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RED COLORED PAVEMENT

by

David W. Gwynn
Supervising Highway Engineer
Bureau of Safety and Traffic
Division of Research and Evaluation
New Jersey Department of Transportation

and

Joseph Seifert
Principal Engineer, Research
Bureau of Safety and Traffic
Division of Research and Evaluation
New Jersey Department of Transportation

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D.W. Gwynn
J. Seifert

ABSTRACT

A "before" and "after" study was performed on a ramp ending with a stop sign and at the ramp's intersection with a one-way roadway. Speeds and lags for both day and night conditions were measured "before" and "after" the ramp was paved red.

Four pneumatic tubes, at various distances from the stop line, were placed on the ramp. Ramp traffic was registered on a twenty-pen recorder. Speeds were computed using the difference in time and the distances between tubes. (Average speeds were determined for points 100 ft., 200 ft., and 316 ft. from the stop line.)

Ramp traffic stopping, and ramp and highway traffic crossing the intersection were manually recorded using a twenty-pen recorder. Average accepted and rejected lags were computed.

"Before" and "after" measurements were compared: the daytime speeds were significantly lower after the ramp was paved red, but for nighttime speeds, and for daytime and nighttime lags, there were no significant differences.

D.W. Gwynn
J. Seifert

RED COLORED PAVEMENT

The motorists on today's highways are called upon to assimilate vast amounts of information about the ever-changing traffic stream around them. They must digest and react to a multitude of traffic-control devices within a relatively short period of time.

Over the past twenty-five to thirty years, various experimental sections of colored pavement have been examined in an effort to determine their potential as an aid to better driver performance and highway safety. However, very little controlled research has been reported, and that which has, did not lead to conclusive results.

Initial attempts at producing colored pavement resulted in some unsatisfactory results. A principal source of complaint was color fading, and early applications suffered from an insufficient amount of pigments.

Although colored pavement studies to date have not proven or disproven, for that matter, its effectiveness as an aid to better driving performance and safety, other studies dealing with the use of color as a means of conveying information indicate that color coding is a significant means of conveying information to the motorist.[1,2]

[1] Birren, Faber "Safety on Highways" Amer. J. Opthal., Series 3, 43, 1957
[2] Robinson, C.C. "Color in Traffic Control," Traffic Engineering Mag., May 1967

In order to evaluate on a limited basis the potential of colored pavement as an aid to driver performance and safety, the New Jersey Department of Transportation has installed a section of red colored pavement to be used in conjunction with stop signs. The study will evaluate (1) the performance of materials used to produce a colored surface, and (2) various driver characteristics related to the use of colored pavement. The first portion of this study, the materials evaluation, will not be discussed in this report as the test section of highway has not been in operation a sufficient period of time to adequately conduct such an evaluation. It is anticipated that the materials evaluation will evaluate such physical characteristics as (1) color uniformity, saturation and retention; (2) visibility and reflectance; (3) skid resistance properties; and (4) reaction to chemicals, among other factors. The Prismo Safety Corporation applied red coated spheres to this section of colored pavement and the results of their tests of reflectivity and sphere retention will be covered in the materials evaluation.

As previously stated, the color selected for evaluation was red and was used in conjunction with a stop condition. This is in accordance with a recommended use of the color red by the special committee on color of the National Joint Committee on Uniform Traffic Control Devices.

The color red in highway practices is accepted to mean "stop" or "do not."[3] There was some apprehension as to what the motorist's reaction would be to this red colored pavement. Would he think there was a stop condition ahead and react accordingly, or would he feel that it meant

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[3] Robinson, C.C. op. Cit.

"do not enter" and cause him to react accordingly? This was an important question at this location since it was at a ramp-type location where the color red could have conveyed either meaning. However, since to our knowledge it has not stopped anyone from entering the ramp, it did not convey the meaning of "do not enter."

PURPOSE

The purpose of this portion of the study is to evaluate the effects of red colored pavement on various aspects of driver behavior at a ramp location ending in a stop condition.

DESCRIPTION OF SITE

The location of the section of highway selected for the study was the intersection of U.S. 206 and N.J. 68 in Mansfield Township, Burlington County, New Jersey (see Figure 1 and Photo 1). A 280-foot section of the Route 206 southbound ramp (between U.S. 206 southbound lanes and U.S. 206 northbound lanes) was paved with a 3/4" red asphalt pavement on June 22, 1967. Prior to this, the ramp was concrete. This ramp leads to a stop condition at the northbound lanes of U.S. 206 and connects into N.J. 68 eastbound (on the east side of the northbound lanes of U.S. 206). The terrain is flat and open, with no sight-distance restrictions. The speed limit on U.S. 206 is 55 mph in both directions. There are two oversize (44" x 44") internally illuminated (neon tubing) flashing stop signs at the end of the ramp (see Photo 2). The ramp is illuminated by two 4,000 lumen incandescent overhead lights spaced 170 ft. apart, on the right-hand side of the ramp. Two 4,000 lumen incandescent overhead lights located on U.S. 206 also contribute illumination to the ramp.

