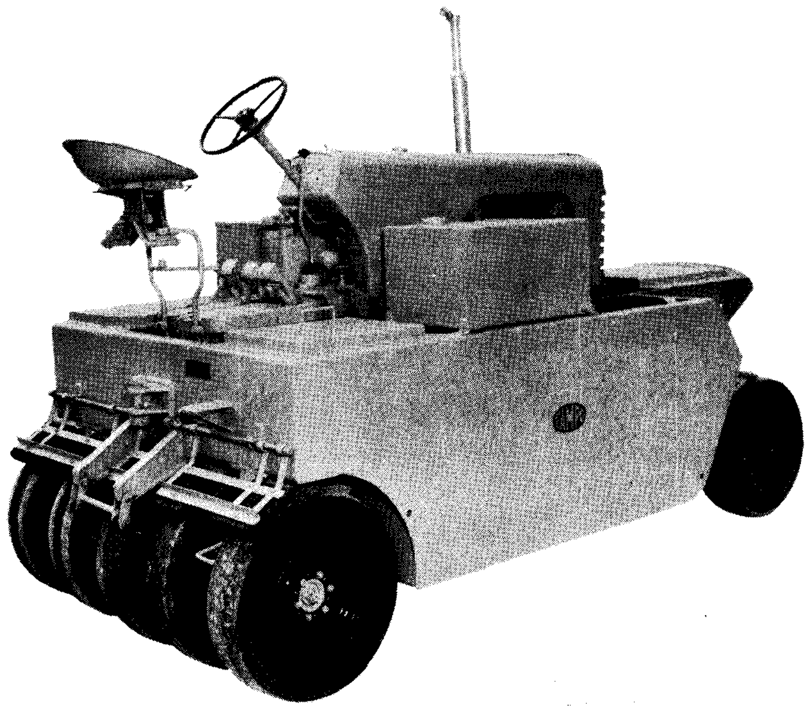


Figure 1 - TYPICAL SELF-PROPELLED (TAMPO SP-9S) PNEUMATIC TIRE ROLLER
Coco mats and water tanks shown in the picture were not available in this study.

Courtesy of Tampo Manufacturing Co.

TABLE 1

GENERAL SPECIFICATIONS FOR THE SP-9S TAMPO ROLLER

Rolling Width	72 in.
Empty Weight	6,200 lb
Maximum Gross Weight	18,900 lb
Number of Wheels	
Front	4
Rear	5
Maximum Tire Pressure	55 lb
Tire Ply	4
Working Speeds (mph)	
Forward	2.5 to 4.5 mph
Reverse	2.5 to 4.5 mph

Selection of Test Sections

The test sections used were selected on straight stretches of roadway and care was taken to keep these sections away from the existing roadway turnouts and intersections, so as to avoid any disturbance or added compaction due to crossing traffic. They varied in length from 200 feet to 300 feet. A summary, showing their beginning and ending stations, compactive efforts and tire pressures of the pneumatic roller, is shown in Table 2.

Table 2

LOCATION AND CHARACTERISTICS OF TEST SECTIONS

Section	Station		Passes			Tire
	Start	End	3-Wheel	Pneumatic	Tandem	Pressure, psi
5	321+30	326+50	5	21	7	55
7	80+00	82+00	5	9	7	55
8	77+50	79+50	5	13	7	55
9	75+00	77+00	5	Control	7	--
10	70+00	72+00	5	15	7	55
11	67+00	69+00	5	17	7	55

Spreading

All trucks leaving the plant were sampled, assigned a number for identification on the road, and the asphaltic concrete was tested for specific gravity, Marshall stability and flow, screen analysis and asphalt content. Upon arrival at the job site, the average temperatures of the hot mix were recorded before dumping same into the spreader. The length of the pavement covered by each load was recorded by stations, in order to be able to correlate the roadway cores with Laboratory compacted samples taken from their respective truck loads.

Immediately behind the spreader and before the three-wheel roller, two thermo-couples, sensitive to 1 F, were placed within the wearing course. This was done by cutting the hot mix with a straightedge, placing the thermo-couples in the cut and covering. A Leeds and Northrop Potentiometer was then used to measure the temperatures.

Rolling

Following the spreader and after the temperatures were taken at each thermo-couple, the rolling was started with the three-wheel roller, five passes* (approximately 2-1/2 coverages)** were made by the three-wheel roller on all test sections. Upon completion of these five passes and before the pneumatic roller was used, additional readings of the temperatures were taken. Passes of the pneumatic roller and its tire pressure were the only variables in the investigation. Forty pounds per square inch of tire pressure was used on the first two sections and was increased to 55 psi thereafter. The weight of the pneumatic roller, as previously mentioned, was kept constant at 15,700 lb.

The number of passes was controlled carefully and was varied as based on results of the preceding test section - then gradually increased to 21 (approximately 10-1/2 coverages).

Following the temperature readings taken upon completion of pneumatic rolling, 7 passes (approximately 3-1/2 coverages) of the tandem roller completed rolling operations. Final temperature readings were then taken and recorded. This sequence and the same rollers were used throughout the project.

The control section was rolled in the same manner using the same number of passes of the three-wheel and tandem rollers in accordance with the requirements of the Department.

(*) one pass of the roller is one trip - one roller width wide, 6 feet - over the whole length of the section.

(**) one coverage is a complete coverage of the 12' land, in this case two passes of the roller.

Tire pressure, as mentioned previously, was increased from 40 psi to 55 psi after the completion of the first two sections. It was observed that nine and thirteen passes at 40 psi did not help density but merely improved surface texture by working the fines to the top.

Coring

No traffic was allowed on the sections until they were cored in order to avoid any disturbance or additional compaction. A truck mounted Molco core drill, employing a bit, 4-1/4 inches in diameter, was used for sampling. Prior to coring, a piece of, "dry ice," was laid on the area to be cored for ten minutes. When pavement was sufficiently cool (approximately 32 F) drilling was started and a constant flow of compressed carbon dioxide gas (CO_2) was applied to the bit to avoid excessive rise in temperature. The cores, 4 inches in diameter, were then tested for specific gravity at the Laboratory.

Calculations

Three different methods were used in calculation of percentage of compaction of different test sections.

Method A - In this first method, the average of the specific gravities of all cores in each section was used as the representative, "average of section specific gravity," and compared to the theoretical specific gravity (2.414) of the job mix formula. These results are given in Table 4.

TABLE 4

PERCENTAGE OF COMPACTION AS COMPARED TO THEORETICAL GRAVITY

Passes of Pneumatic Roller	55 lb Tire Pressure Average Core Specific Gravity	55 lb Tire Pressure Percent of Theoretical Gravity
Control	2.246	93.04
9	2.260	93.62
13	2.273	94.16
15	2.295	95.08
17	2.278	94.37
21	2.252	93.29

Method B - In the second method, comparison of the core averages used in Case A and Table 4 was made to the average of the specific gravities of all roadway samples (2.257) taken from the entire project. Results of this comparison are shown in Table 5.

