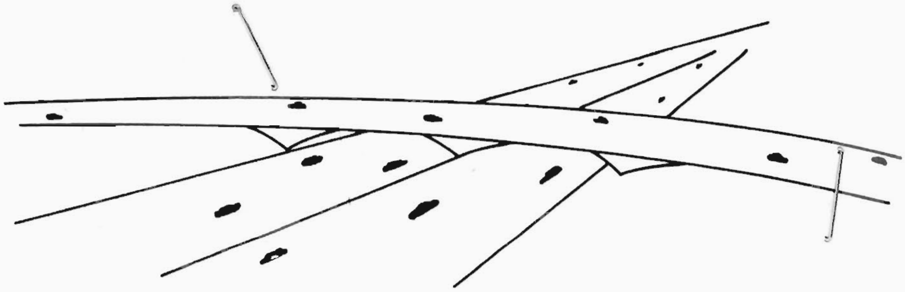

DEPARTMENTAL RESEARCH

Report Number SS 6.0

EVALUATION OF ASPHALT DENSITY GAUGE AND COMPACTION OF BITUMINOUS PAVEMENTS

TEXAS HIGHWAY DEPARTMENT

EVALUATION OF THE ASPHALT DENSITY GAUGE AND COMPACTION OF BITUMINOUS PAVEMENTS

By

Henry Hardy
Geologist II
and
Charles W. Baxter
Supervising Laboratory Engineer

Report Number No. SS 6.0

District 15
San Antonio, Texas
R. O. Lytton
District Engineer
July 1967

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INTRODUCTION AND SYNOPSIS

This report represents a study and investigation of bituminous pavement compaction in District 15. Standard rolling and compaction procedures in use today may not be adequate to provide the desired density when the pavement is placed. In many instances, the compactive effort exerted by present day traffic loads exceed that compactive effort exerted by construction compaction equipment. This report is an effort to obtain information substantiating the need for improved compaction control.

In place density data was obtained by the nuclear method of measurement.

DISCUSSION

Compaction control of bituminous pavements continues to be a problem of primary concern to the highway engineer. The importance of density to provide stability and durability in a completed pavement is well known. Sufficient control is provided our base and subbase materials to insure that the required density as shown in the specifications is obtained. However, asphaltic materials are compacted using only standard compaction procedures. These rolling procedures may not necessarily provide the desired density in every case. Considerable time and money are spent in the design of asphaltic concrete pavements; therefore, it seems essential that construction compaction be adequate to insure the required strength during the load carrying period after the roadway has been opened to traffic. One reason for the lack of compaction control is the fact that conventional test methods are too time consuming and difficult. By the time test results are available, the section of pavement has usually cooled beyond correction with additional rolling. The advent of nuclear type testing equipment has now minimized this problem. Nuclear instruments are now available that will permit rapid density measurements, thus enabling the contractor to correct mat density before the asphaltic material has cooled. In-place density test results can be determined in less than five (5) minutes.

In June, 1965, District 15 purchased a Nuclear Chicago Model 5846 Asphaltic Concrete Density Gauge as a means of investigating and studying those problems associated with compaction procedures of bituminous pavements. Prior to the formulation of a specific field test program, the standardization and operational procedures as outlined by the manufacturer were determined. Instrument errors as well as other conditions effecting test results were studied and evaluated. The results of this preliminary investigation indicated that the equipment was capable of producing reliable test data provided the recommended operating procedures were closely followed.

FIELD TESTING

Field testing was essentially divided into the following categories:

(A) Rolling Pattern Investigations.
(B) Effect of Traffic on Pavement Density.

(A) Rolling Pattern Investigation.

Initial testing consisted of obtaining basic field data on the various types of compaction rollers in use in the district. Test procedures used to obtain field data consisted of measuring the density of the asphaltic mat immediately following the compaction operations of the 3-wheel breakdown roller, pneumatic roller, and the steel wheel tandem roller. Figure 1 shows the results of measurements made on a 1 inch mat of Type "D" Hot Mix Asphaltic Concrete using crushed limestone aggregate.

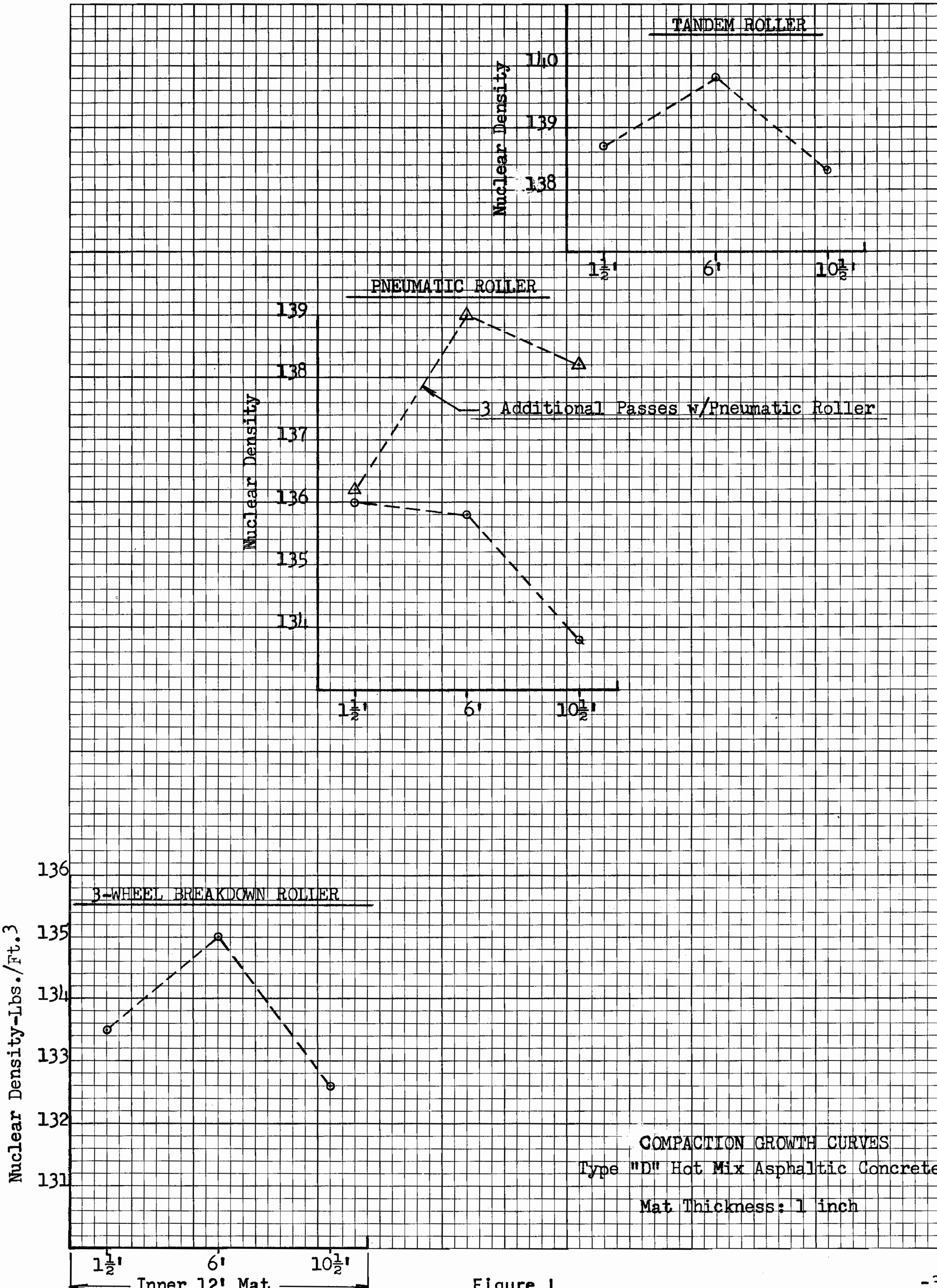

TANDEM ROLLER
Nuclear Density
140
139
138
1½'
6'
10½'
PNEUMATIC ROLLER
Nuclear Density
139
138
137
136
135
134
3 Additional Passes w/Pneumatic Roller
1½'
6'
10½'
3-WHEEL BREAKDOWN ROLLER
Nuclear Density-Lbs./Ft.3
136
135
134
133
132
131
1½'
6'
10½'
Inner 12' Mat
COMPACTION GROWTH CURVES
Type "D" Hot Mix Asphaltic Concrete
Mat Thickness: 1 inch