The AADT on U.S. 206 south, at the entrance to the ramp, is 7,500 vehicles per day, with approximately 54%, or 4,050 vehicles per day, using the ramp. The AADT on U.S. 206 north is 3,500 vehicles per day at the ramp crossing with U.S. 206 north. The ramp consists of two 16 ft. lanes bordered by mountable concrete curbs. White solid edge-marking lines were in place next to the concrete curb and a white skip-line separated the two lanes. A white stop line was at the location of the stop signs at the east end of the ramp. The same markings were replaced after the red pavement was installed.

Although accidents are not reported in this report due to insufficient time to evaluate them after the pavement was laid, they did play a role in the selection of the location as a study section. A "before" and "after" accident analysis will be conducted after sufficient time has elapsed to adequately conduct such a study.

For the period from January 1, 1963 to December 31, 1965, a total of 31 accidents occurred -- three fatal, killing five persons, and eleven injury accidents, injuring 44 persons. Twenty-two of the accidents were right angle and seven were rear-end. All rear-end accidents occurred on the ramp.

STUDY PROCEDURE

One of the major reasons for adding color to the road surface is that the color should alert the motorist to an impending special condition.

In this case, the red color was to alert the motorist to an impending stop condition. In an attempt to evaluate this, two characteristics were measured -- the speeds of vehicles* approaching the stop signs were measured "before" and "after" the installation of the red pavement at various points to be discussed later. Also, the number of vehicles disregarding the stop signs were measured "before" and "after" the installation of the red pavement. A third characteristic was also measured that was felt could be affected by the red pavement. This was the acceptance of lags by vehicles crossing U.S. 206 north from the ramp. It was felt that the red pavement might alert the motorist to a hazardous condition and cause him to be more cautious to conditions at the intersection, thereby perhaps choosing to accept longer lags. A lag, for the purpose of this study, is the time interval between the arrival of a vehicle at the stop sign on the ramp and the arrival of the first vehicle on U.S. 206 at the center of the intersection of the ramp and U.S. 206 north. A lag will also be referred to as a time interval between the arrival of a vehicle at the center of the intersection of U.S. 206 north and the arrival of the next vehicle on U.S. 206 north at the same location when a vehicle is waiting on the ramp to cross U.S. 206 north. To insure an adequate, consistent sample, only lags for cars which are first in line on the ramp will be tabulated. (Lags for queued vehicles will not be tabulated.)

SPEED MEASUREMENTS

Speeds were measured by use of pneumatic tubes stretched across the ramp at distances of 50 ft., 150 ft., 250 ft., and 386 ft., from the

*Vehicles refer to passenger cars or vehicles with four tires.

stop line and connected to a twenty-pen recorder. The speed data was collected during both day and night conditions; only vehicles which stopped for the stop sign were recorded. Since speeds recorded are average speeds over a measured distance, they are plotted at the mid-points between the tubes at which the speeds were determined. In other words, the speeds are plotted at distances of 100 ft., 200 ft., and 318 ft. from the stop line (see Figure 1). "Before" and "after" speed data was taken as shown in Table 1.

The weather was clear and dry during all data collection periods.

LAG MEASUREMENTS

The measurements of lag acceptance and rejection were made by utilizing a telegraph key connected to a twenty-pen recorder. The recorded data was (1) a vehicle arriving at the center of the intersection of U.S. 206 and the ramp on U.S. 206, (2) a vehicle arriving at the stop line on the ramp, and (3) a ramp vehicle crossing the intersection. The sample data recorded on the recorder is shown in Figure 2. Referring to this Figure, line 1 shows a blip for the arrival of a vehicle on U.S. 206, line 2 shows a blip for the arrival of a vehicle on the ramp, and line 3 shows the crossing of a vehicle on U.S. 206. Distance R in Figure 2 is a time lag rejected, while distance A is the time lag accepted by the vehicle on the ramp to cross U.S. 206 north. Lag data was taken "before" and "after" the installation of the red pavement as shown in Table 2.

VEHICLES DISREGARDING STOP SIGN

The number of vehicles which passed through the stop sign, making no attempt to slow or stop, was recorded during the same time periods as the collection of lag data.