TABLE 5

PERCENTAGE OF COMPACTION AS COMPARED TO ROADWAY SAMPLES OF THE ENTIRE PROJECT

Passes of Pneumatic Rollers	Percent of Roadway Sample Specific Gravity of the Entire Project 55 psi Tire Pressure
Control	99.51
9	100.13
13	100.71
15	101.68
17	100.93
21	99.78

Method C - In the third and last method, specific gravity of each core was compared to specific gravity of briquettes molded from the same truck load of hot mix as the one from which the core was taken. In other words, the hot mix from which briquettes were made and cores were cut, came from the same load. The percentages of compaction thus obtained were averaged as percent of compaction of each section and are shown in Table 6.

TABLE 6

PERCENTAGES OF COMPACTION AS COMPARED TO THE CORRESPONDING BATCH BRIQUETTES

Passes of Pneumatic Rollers	Percent Laboratory Briquette Gravity 55 psi Tire Pressure
Control	95.90
9	96.62
13	97.19
15	97.66
17	97.13
21	96.36

Discussion of Test Results - Immediately After Construction

In all of the different methods used for evaluation of results, there is a definite increase in percentage of compaction of the pavement when pneumatic tire roller is used (Figure 2). It is also noted that after a certain increase of the number of passes, this percentage tends to decrease. In other words, it increases to a certain peak and then decreases. It is

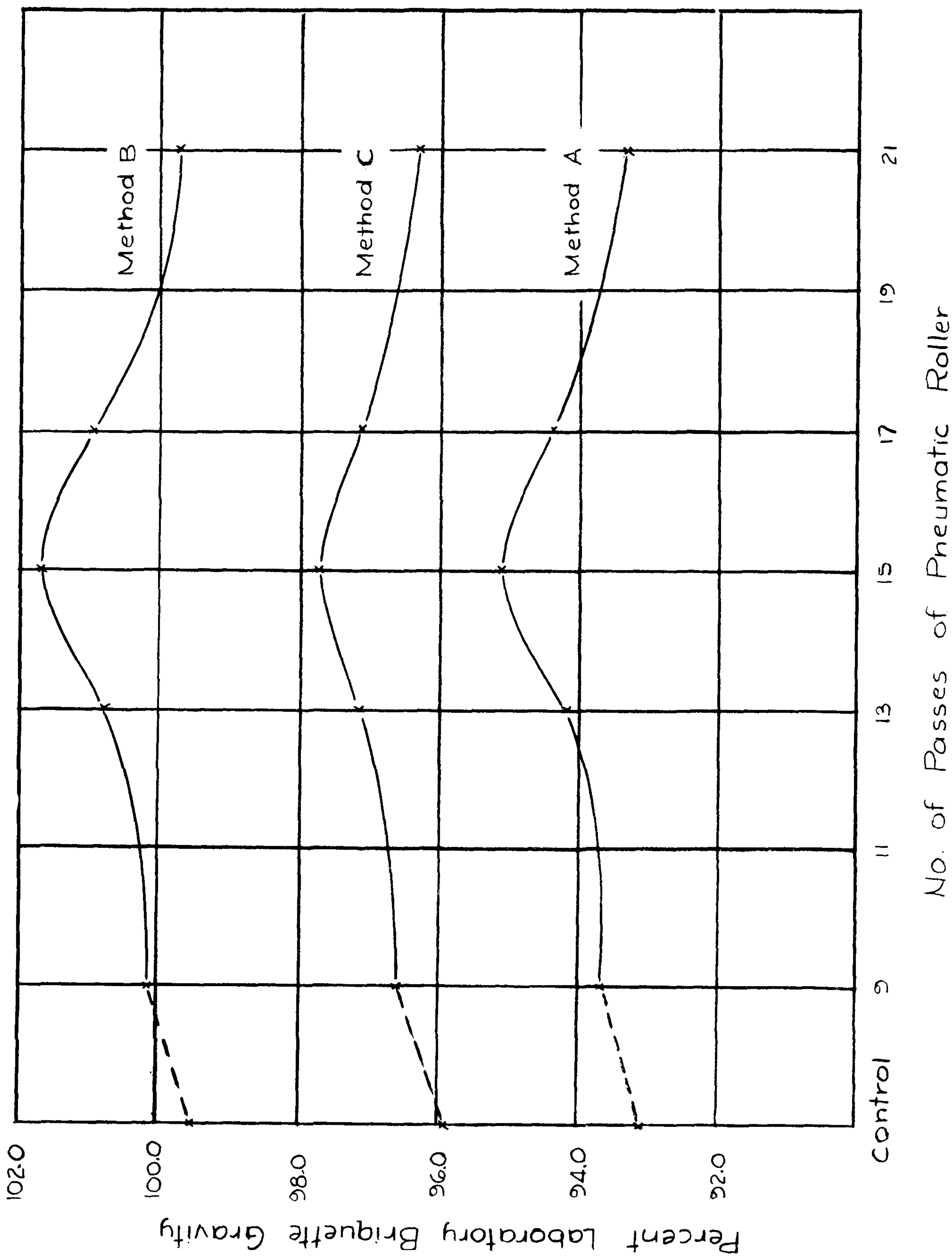

Method B
Method C
Method A
102.0
100.0
98.0
96.0
94.0
92.0
Percent Laboratory Briquette Gravity
Control
9
11
13
15
17
19
21
No. of Passes of Pneumatic Roller

Fig. 2

our belief that the true method of comparison would be Case C, where each roadway sample is compared to a briquette made from the same truck load. In this method of comparison, all the variables that affect the compaction of a mixture - such as temperature, composition, asphalt content and any possible change in the theoretical gravity - would be eliminated, or at least minimized. Hence, each truck load would be evaluated as based on its densification ability rather than some value determined theoretically. In this case and in all other cases, percentage of compaction reaches a maximum at 15 passes, as shown in Figure 3, giving an additional density of 1.76 percent by difference, as compared to the control section. It should be noted here that exudation of the asphalt to the surface was not observed at 15 passes. Therefore, this compactive effort will <u>not</u> require a change in the mix design procedure but will merely increase the roadway density to the desired value as necessitated by increased traffic, within allowable tolerances. Nevertheless, these are only the present indications and other cases may prove otherwise.

Twenty-one passes of the rubber tire roller is believed to be excessive and detrimental because of slight exudation of asphalt to the surface of the mixture. This situation would definitely require a change in the design criteria, resulting in the usage of less asphalt, which possibly would not be very desirable with climatic conditions encountered in Louisiana. Since it was not intended to change the design criteria or namely decrease the bitumen content, only one