Figure 1

Note the increase in density obtained with additional rolling with the pneumatic roller. Figure 2 shows results obtained at another location on the same project. Note the similarity between these compaction growth curves. These graphs indicate that higher densities are obtained near the center of the mat. This is attributable to the fact that more rolling takes place in this area.

Figures 3, 4 and 5 show density test results obtained on a 1 3/4 inch mat of Type "B" Hot Mix Asphaltic Concrete using crushed gravel aggregate. These curves again indicate that higher density values are obtained near the center of the mat. The rolling sequence here consisted of the steel wheel breakdown roller, followed by the tandem roller, and then the pneumatic roller. The results of only two projects are shown on these graphs. They are typical, however, of the density data obtained on all projects that were investigated.

Table 1 shows the results of density measurements made on a 4 inch lift of asphalt stabilized base material using both the three-wheel and the pneumatic compactor as a breakdown roller. So far, the results indicate that higher density values can be obtained using the pneumatic compactor as a breakdown roller on thick lift construction. As a result of personal inspection and a study of the test results, the Resident Engineer elected to continue using the pneumatic compactor as a breakdown roller for compaction operations on the asphalt stabilized base. Road samples and visual inspection

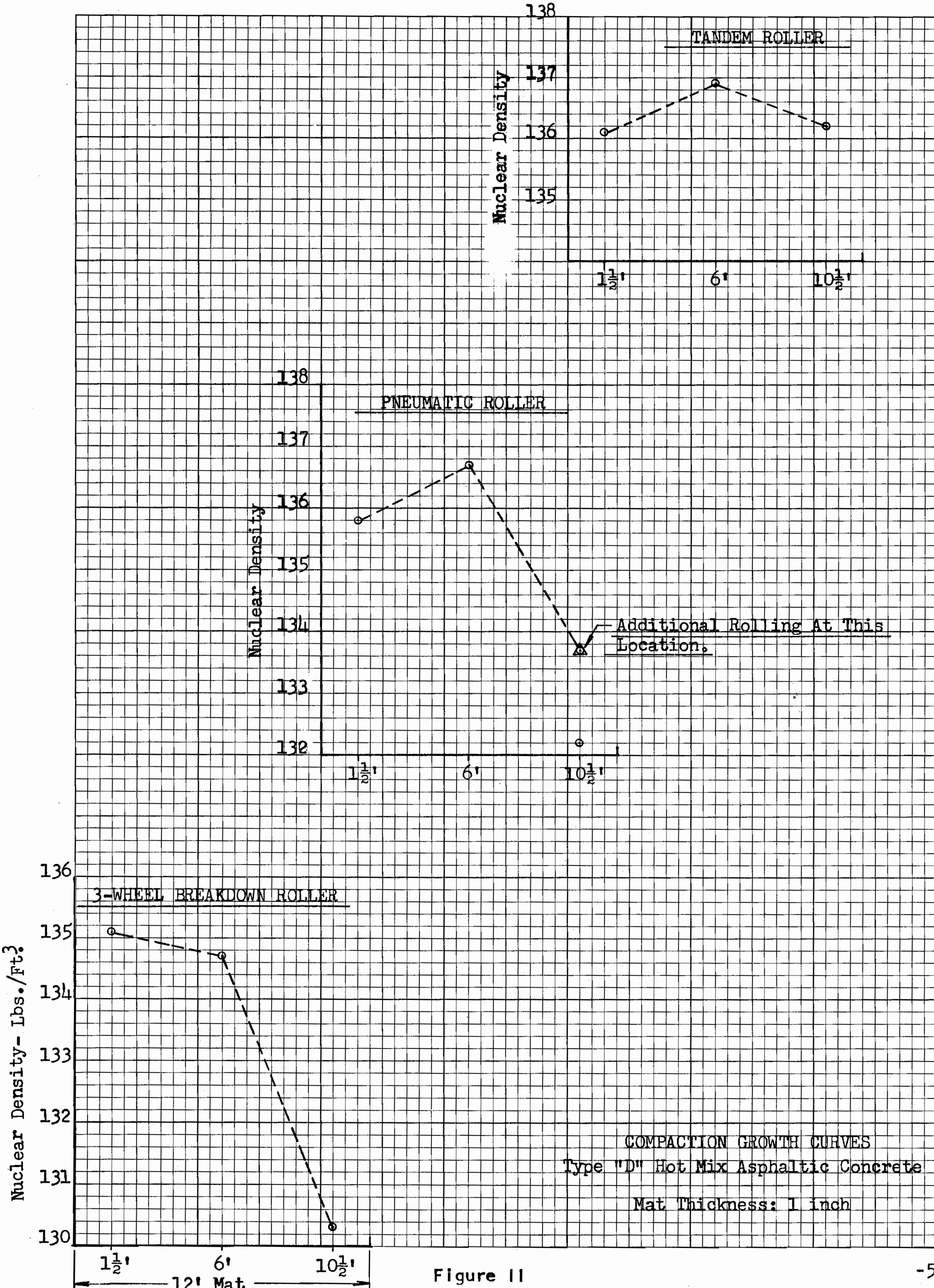

TANDEM ROLLER
Nuclear Density
138
137
136
135
1½'
6'
10½'
PNEUMATIC ROLLER
Nuclear Density
138
137
136
135
134
133
132
Additional Rolling At This Location.
1½'
6'
10½'
3-WHEEL BREAKDOWN ROLLER
Nuclear Density- Lbs./Ft.³
136
135
134
133
132
131
130
1½'
6'
10½'
12' Mat
COMPACTION GROWTH CURVES
Type "D" Hot Mix Asphaltic Concrete
Mat Thickness: 1 inch