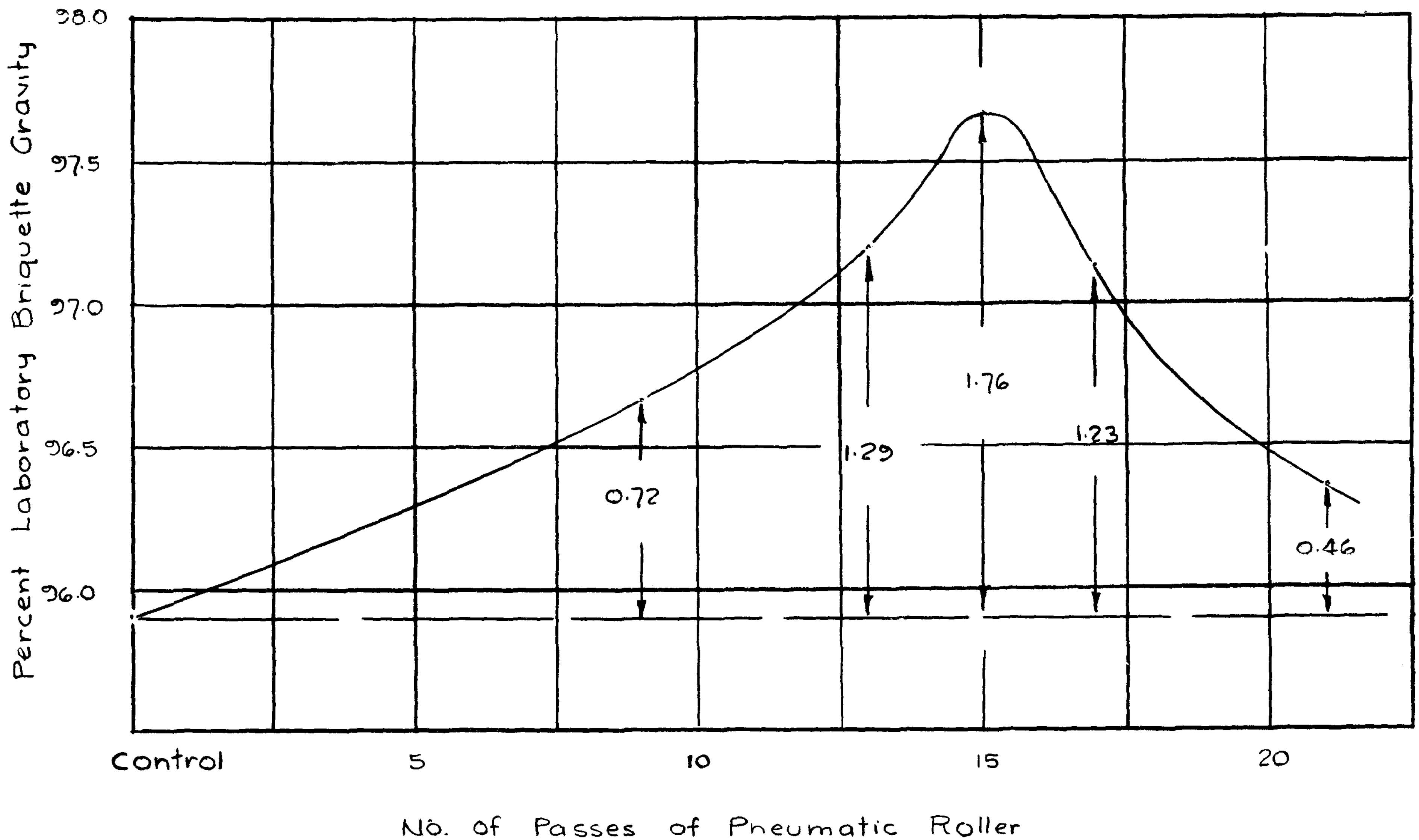

98.0
97.5
97.0
96.5
96.0
Percent Laboratory Briquette Gravity
0.72
1.29
1.76
1.23
0.46
Control
5
10
15
20
No. of Passes of Pneumatic Roller

Fig. 3

percentage of asphalt was used in this study. If the loads encountered in the future necessitate a leaner and tougher mixture at the risk of sacrificing durability, it would then be advisable to do so.

Average temperature readings for this project are given in Table 7. The maximum and minimum variations obtained are shown in Table 8.

It will be noted in these two tables that a maximum variation of a decrease of 24 F to an increase of 17 F, from the average, were obtained in temperatures taken immediately after completion of three-wheel rolling. These are in all cases, except the section where nine passes were used, the temperatures at which the pneumatic rolling was started.

TABLE 7

TEMPERATURE AVERAGES FOR TEST SECTION

		Thermo-Couple Temperatures (^{o}F)					
	Thermo-	3-Wheel		Pneumatic		Tandem	
Section	Couple	Before*	After	Before	After	Before	After
5	7 & 8	251	209	188	155	148	146
7	9 & 10	264	175	-	-	-	160
8	11 & 12	283	203	-	-	-	160
9 (Control)	13 & 14	251	185	-	-	-	170
10	15 & 16	273	205	203	172	171	163
11	17 & 18	302	216	216	174	174	171

(*) Also spreading temperatures

TABLE 8

MAXIMUM AND MINIMUM VARIATIONS IN TEMPERATURES

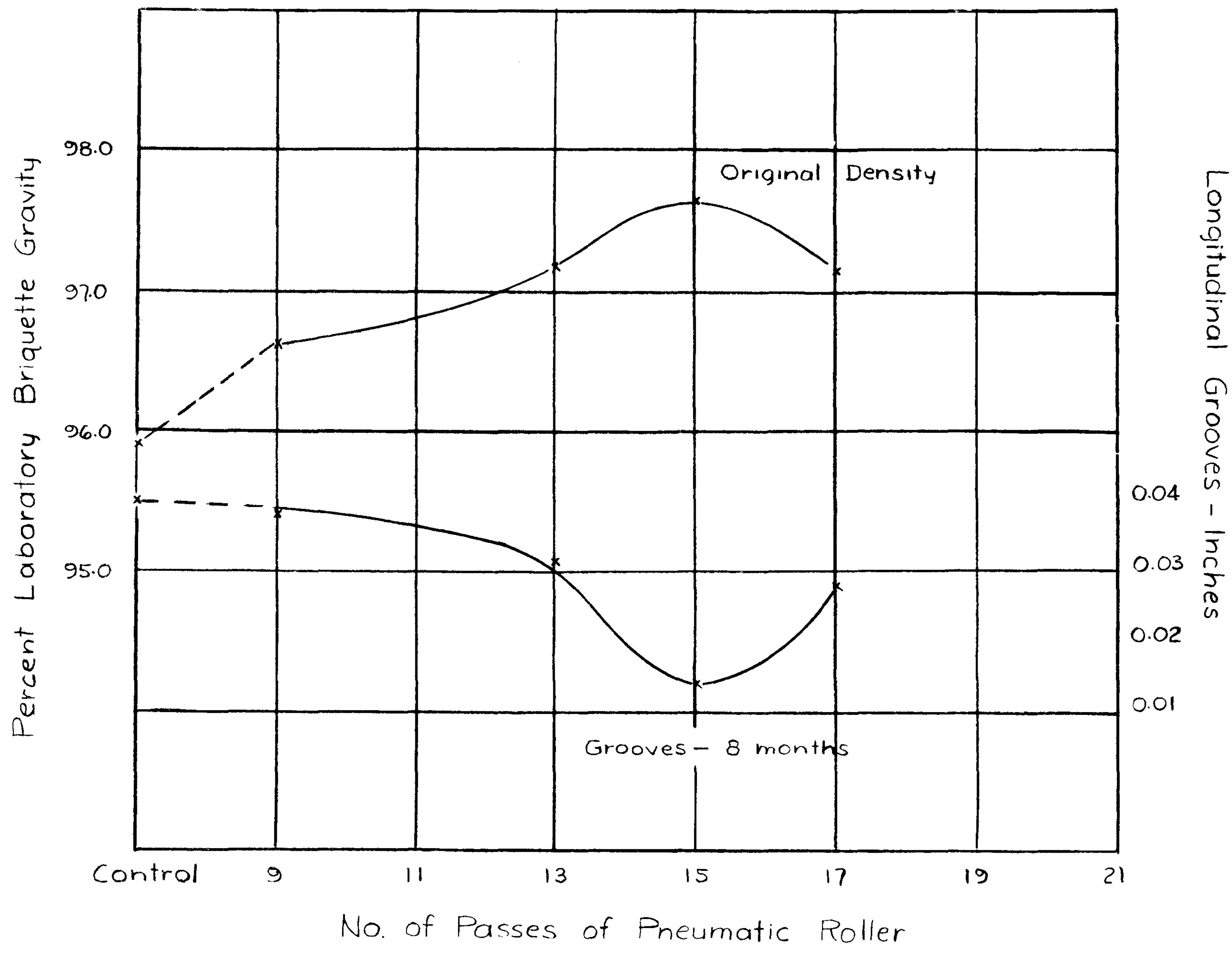
Average	271 F	199 F	202 F	167 F	164 F	162 F
	3-Wheel		Pneumatic		Tandem	
Section	Before*	After	Before	After	Before	After
5	-20 F	+10 F	-14 F	-12 F	-16 F	-16 F
7	-7 F	-24 F	--	--	--	-2 F
8	+12 F	+4 F	--	--	--	-2 F
9(Control)	-20 F	-14 F	--	--	--	+8 F
10	+2 F	+6 F	+1 F	+5 F	+7 F	+1 F
11	+31 F	+17 F	+14 F	+7 F	+10 F	+9 F

(*) Also spreading temperatures

Minus indicates a decrease from the average temperature and plus indicates an increase.

Discussion of Test Results - After Eight Months of Traffic Densification

Each section after eight months of service was inspected, cored every 30 feet and the rutting or longitudinal grooves under each tire track were measured every 25 feet. The average groove measurements for these are given in Table 9 and a graphic comparison of these values with the original densities of the sections are given in Figure 4. It will be noted that the grooves gradually decrease as the number of passes are increased up to 13. Then there is a sudden drop and a sharp increase showing exactly the same tendency as the original density, only in reverse.



Percent Laboratory Briquette Gravity
98.0
97.0
96.0
95.0
Original Density
Grooves - 8 months
Longitudinal Grooves - Inches
0.04
0.03
0.02
0.01
Control
9
11
13
15
17
19
21
No. of Passes of Pneumatic Roller

Fig.- 4

TABLE 9

GROOVE MEASUREMENTS
(Eight Months)

Passes of Pneumatic Tire Roller	Average Grooves inches
Control	0.040
9	0.038
13	0.031
15	0.014
17	0.028

Different sections of the project were cored to give a minimum of 3 cores on the right of the centerline of the lane, 3 on the centerline and 3 on the left, resulting in 6 cores from the tire tracks and 3 from the centerline. The cores were spaced evenly (every 30 feet).

Average results of the percentage of Laboratory Briquette Gravity are given in Table 10.

TABLE 10

AVERAGE PERCENTAGES OF LABORATORY BRIQUETTE SPECIFIC GRAVITY

Number of passes of Pneumatic Tire Roller	Percent Laboratory Briquette Specific Gravity Original	8 months Center of Lane	8 months Tire Track
Control	95.90	98.59	99.06
9	96.62	98.72	99.15
13	97.19	99.23	99.27
15	97.66	99.45	99.62
17	97.13	99.01	99.20

Note: Individual results for the above are given in the Appendix.

A graphic representation of same and a comparison with the original density is given in Figure 5.

It will be noted that after eight months of service:

a) The control section showed an increase of 3.16 percent (by difference) at the tire tracks and 2.69 percent on the middle of the lane. This results in a difference of 0.47 percent or roughly 1/2 percent between the centerline and the sides.

b) The section where 15 passes were applied showed an increase of only 1.96 percent on the tire tracks and 1.79 percent on the centerline resulting in a difference of 0.17 percent or roughly 0.2 percent.

In other words, the control section shows twice as much difference in density between the tire tracks and centerline as the pneumatic rolled section at its optimum. Furthermore, the average of measured grooves is three times as much in the control section as in the optimum pneumatic rolled section.

Conclusions

The pneumatic tire roller definitely does improve the surface texture of the pavement, gives a much tighter surface with possibly more fine material near the surface. In our opinion, this situation will decrease ravelling and be most benefical when used on the wearing course on heavily travelled roads and over areas with numerous junctions and driveways where this situation is very pronounced due to the presence of loose gravel on the surface. Furthermore, on rural highways the increased density will reduce rutting (longitudinal grooves) resulting from compaction of the