Figure II

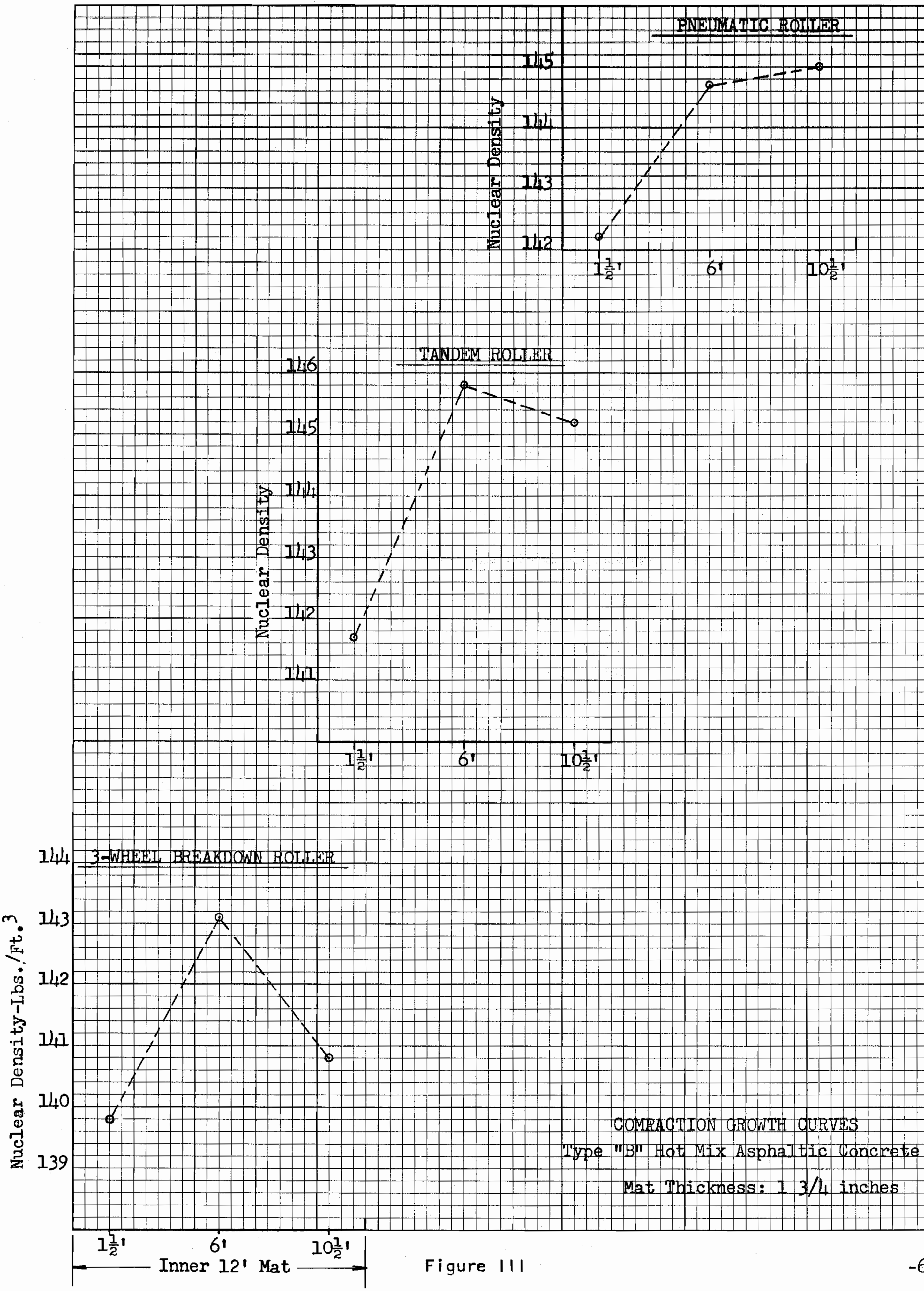
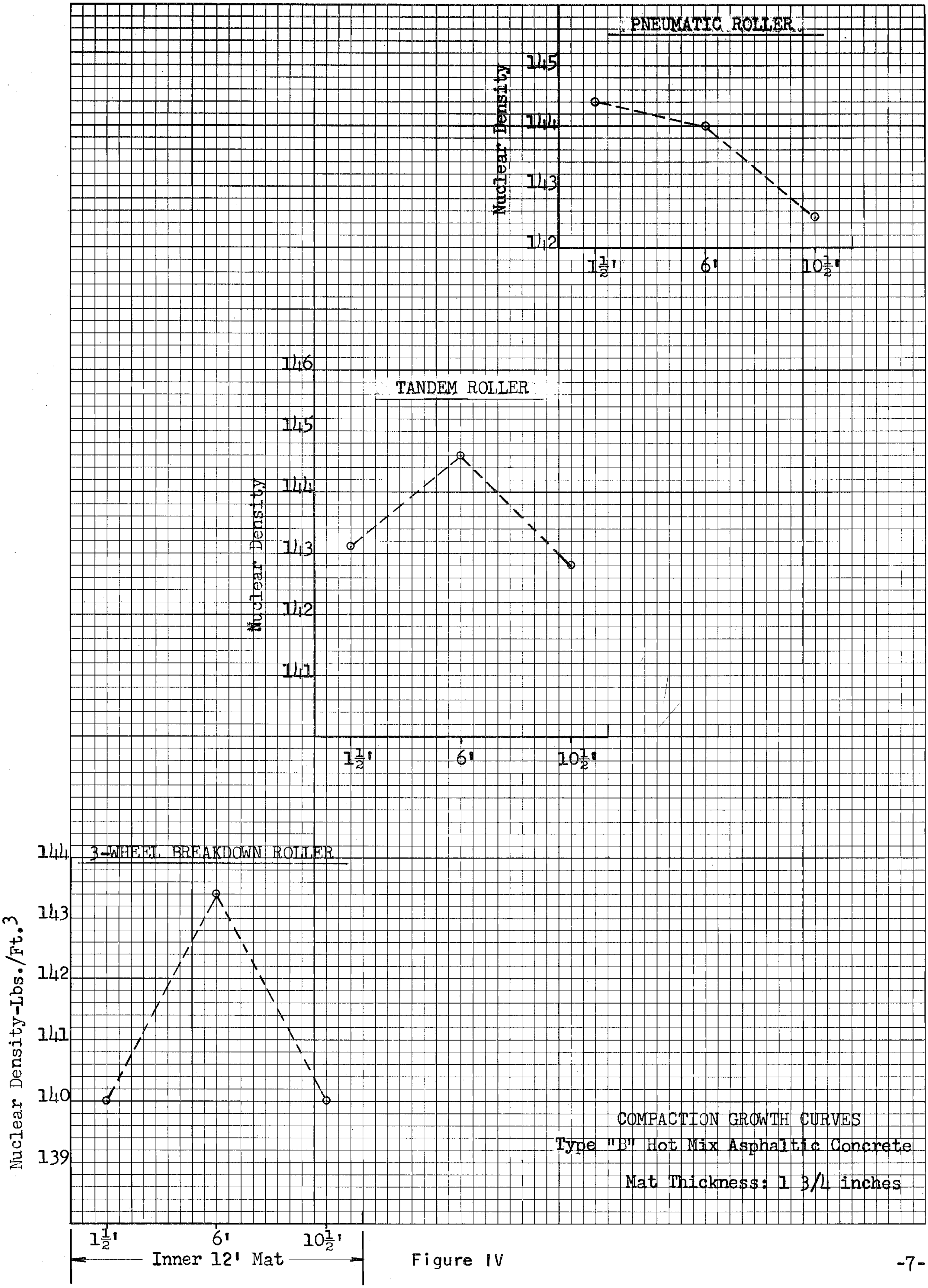

PNEUMATIC ROLLER
Nuclear Density
145
144
143
142
1½'
6'
10½'
TANDEM ROLLER
Nuclear Density
146
145
144
143
142
141
1½'
6'
10½'
3-WHEEL BREAKDOWN ROLLER
Nuclear Density-Lbs./Ft.³
144
143
142
141
140
139
1½'
6'
10½'
Inner 12' Mat
COMPACTION GROWTH CURVES
Type "B" Hot Mix Asphaltic Concrete
Mat Thickness: 1 3/4 inches