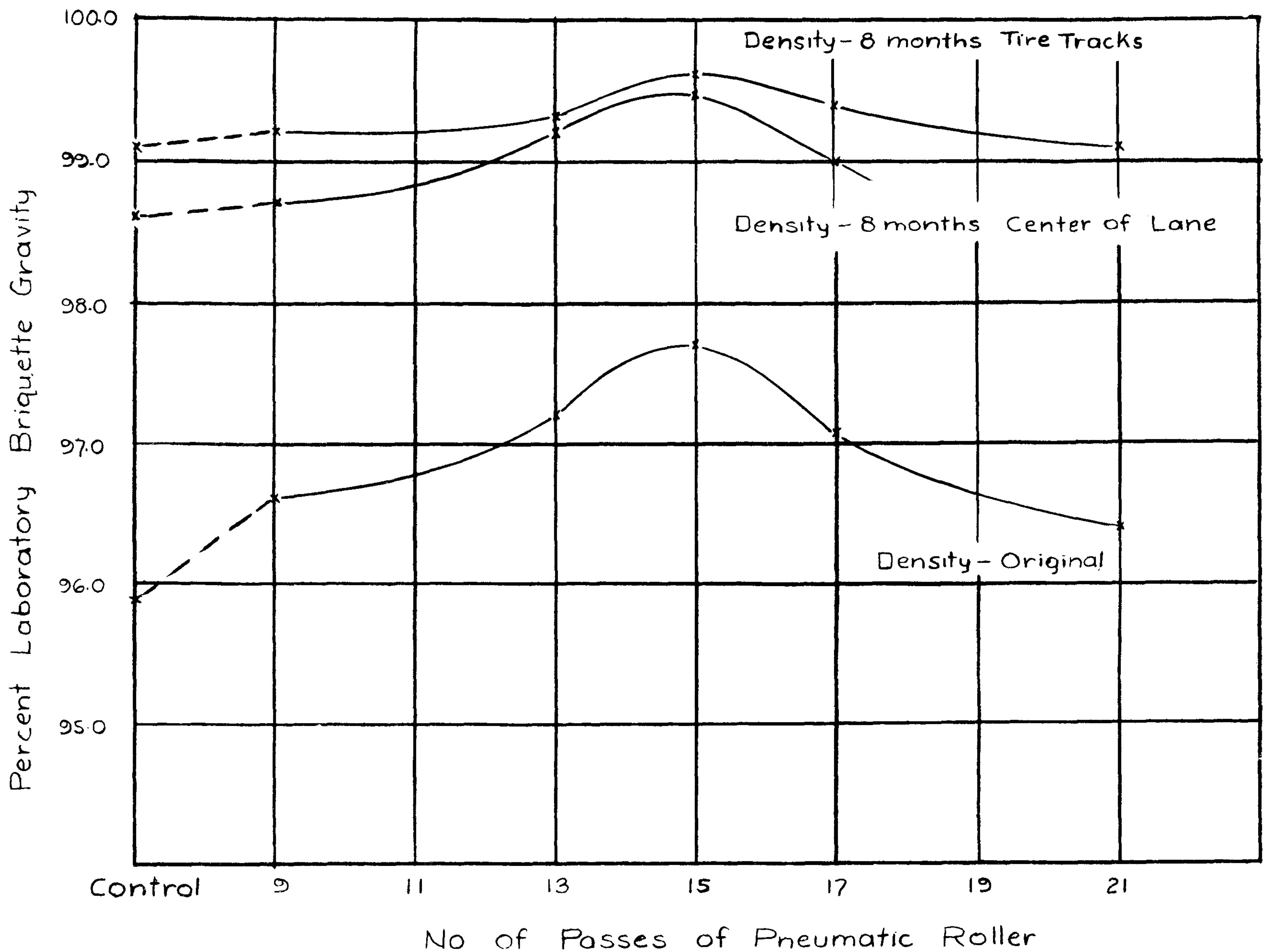

Density - 8 months Tire Tracks
Density - 8 months Center of Lane
Density - Original
100.0
99.0
98.0
97.0
96.0
95.0
Percent Laboratory Briquette Gravity
Control
9
11
13
15
17
19
21
No of Passes of Pneumatic Roller

Fig. 5

pavement under traffic.

Of course these conclusions are subject to change with different types of mixtures.

The performance of pneumatic tire rollers is highly controlled by the number of passes, tire pressure and weight of the roller. All three of these factors are equally important in improving density.

Although the weight of the roller is very important, when a low tire pressure is used the desired results cannot be obtained. Low tire pressures tend to densify only the surface of the lift, and as the pressure is increased the densification penetrates farther into the mat.

The indications of this study are that an eight or nine ton roller, a tire pressure of 55 psi, with seven coverages or fifteen passes, yields the optimum results. The tire pressure should not vary by more than 5 psi in between different tires of a roller. All tires of the same roller should be of equal size and diameter, and should be arranged in such a manner that the gap between the tires of one axle will be covered by the tires of the other.

Pneumatic rollers in highway pavement construction should not be used before the three-wheel roller, nor after the tandem. The best results were observed when they were used immediately after the three-wheel and before the tandem.

The tires will pick up the fine fractions of the mixture, resulting in a slightly uneven appearance. This can and should be eliminated by use of coco mats sprayed with water and, sometimes, only if necessary, diesel fuel. Another method would be to soak the mats in diesel fuel, allow them to drain and use them on the tires.

These rollers can be operated much faster than steel wheel rollers. The desirable speed is four to six miles per hour. Therefore, it is absolutely necessary to have an experienced operator on these rollers. Inexperienced operators will have trouble in keeping the roller in a straight path when backing up, giving an uneven densification, as well as rounding off the longitudinal joints or the edge of the mat.

In order to get a good joint, when rubber tire rollers are used, the roller should be kept six inches from the unsupported joint if only one lane is in place. However, when both lanes are down, it should be overlapped at least six inches to get additional sealing of the joint.

The temperature of the mixture when rolling is started should be such that the Saybolt-Furol viscosity of the asphalt will not be less than 1000 seconds nor more than 4500 seconds. In the absence of suitable temperature viscosity data, a rolling temperature of 190 F - 225 F for 85-100 and 200 F - 235 F for 60-70 penetration grade for asphalts produced from Gulf Coast crudes can be used.

These recommendations are only for wearing course. Binder course mixtures may require different numbers of passes.

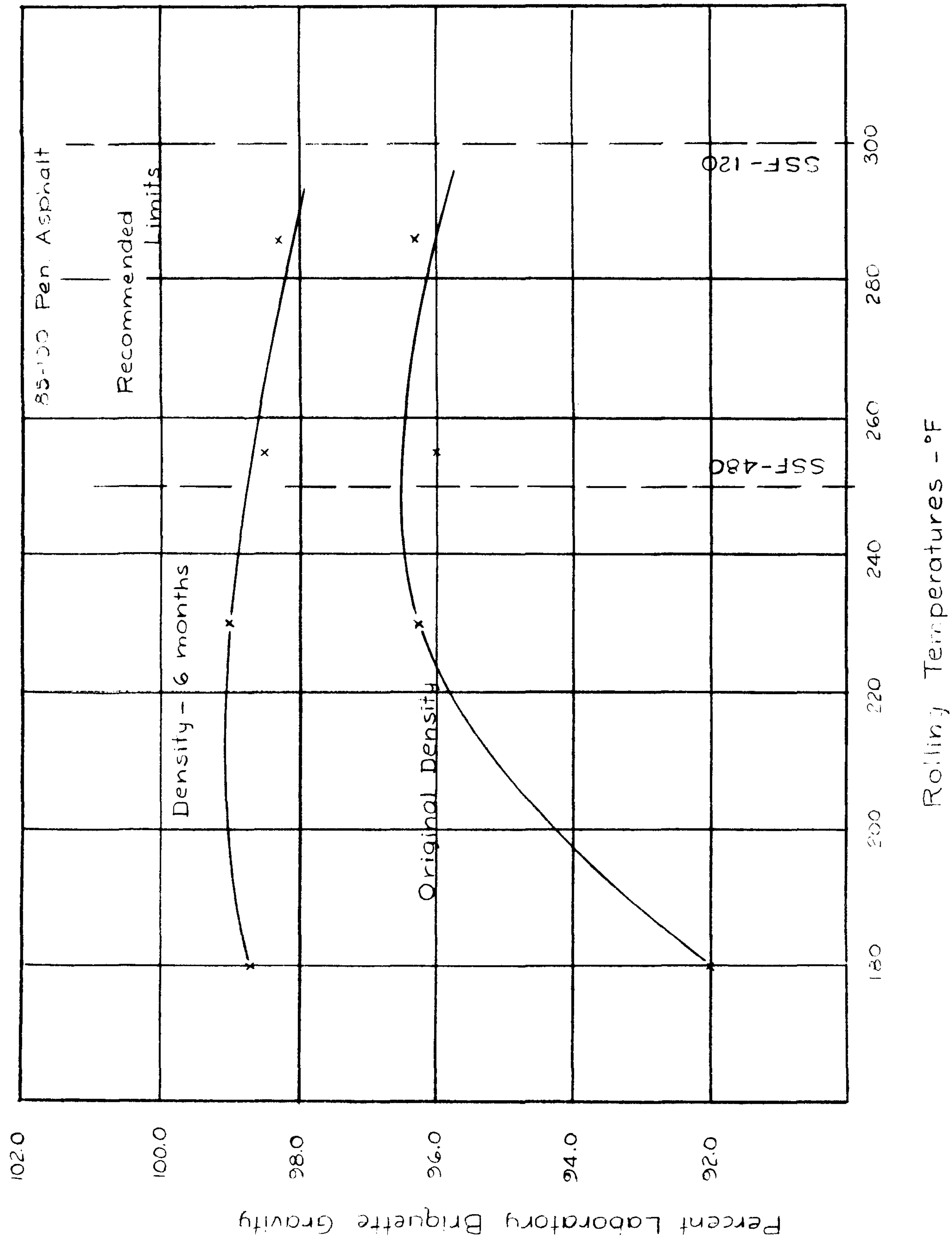
It was also observed during this investigation that rolling with a tandem roller should not be stopped before the mixture cools to approximately 160 F for Gulf Coast 85-100 penetration asphalt. Stopping the tandem roller at a higher temperature results in excessive roller marks on the pavement and gives a slightly lower density.

It should be brought out at this point that another compaction study is underway in Louisiana to establish a correlation between density of the mix and viscosity of asphalt at the time of rolling. In other words, we are trying to establish whether the final density of the pavement is mainly controlled by viscosity of the asphalt at which the mix was rolled or by the aggregate characteristics. We are inclined to believe that for reasonable variations in aggregate properites the optimum or the proper rolling viscosities stay the same.

In the first one of these studies, it was indicated that the three-wheel roller should be started when the temperature of the mix is such that the Saybolt-Furol viscosity of the asphalt will be 480 - 120 seconds. The approximate temperature range for Gulf Coast asphalts, in this case, would be 250 F - 300 F for 85-100 penetration grade and 260 F - 310 F for 60-70 penetration grade.

The former limits given in the preceding paragraph were actually established by field tests. The latter were obtained from viscosity temperature charts using the corresponding viscosities, and have not been checked in actual field conditions. Mixtures compacted at these temperature viscosity ranges showed one-third as much increase in density after six months of traffic densification than those compacted at lower temperatures, Figure 6.

Furthermore, the groove measurements (six months) are only one-third as much for the recommended limits than lower temperatures, Figure 7. When this study is completed, results will be reported.



85-100 Pen. Asphalt
Recommended Limits
SSF-120
SSF-480
Density - 6 months
Original Density
102.0
100.0
98.0
96.0
94.0
92.0
Percent Laboratory Briquette Gravity
180
200
220
240
260
280
300
Rolling Temperatures - °F

Fig. 6

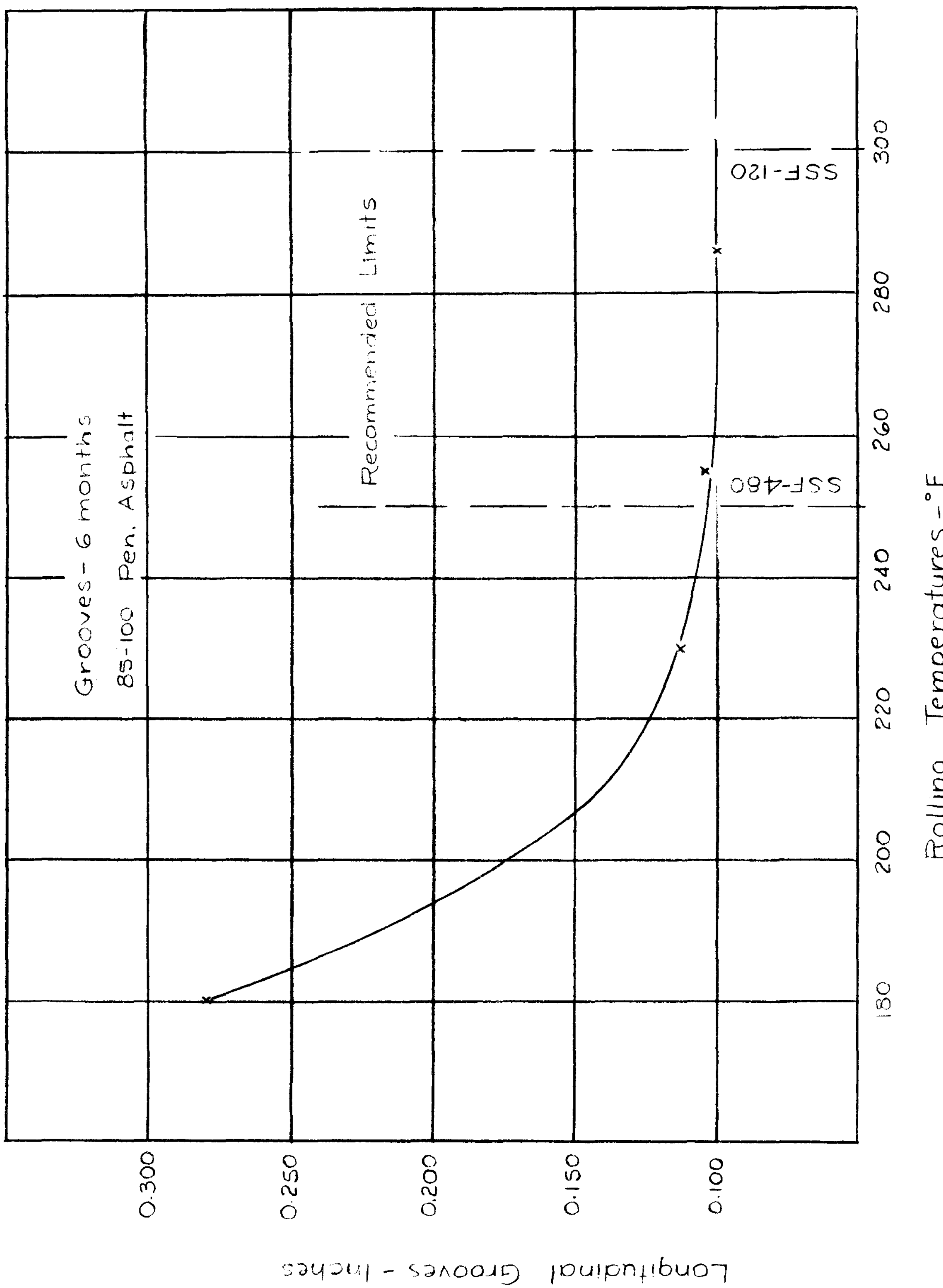

Grooves - 6 months
85-100 Pen. Asphalt
Recommended Limits
SSF-120
SSF-480
180
200
220
240
260
280
300
0.300
0.250
0.200
0.150
0.100
Rolling Temperatures - °F
Longitudinal Grooves - Inches

Fig. 7

APPENDIX

TABLE 3

JOB MIX FORMULA C-86 WEARING COURSE

Bin No. 1 (Fine)	Specific Gravity	2.646	43.0%
Bin No. 2 (Intermediate)	Specific Gravity	2.604	38.0%
Bin No. 3 (Coarse)	Specific Gravity	2.584	15.0%
Mineral Filler (Limestone Dust)	Specific Gravity	2.700	4.0%
Asphalt 85-100 Penetration	Specific Gravity	1.020	5.5%
Theoretical Gravity		2.414	