Figure III



COMPACTION GROWTH CURVES
Type "B" Hot Mix Asphaltic Concrete
Mat Thickness: 1 3/4 inches

Figure IV

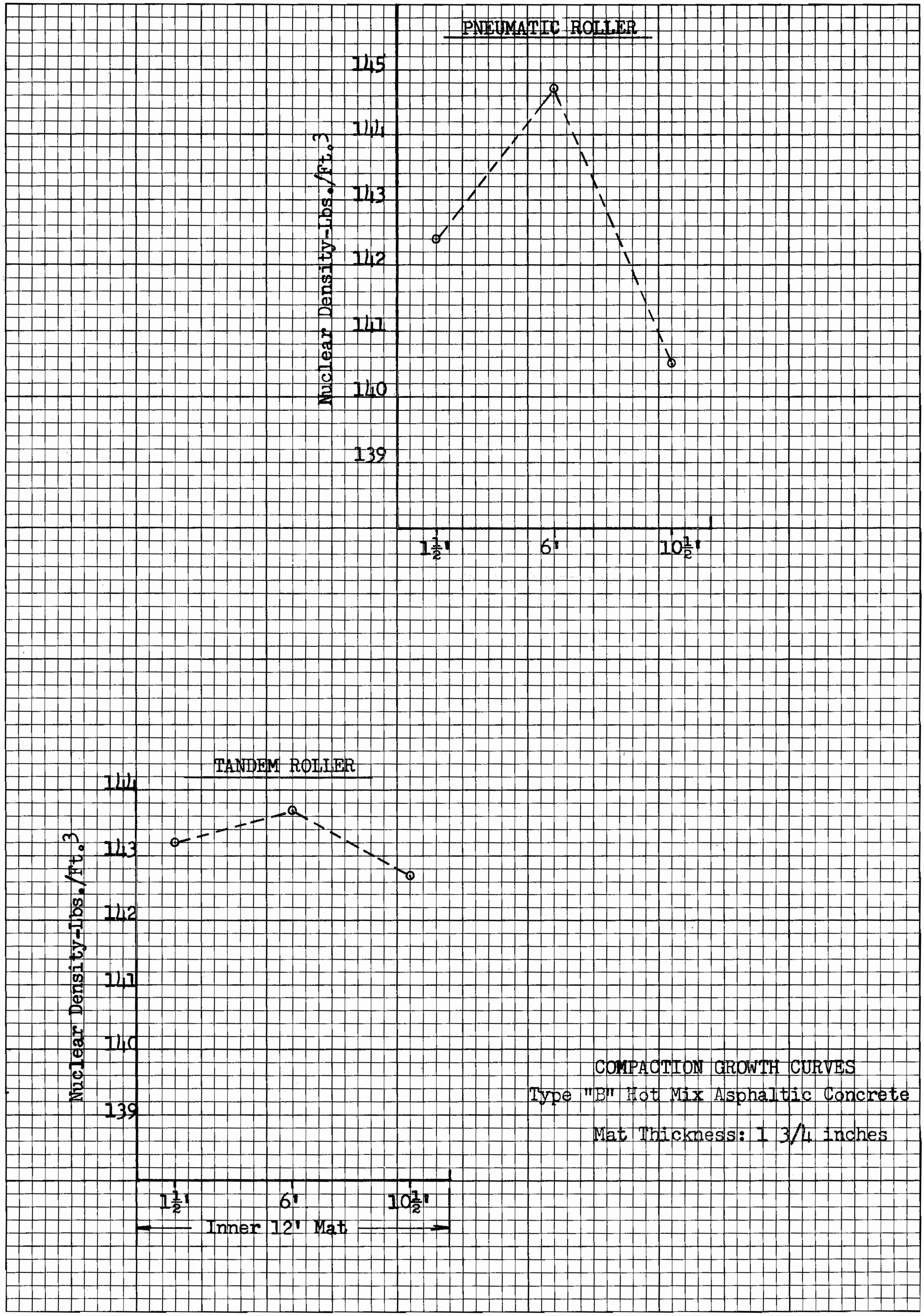

PNEUMATIC ROLLER
Nuclear Density-Lbs./Ft.3
145
144
143
142
141
140
139
1½'
6'
10½'
TANDEM ROLLER
Nuclear Density-Lbs./Ft.3
144
143
142
141
140
139
1½'
6'
10½'
Inner 12' Mat
COMPACTION GROWTH CURVES
Type "B" Hot Mix Asphaltic Concrete
Mat Thickness: 1 3/4 inches

Figure V

show that the compacted asphalt stabilized base to be well densified as well as having excellent water proofing qualities.

In-place density results obtained from the road samples compare favorably with the nuclear density measurements. These results are also shown in Table 1.

Nuclear density test results obtained on Type "A" Hot Mix Asphaltic Concrete are limited and appear to be effected by surface voids; therefore, density data is inconclusive at this time. Due to the gradation requirements for Type "A" Hot Mix Asphaltic Concrete, it may be difficult to obtain a calibration curve for coarse graded pavements having excessive surface voids.

(B) Effect of Traffic on Pavement Density.

The data obtained in this investigation was an effort to determine to some extent the magnitude of density increase due to consolidation under traffic loads. Further consolidation undergone by bituminous pavements result in rutting or depressions in the wheel paths. Severe rutting may occur in pavements on roads where high traffic density or volume occurs, and where insufficient compaction was accomplished during construction. Figure 6 shows a good example of rutting. View 1 shows the string line stretched across the pavement section. View 2 shows the string line and rule located at the center stripe of the traffic lane. View 3 shows

Comparison of Density Measurements using the Pneumatic Compactor and Three Wheel Compactor as a Breakdown Roller.

Material Tested: Asphalt Stabilized Base.

Mat Thickness: 4 Inches.

Initial Compaction

Pneumatic Roller		3-Wheel Roller	
In-Place Density #/Ft. 3	Asphalt Content Percent	In-Place Density #/Ft. 3	Asphalt Content Percent
139.8	5.5	137.5	5.5
141.9	5.5	140.9	5.5
141.8	5.5	140.7	5.8
142.5	5.8	138.8	5.8
144.5	5.8	141.7	6.0
141.7	5.5	140.6	6.0
141.0	5.5	139.0	6.0
144.1	5.5	140.4	6.0
143.9	5.5	142.5	6.0
139.5	5.5	137.9	6.0
141.8	5.5	142.4	6.0
140.2	5.5	142.4	6.0
142.6	5.5	139.8	6.0
141.2	5.5		
141.3	5.0		
140.8	5.0		
139.7	5.0		

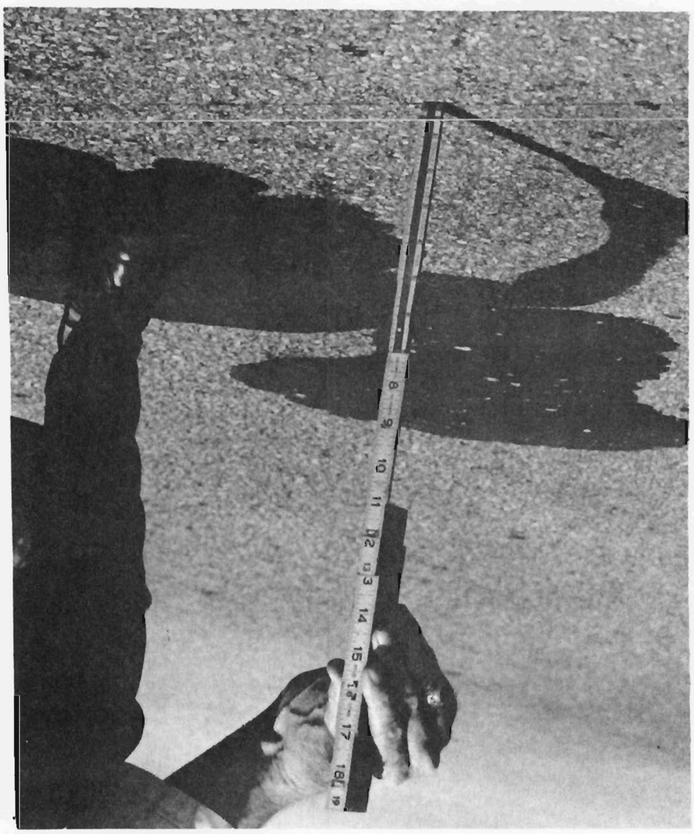
Comparison of Nuclear and Actual Density

Density-Lbs/Cubic Foot

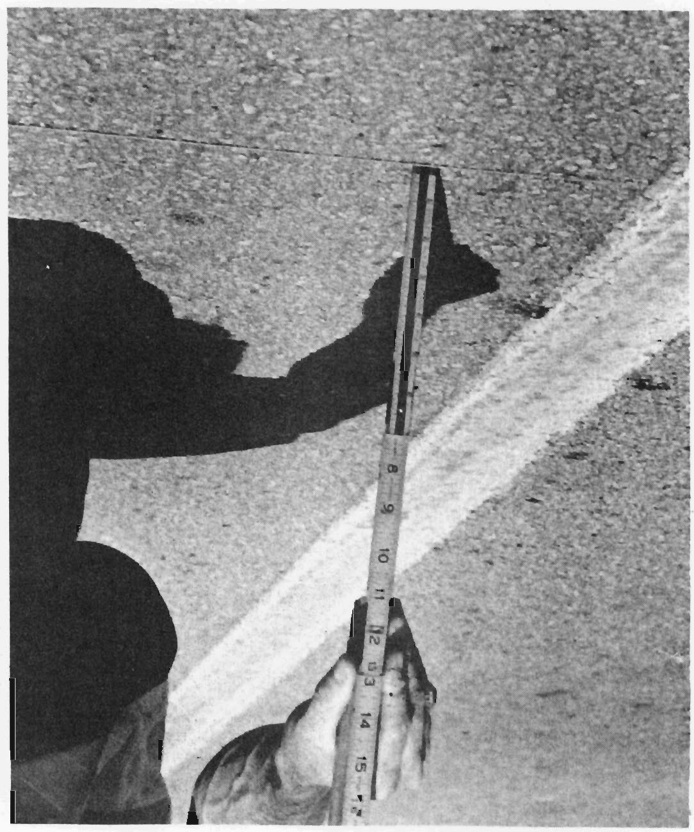
Nuclear	Road Sample
139.0	140.4
139.6	141.5

Table 1

View 1



View 2



View 3

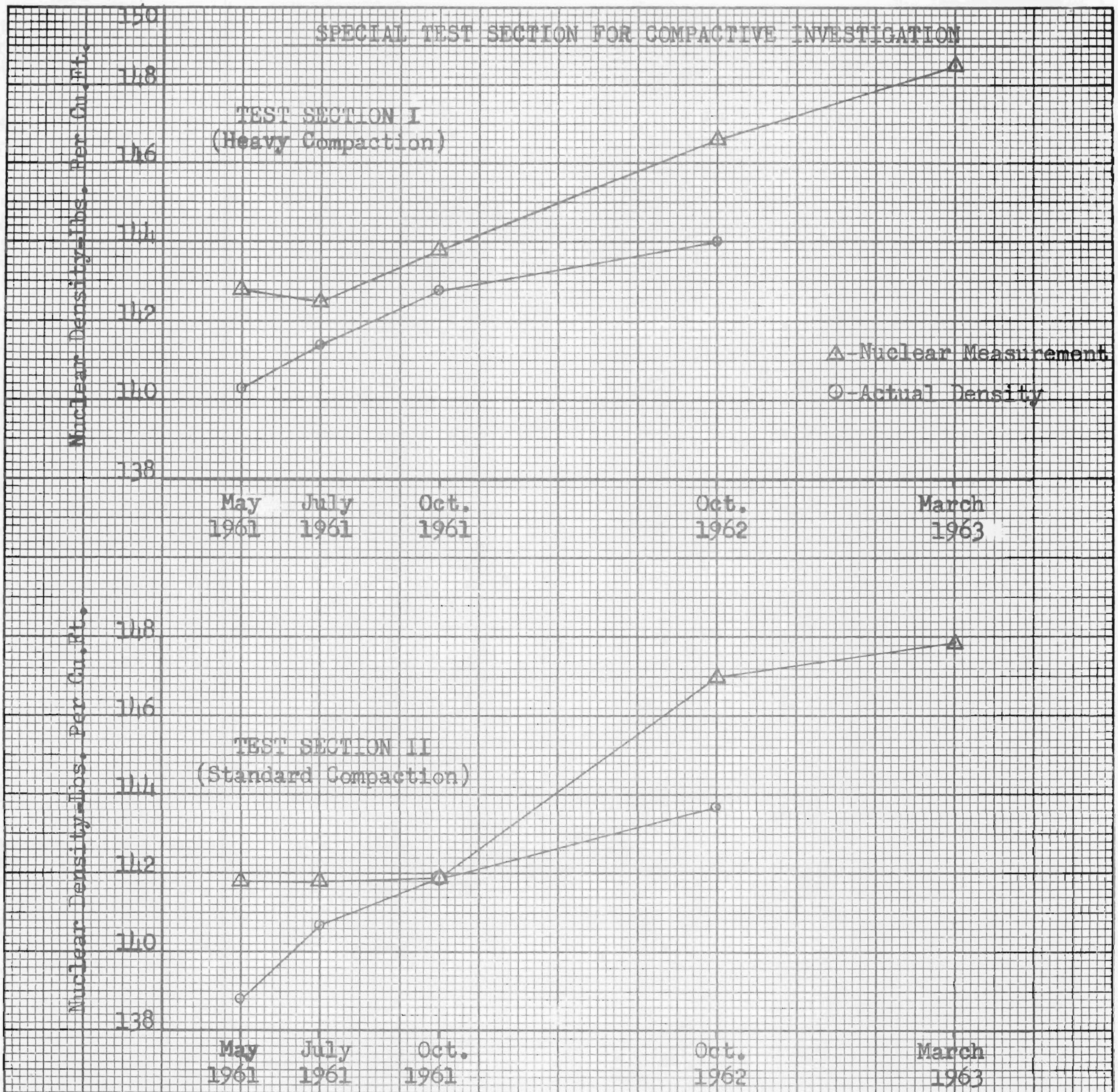
Figure VI

the string line and rule located in the outer wheel path. This pavement has been in use for some eight years and handles a large volume of traffic.

The results of in-place density measurements made on a Hot Mix Asphaltic Concrete test section used by the Materials and Test Division for a compaction investigation study are shown in Figure VII.