Job Mix Formula

U. S. Sieve	Percent Passing
3/4 inch	100
1/2 inch	86 - 100
No. 4	60 - 74
No. 10	40 - 50
No. 40	25 - 35
No. 80	12 - 17
No. 200	4 - 8
Asphalt, %	5.4 - 5.6

TABLE 11

TEMPERATURE MEASUREMENTS OF DENSITY TEST SECTIONS

Thermo-Couple Number	Station	Section	Temperature (3 wheels) Before*	Temperature (3 wheels) After	Temperature (Pneumatic) Before	Temperature (Pneumatic) After	Temperature (Tandem) Before	Temperature (Tandem) After
1	527+50	1 Control	251 F	225 F	-	-	160 F	157 F
2	525+50	1 Control	280 F	180 F	-	-	169 F	166 F
3	404+50	3	264 F	178 F	173 F	156 F	156 F	152 F
4	402+50	3	246 F	189 F	177 F	160 F	160 F	156 F
5	394+50	4	248 F	175 F	175 F	158 F	158 F	151 F
6	392+50	4	321 F	232 F	232 F	206 F	206 F	186 F
7	325+00	5	231 F	198 F	190 F	154 F	141 F	138 F
8	322+56	5	272 F	220 F	186 F	156 F	156 F	154 F
9	81+50	7	255 F	171 F	-	-	-	160 F
10	80+50	7	273 F	179 F	-	-	-	160 F
11	79+00	8	292 F	180 F	-	-	-	148 F
12	78+00	8	273 F	226 F	-	-	-	172 F
13	76+50	9 Control	258 F	172 F	-	-	-	160 F
14	75+00	9 Control	244 F	198 F	-	-	-	180 F
15	71+50	10	274 F	198 F	198 F	168 F	168 F	162 F
16	70+50	10	273 F	212 F	208 F	176 F	175 F	164 F
17	68+50	11	295 F	180 F	180 F	152 F	152 F	149 F
18	67+50	11	308 F	252 F	252 F	196 F	196 F	193 F

(*) Also spreading temperatures

TABLE 12

SUMMARY OF TEMPERATURE MEASUREMENTS OF DENSITY TEST SECTIONS

Thermo-Couple Number	Section	Temperature (3 wheels) Before*	After	Temperature (Pneumatic) Before	After	Temperature (Tandem) Before	After
1 & 2	1 Control	265 F	203 F	-	-	164 F	162 F
3 & 4	3	255 F	183 F	175 F	158 F	158 F	154 F
5 & 6	4	284 F	203 F	203 F	182 F	182 F	169 F
7 & 8	5	251 F	209 F	188 F	155 F	148 F	146 F
9 & 10	7	264 F	175 F	-	-	-	160 F
11 & 12	8	283 F	203 F	-	-	-	160 F
13 & 14	9 Control	251 F	185 F	-	-	-	170 F
15 & 16	10	273 F	205 F	203 F	172 F	171 F	163 F
17 & 18	11	302 F	216 F	216 F	174 F	174 F	171 F

(*) Spreading temperatures

TABLE 13

GRADATION OF THE AGGREGATE

	Bin #1	Bin #2	Bin #3	Filler
Lab. No.	496713	496714	496715	
U. S. Sieve		Percent	Passing	
3/4 inch	100.0	100.0	100.0	100.0
1/2 inch	100.0	99.6	75.1	100.0
No. 4	100.0	35.6	1.5	100.0
No. 10	96.0	7.0		100.0
No. 40	69.5	2.0		100.0
No. 80	25.5	1.1		99.0
No. 200	11.0	0.7		89.0

TABLE 14

BRIQUETTE AND CORE RESULTS

TEST SECTION 5

21 Passes

Laboratory Number	494126	494127	494128	494129
Briquette Results				
Specific Gravity	2.348	2.311	2.345	2.335
Theoretical Gravity	2.414	2.414	2.414	2.414
% Theoretical Gravity	97.3	95.7	97.1	96.7
Density lb/cu ft	146.5	144.2	146.3	145.7
Marshall Stability - lb	1495	1250	1400	1335
Flow 1/100 inch	16	13	16	15
Gradation				
U. S. Sieve		Percent	Passing	
3/4 inch	100.0	100.0	100.0	100.0
1/2 inch	94.5	95.7	94.5	97.0
No. 4	63.8	64.6	60.6	62.6
No. 10	49.3	51.0	47.2	48.3
No. 40	31.1	32.6	29.8	31.6
No. 80	14.9	12.9	13.8	13.7
No. 200	6.6	4.9	5.5	5.8
Bitumen, %	5.7	5.7	5.8	5.7
Crushed Aggregate (ret. on #10), %	71	64	67	62

Roadway Density

Core No.	15	16	17	18	19
Specific Gravity	2.241	2.256	2.235	2.240	2.287
Theoretical Gravity	2.414	2.414	2.414	2.414	2.414
% Theoretical Gravity	92.8	93.4	92.6	92.8	94.7

TABLE 15

BRIQUETTE AND CORE RESULTS

TEST SECTION 7

9 Passes

Laboratory Number	497726	497727	497728
Briquette Results			
Specific Gravity	2.342	2.335	2.339
Theoretical Gravity	2.414	2.414	2.414
% Theoretical Gravity	97.0	96.7	96.9
Density lb/cu ft	146.1	145.7	146.8
Marshall Stability - lb	1182	1115	1100
Flow 1/100 inch	10	10	8
Gradation			
U. S. Sieve	Percent Passing		
3/4 inch	100.0	100.0	100.0
1/2 inch	87.8	95.2	90.9
No. 4	56.5	62.1	64.7
No. 10	46.3	47.8	53.7
No. 40	31.5	30.8	35.9
No. 80	12.5	11.5	15.8
No. 200	3.5	3.8	4.8
Bitumen, %	5.3	5.6	5.2
Crushed Aggregate (ret. on #10), %	69	66	62

Roadway Density

Core No.	20	21	22	23
Specific Gravity	2.242	2.282	2.232	2.282
Theoretical Gravity	2.414	2.414	2.414	2.414
% Theoretical Gravity	92.9	94.5	92.5	94.5

TABLE 16

BRIQUETTE AND CORE RESULTS

TEST SECTION 8

13 Passes

Laboratory Number	497728	497729
Briquette Results		
Specific Gravity	2.339	2.341
Theoretical Gravity	2.414	2.414
% Theoretical Gravity	96.9	97.0
Density lb/cu ft	146.8	146.1
Marshall Stability - lb	1100	1135
Flow 1/100 inch	8	15
Gradation		
U. S. Sieve	Percent	Passing
3/4 inch	100.0	100.0
1/2 inch	90.9	96.3
No. 4	64.7	58.8
No. 10	53.7	41.6
No. 40	35.9	28.9
No. 80	15.8	14.7
No. 200	4.8	6.5
Bitumen, %	5.2	5.6
Crushed Aggregate (ret. on #10), %	62	68

Roadway Density

Core No.	24	26	27
Specific Gravity	2.284	2.266	2.269
Theoretical Gravity	2.414	2.414	2.414
% Theoretical Gravity	94.6	93.9	94.0