Total pavement thickness on the project is 4 1/2 inches. Test Section 1 was subjected to heavy compactive effort. Test Section 2 was subjected to standard or normal compactive effort. Nuclear density measurements and road samples were taken on the dates shown. Road samples were obtained by Materials and Test Personnel at the same location following nuclear density testing. Actual density values were then determined from these specimens. Test results show nuclear density values compare favorably with actual density values. The initial measurements indicated heavier rolling resulted in greater density; however, both sections after 22 months under traffic had gained approximately 6 pounds in density. This represents a 4.0% increase in pavement density in Test Section 1 and a 4.3% density increase in Test Section 2.

Nuclear density data show that the pavement density in both test sections approaches 95% of the absolute volume density after 22 months under traffic or in March 1963 as shown in Figure 7. Actual



Test Section	Density-Lbs/Cu.Ft.		% Compaction		Date Measured
	Nuclear	Actual	Nuclear	Actual	
1	142.8	140.3	91.2	89.7	May 1961
2	141.8	138.8	90.6	88.7	" "
1	142.5	141.4	91.1	90.4	July 1961
2	141.8	140.7	90.6	89.9	" "
1	143.8	142.8	91.9	91.2	October 1961
2	141.9	141.9	90.7	90.7	" "
1	146.6	144.0	93.7	92.0	October 1962
2	147.0	143.7	93.9	91.8	" "
1	148.5	No Data	94.9	No Data	March 1963
2	147.9	No Data	94.5	No Data	" "

Figure VII

density determinations show that the pavement density in both test sections approaches 92% of the absolute volume density after 18 months under traffic. These figures indicate higher densities could be obtained during construction of the asphaltic concrete pavement.

Figures 8, 9, and 10 show results of density measurements made at three different locations across the East Bound and West Bound Main Lanes on a 3 inch course of Type "D" Hot Mix Asphaltic Concrete Pavement. Nuclear density measurements were made before and after the project was open to traffic. Initial measurements were made in August of 1965. Final measurements were made in February 1967 after the roadway had been open to traffic for a period of 18 months. Generally, these graphs show that pavement density had increased due to traffic loads with the maximum increase occuring, as expected, in the wheel paths. The maximum increase indicated by these figures amounts to 3.4%. The percent compaction again approaches 95% of the absolute volume density. The minimum increase amounts to only 0.5% or 90% of the absolute volume density. The wheel path was difficult to define in some instances which possibly could account for the density gradient across the East Bound and West Bound Lanes as shown in Figure 10.

Figure 11 represents the results obtained from another pavement density investigation, and shows the density gradient across Third Avenue, the street, which runs East and West in the rear of the District Laboratory Building. As indicated in Figure 10, a parking

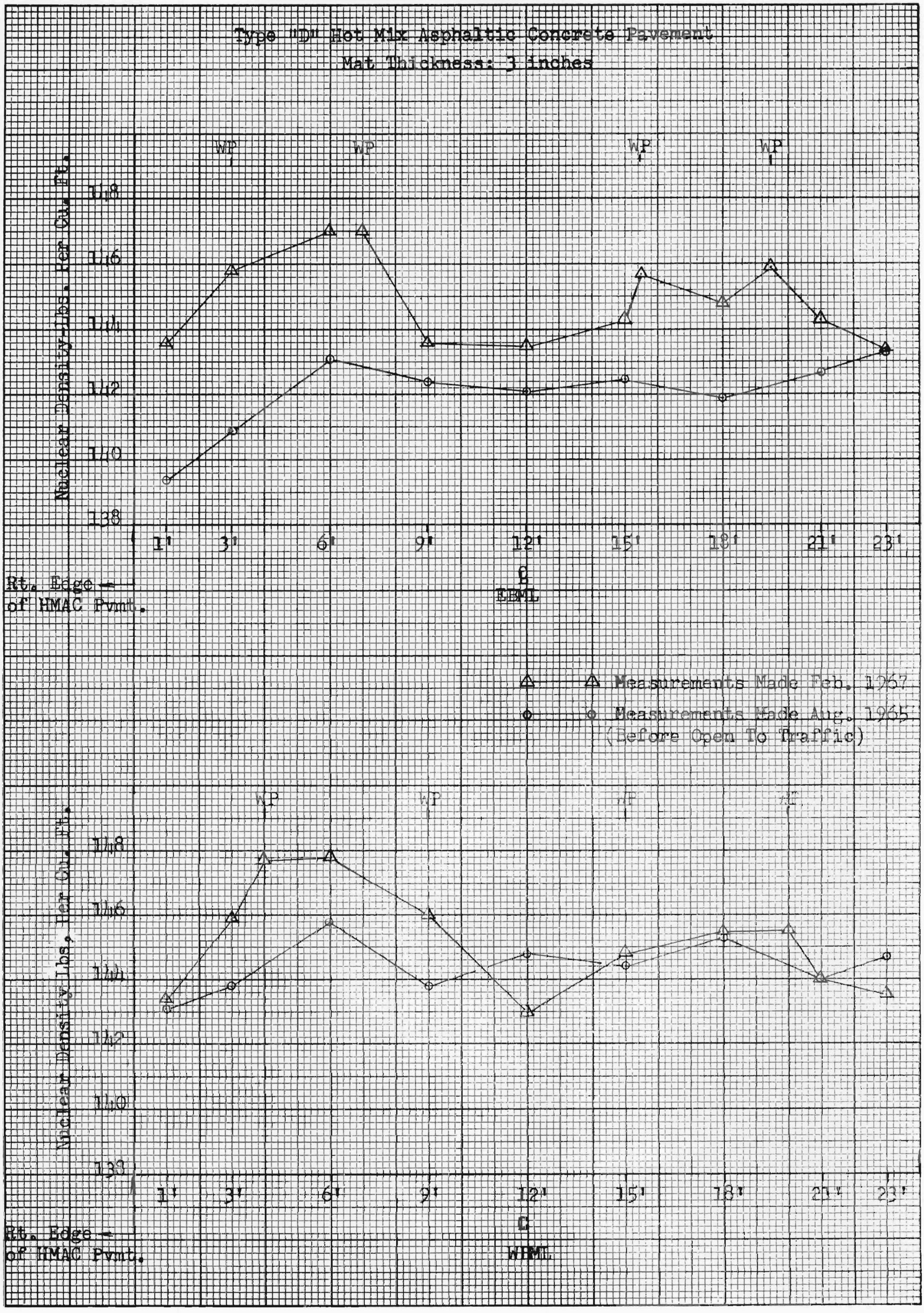

Type "D" Hot Mix Asphaltic Concrete Pavement
Mat Thickness: 3 inches
WP
WP
WP
WP
Nuclear Density-Lbs. Per Cu. Ft.
148
146
144
142
140
138
1'
3'
6'
9'
12'
15'
18'
21'
23'
Rt. Edge
of HMAC Pvmt.
EBML
Measurements Made Feb. 1967
Measurements Made Aug. 1965
(Before Open To Traffic)
WP
WP
Nuclear Density-Lbs. Per Cu. Ft.
148
146
144
142
140
138
1'
3'
6'
9'
12'
15'
18'
21'
23'
Rt. Edge
of HMAC Pvmt.
WBML

Figure VIII

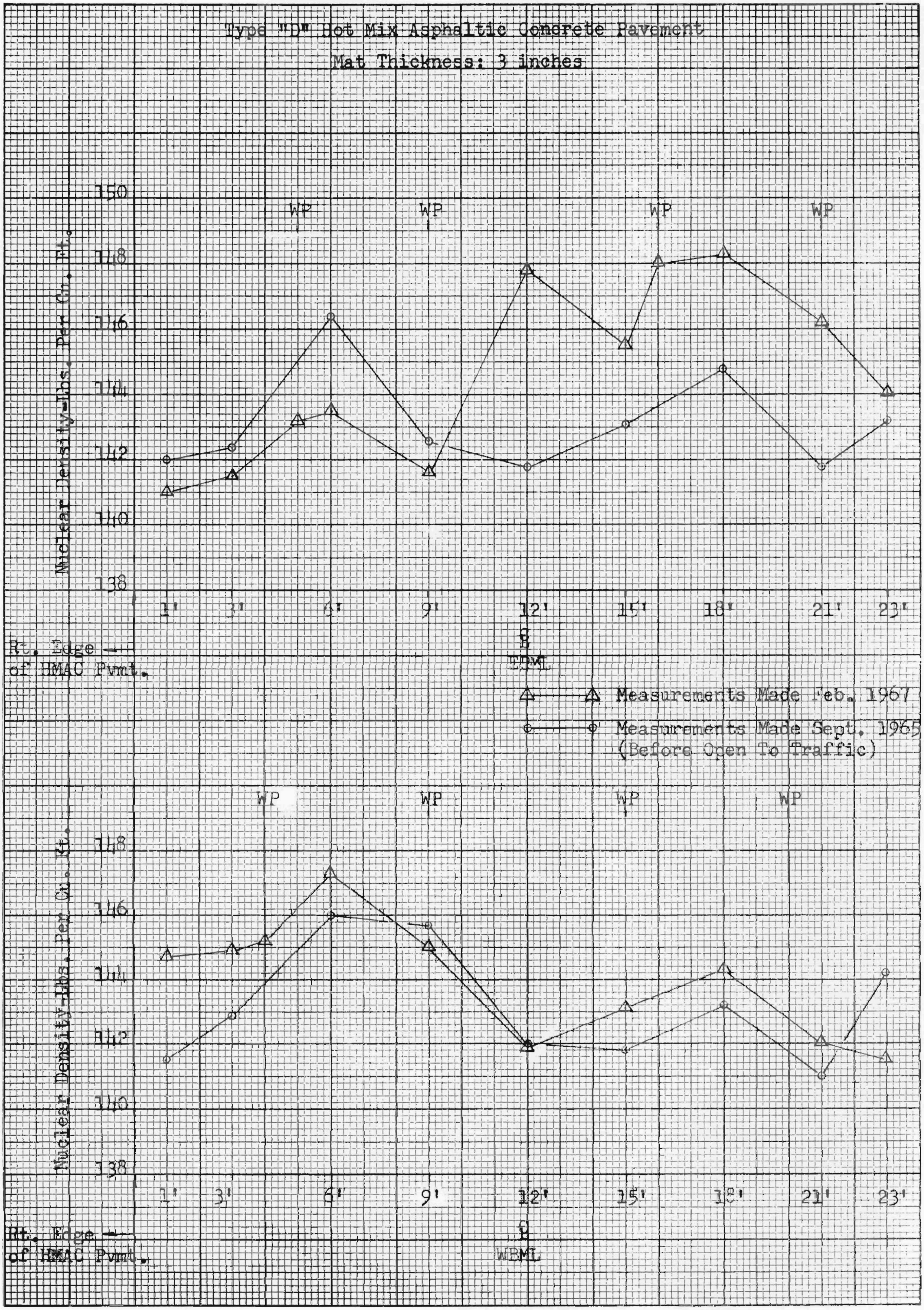
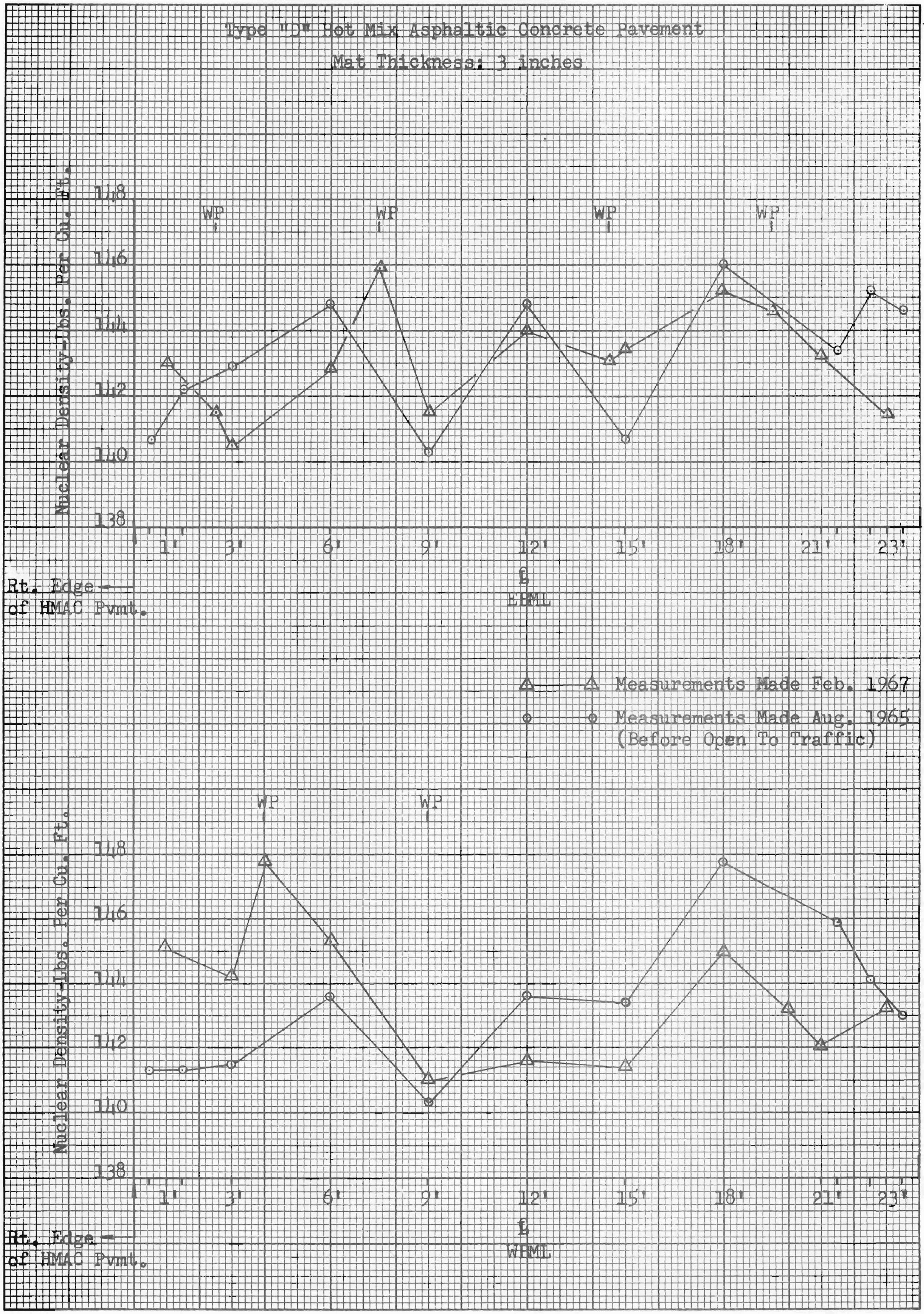