TABLE 17

BRIQUETTE AND CORE RESULTS

TEST SECTION 9

Control Section

Laboratory Number	497731	497732	497733
Briquette Results			
Specific Gravity	2.341	2.342	2.341
Theoretical Gravity	2.414	2.414	2.414
% Theoretical Gravity	97.0	97.0	97.0
Density lb/cu ft	146.1	146.1	146.1
Marshall Stability - lb	927	937	940
Flow 1/100 inch	10	11	11
Gradation			
U. S. Sieve	Percent Passing		
1 inch	100.0		
3/4 inch	96.2	100.0	100.0
1/2 inch	83.8	88.7	95.5
No. 4	53.4	53.3	60.6
No. 10	44.9	43.0	47.0
No. 40	30.7	30.3	33.8
No. 80	11.8	12.1	14.1
No. 200	4.2	4.4	4.8
Bitumen, %	5.0	5.1	5.2
Crushed Aggregate (ret. on #10), %	69	60	65
Roadway Density			
Core No.	29	30	31
Specific Gravity	2.230	2.254	2.253
Theoretical Gravity	2.414	2.414	2.414
% Theoretical Gravity	92.4	93.4	93.3

TABLE 18

BRIQUETTE AND CORE RESULTS

TEST SECTION 10

15 Passes

Laboratory Number	497735
Briquette Results	
Specific Gravity	2.350
Theoretical Gravity	2.414
% Theoretical Gravity	97.3
Density lb/ cu ft	146.6
Marshall Stability - lb	927
Flow 1/100 inch	14

Gradation

U. S. Sieve	Percent Passing
1 inch	100.0
3/4 inch	97.4
1/2 inch	76.5
No. 4	53.2
No. 10	46.5
No. 40	33.9
No. 80	14.4
No. 200	5.4
Bitumen, %	5.4
Crushed Aggregate (ret. on #10), %	62

Roadway Density

Core No.	33	34	35
Specific Gravity	2.286	2.295	2.304
Theoretical Gravity	2.414	2.414	2.414
% Theoretical Gravity	94.7	95.1	95.4

TABLE 19

BRIQUETTE AND CORE RESULTS

TEST SECTION 11

17 Passes

Laboratory Number	497736	497737
Briquette Results		
Specific Gravity	2.345	2.346
Theoretical Gravity	2.414	2.414
% Theoretical Gravity	97.1	97.2
Density lb/cu ft	146.3	146.4
Marshall Stability - lb	1037	1154
Flow 1/100 inch	13	15
Gradation		
U. S. Sieve	Percent	Passing
3/4 inch	100.0	100.0
1/2 inch	92.0	86.4
No. 4	62.2	53.7
No. 10	48.6	45.7
No. 40	34.2	31.4
No. 80	12.9	11.4
No. 200	4.7	4.2
Bitumen, %	5.7	5.4
Crushed Aggregate (ret. on #10), %	62	68

Roadway Density

Core No.	36	37	38	39
Specific Gravity	2.273	2.273	2.285	2.282
Theoretical Gravity	2.414	2.414	2.414	2.414
% Theoretical Gravity	94.2	94.2	94.7	94.5

TABLE 20

CORE RESULTS (8 MONTH SURVEY)

CONTROL SECTION

Tire Tracks

Core Number	1	2	3	4	5	6	Average
Spec. Grav. - Core	2.320	2.311	2.319	2.316	2.326	2.329	2.320
Briq. Grav. - Original							2.342
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.06
% Theo. Grav.							96.10
Marshall Sta. @140 F	2500	2250	1200	2400	2500	1222	2012
Flow 1/100 inch	13	11	12	11	10	11	11

Centerline

Spec. Grav. - Core	2.303	2.313	2.311				2.309
Briq. Grav. - Original							2.342
Theo. Grav.							2.414
% Lab. Briq. Grav.							98.59
% Theo. Grav.							95.65
Marshall Sta. @140 F	1750	1095	1022				1289
Flow 1/100 inch	12	10	12				11

TABLE 21

CORE RESULTS (8 MONTH SURVEY)

SECTION 7

9 PASSES

Tire Tracks

Core Number	1	2	3	4	5	6	Average
Spec. Grav. - Core	2.306	2.335	2.339	2.319	2.296		2.319
Briq. Grav. - Original							2.339
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.15
% Theo. Grav.							96.07
Marshall Sta. @140 F	1800	2300	2200	2050	2300		2130
Flow 1/100 inch	9	10	11	10	7		9

Centerline

Spec. Grav. - Core	2.316	2.301					2.309
Briq. Grav. - Original							2.339
Theo. Grav.							2.414
% Lab. Briq. Grav.							98.72
% Theo. Grav.							95.65
Marshall Sta. @140 F	1750	1750					1750
Flow 1/100 inch	10	12					11

TABLE 22

CORE RESULTS (8 MONTH SURVEY)

SECTION 8

13 PASSES

Tire Tracks

Core Number	1	2	3	4	5	6	Average
Spec. Grav. - Core	2.328	2.324	2.313	2.324	2.323	2.317	2.322
Briq. Grav. - Original							2.339
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.27
% Theo. Grav.							96.20
Marshall Sta. @140 F	2300	2700	1450	1750	2200	2400	2133
Flow 1/100 inch	11	14	22	10	12	10	13

Centerline

Spec. Grav. - Core	2.324	2.324	2.316				2.321
Briq. Grav. - Original							2.339
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.23
% Theo. Grav.							96.15
Marshall Sta. @140 F	2250	2500	1900				2217
Flow 1/100 inch	10	11	10				10

TABLE 23

CORE RESULTS (8 MONTH SURVEY)

SECTION 10

15 PASSES

Tire Tracks

Core Number	1	2	3	4	5	6	Average
Spec. Grav. - Core	2.325	2.337	2.354	2.357	2.340	2.333	2.341
Briq. Grav. - Original							2.350
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.62
% Theo. Grav.							96.98
Marshall Sta. @140 F	1143	918	1222	1156	1244	1222	1151
Flow 1/100 inch	8	8	13	9	11	10	10

Centerline

	1	2	Average
Spec. Grav. - Core	2.323	2.337	2.330
Briq. Grav. - Original			2.350
Theo. Grav.			2.414
% Lab. Briq. Grav.			99.45
% Theo. Grav.			96.98
Marshall Sta. @140 F	857	1000	929
Flow 1/100 inch	10	11	11

TABLE 24

CORE RESULTS (8 MONTH SURVEY)

SECTION 11

17 PASSES

Tire Tracks

Core Number	1	2	3	4	5	6	Average
Spec. Grav. - Core	2.329	2.338	2.289	2.335	2.336		2.325
Briq. Grav. - Original							2.345
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.20
% Theo. Grav.							96.31
Marshall Sta. @140 F	1200	976	1119	974	1347		1123
Flow 1/100 inch	10	9	11	12	8		10

Centerline

Spec. Grav. - Core	2.318	2.308	2.339				2.322
Briq. Grav. - Original							2.345
Theo. Grav.							2.414
% Lab. Briq. Grav.							99.01
% Theo. Grav.							96.20
Marshall Sta. @140 F	800	940	939				893
Flow 1/100 inch	12	10	16				13

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