Type "D" Hot Mix Asphaltic Concrete Pavement
Mat Thickness: 3 inches
Nuclear Density-Lbs. Per Cu. Ft.
150
148
146
144
142
140
138
WP
WP
WP
WP
1'
3'
6'
9'
12'
15'
18'
21'
23'
Rt. Edge
of HMAC Pvmt.
EBML
Measurements Made Feb. 1967
Measurements Made Sept. 1965
(Before Open To Traffic)
WP
WP
WP
WP
Nuclear Density-Lbs. Per Cu. Ft.
148
146
144
142
140
138
1'
3'
6'
9'
12'
15'
18'
21'
23'
Rt. Edge
of HMAC Pvmt.
WBML

Figure IX



Type "D" Hot Mix Asphaltic Concrete Pavement
Mat Thickness: 3 inches
Nuclear Density-lbs. Per Cu. Ft.
148
146
144
142
140
138
WP
WP
WP
WP
1'
3'
6'
9'
12'
15'
18'
21'
23'
Rt. Edge
of HMAC Pvmt.
℄
EBML
Measurements Made Feb. 1967
Measurements Made Aug. 1965
(Before Open To Traffic)
Nuclear Density-lbs. Per Cu. Ft.
WP
WP
148
146
144
142
140
138
1'
3'
6'
9'
12'
15'
18'
21'
23'
Rt. Edge
of HMAC Pvmt.
℄
WBML

Figure X

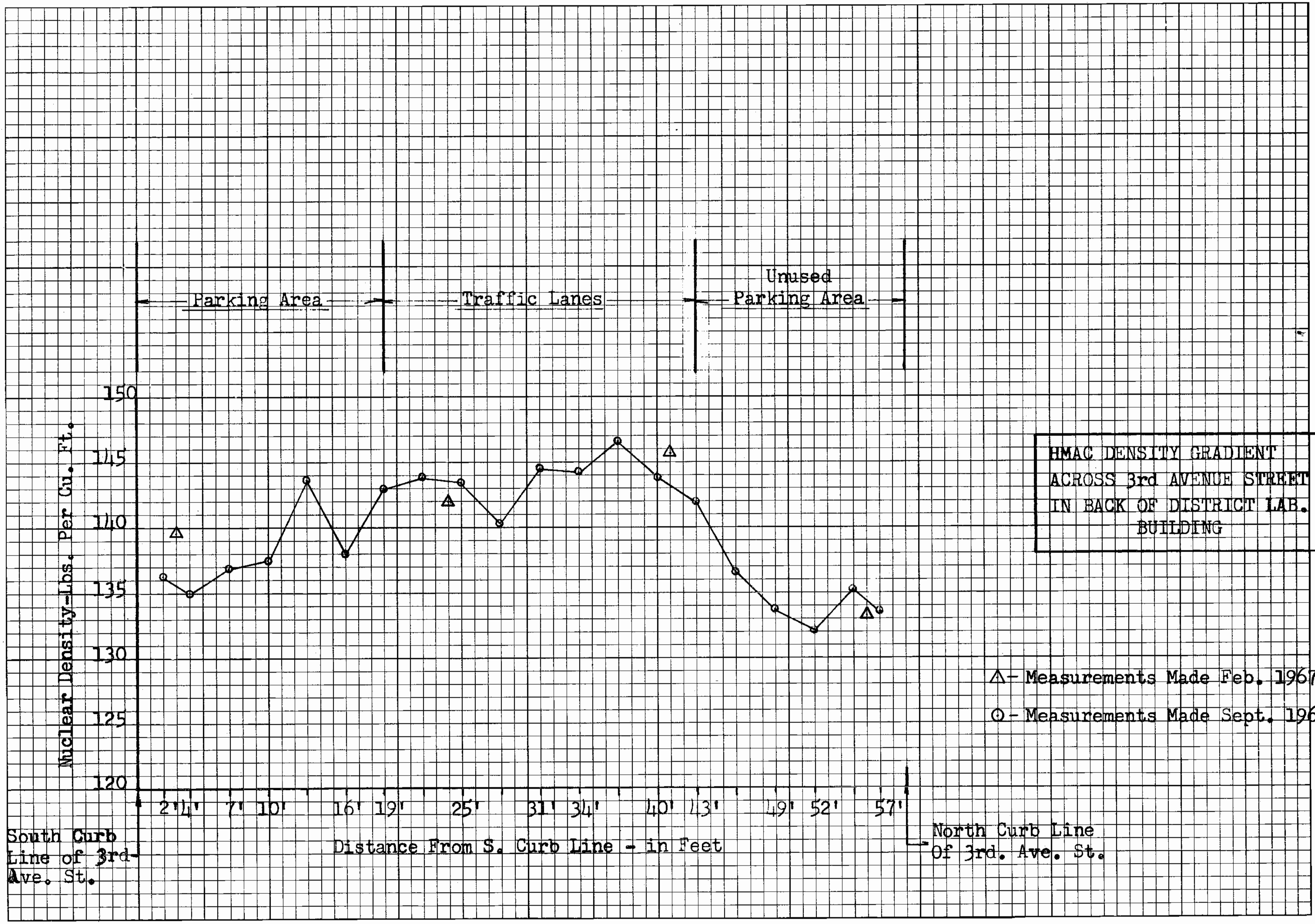

HMAC DENSITY GRADIENT
ACROSS 3rd AVENUE STREET
IN BACK OF DISTRICT LAB.
BUILDING
Parking Area
Traffic Lanes
Unused
Parking Area
Nuclear Density-Lbs. Per Cu. Ft.
150
145
140
135
130
125
120
2' 4' 7' 10' 16' 19' 25' 31' 34' 40' 43' 49' 52' 57'
Distance From S. Curb Line - in Feet
South Curb
Line of 3rd
Ave. St.
North Curb Line
Of 3rd. Ave. St.
Δ - Measurements Made Feb. 1967
⊙ - Measurements Made Sept. 1965

Figure XI

area is located along the South curb line; an unused parking area is located along the North curb line, and the traffic lanes located in between. This street is well traveled and is subjected to truck as well as passenger car wheel loads. Maintenance trucks and various types of delivery vehicles travel this street each day.

Initial nuclear density measurements were made in September, 1965. Additional measurements were made 18 months later in February, 1967. Results from the initial tests show that lower densities were found in the unused parking area; intermediate densities were found in the used parking area; higher densities were found in the traffic lanes. The density gradient curve occurs as expected. Density measurements made in 1967 show similar results even though a minimum number of tests were made for that period. A comparison of these results show some increase in pavement density; however, 3rd Avenue had been in use for some six years prior to the initial density measurements. Consequently, some consolidation due to traffic loads probably had occurred during this time period.

Conclusions

(1) Density test results are rapidly determined with the Asphalt Density Gauge.

(2) Rolling patterns can be readily determined with nuclear density test equipment.

(3) Nuclear and road sample density results compare favorably and are within acceptable tolerance.

(4) With the use of Nuclear Equipment density tests can be made when the asphaltic material is still in a condition that will enable the contractor to make corrections by additional compaction.

(5) Nuclear density tests for compaction control of Hot Mix Asphaltic Concrete during construction are possible and practical.

(6) Use of the pneumatic compactor as a breakdown roller appears to result in higher pavement density on thick lift construction.

(7) Test results show an increase in pavement density due to traffic loads indicating a need for additional construction compaction to minimize consolidation of bituminous pavements after the roadway has been opened to traffic.

(8) Nuclear density test results obtained from coarse graded asphaltic concrete pavements, having excessive surface voids, are inconclusive at the present time.