ANALYSIS AND RESULTS

Speeds "Before" and "After"

The speed data was analyzed statistically by utilizing the standard test for testing significant differences in means:

The formula utilized for this test is as follows:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}}$$

Where:

$\overline{X}_1$ and $\overline{X}_2$ are the mean speeds for "before" and "after";

N_1 and N_2 are the sample sizes for "before" and "after";

S_1 and S_2 are the standard deviations of the speeds "before" and "after."

The level of significance used in the test was the 90% level of significance. If the t value obtained in the test is greater than the t value for the 90% level (1.65) of significance, then there is assumed to be a significant difference in the results at this level of significance.

As stated previously, the speeds were obtained at distances of 100, 200, and 318 feet from the stop line. Table 3 shows the speeds "before" and "after" at each point and for "day" and "night" conditions. This is also shown in Figures 3 and 4.

It can be seen (Figure 3) that at all three points where the speeds were recorded for the "day" conditions, the "after" average speeds were less than the corresponding "before" speeds. Although the average speeds "after" were less by only approximately one (1) mph, they were significantly different at the 90% level of confidence at points A and B. At point C there was no significant difference in the average speeds "before" and "after."

At the same three points (Figure 4) during night conditions, the average speed during the "after" portion was also less than the "before" average speed. However, at none of the three points were the average speeds significantly different at the 90% level for "before" and "after."

A second test, the "F" test was used to check for a significant difference in the variance of the "before" and "after" speeds. The formula utilized for this test is:

$$F = \frac{S_1^2}{S_2^2}$$

where S_1^2 = variance of "before" speed data

S_2^2 = variance of "after" speed data

The 90% level of significance was used in this test also.

At points A and C there is a significant difference in the variability of the "before" and "after" speeds for day conditions. At point A, the variance "before" is greater than the "after" variance, while at point C, the reverse is true. At point B there is no difference at the 90% level of significance. The colored pavement may have the effect of causing speeds to be grouped closer around the mean at point A, while it appears that the reverse occurred at point C. It would appear more desirable to have the speeds grouped closer around the mean, as at point A, than to have a larger variation, as at point C.

For "night" conditions, there was a significant difference at the 90% level at point A, as was for "day" conditions. However, there was no significant difference at points B and C. The "after" variance was again less than the "before" variance.

The fact that the mean speeds are not significantly different for "before" and "after" conditions during hours of darkness, appears to support the opinions of our engineers who have driven the section during both "day" and "night" conditions. The red pavement is certainly visible during "day" conditions, but appears to "blackout" at night. The red color does not appear to be discernible, thereby logically indicating that the red pavement should have no effect on changing speeds in the area.

Although the average speeds were only slightly less during the "after" period for "day" conditions, it is possible that the red pavement alerted the motorist to the impending stop-hazardous condition which thereby contributed to the reduction in the average approach speeds. For "night" conditions, since it appears at least visually that the red pavement was not distinguishable, the average speeds should not have been affected by the red pavement and, statistically, they were not.

LAG ACCEPTANCE AND REJECTION

Vehicles accepting or rejecting lags of from 0.5 seconds to 15.0 seconds were analyzed to determine the mean lag accepted and the mean lag rejected for both "before" and "after" conditions. The 15-second maximum lag was used as no vehicle rejected a lag over 15 seconds.

During the "before" and "after" period for "day" conditions, the average lag accepted was 10.52 seconds and 10.72 seconds, respectively. A test for significant differences in means at the 90% level of confidence indicated that there was no significant difference between the average lag accepted "before" and "after" the installation of the red pavement. The average lag rejected for the same conditions were 3.70 seconds "before" and 3.97 seconds "after." Here, also, there was no significant difference in the two average values "before" and "after" (see Table 4).

It does not appear that the red colored pavement has any effect on causing the driver to be more cautious and perhaps accept a longer lag.

For "night" conditions "before" and "after," the average lags accepted were 11.28 seconds and 11.05 seconds, respectively (see Table 5). Here again, the test for significant differences in means indicates that there was no significant difference between the average lag accepted at night "before" or "after" the installation of the red pavement. The average lag rejected at night "before" was 4.49 seconds, and "after" it was 4.51 seconds. There was no significant difference at night in the average lag rejected "before" and "after" the installation of the red pavement.

Here again, it does not appear that the red colored pavement had any effect on causing the driver to be more cautious and perhaps accept a longer lag.

DISREGARD OF STOP SIGN

Under "day" conditions before the pavement was installed, 8 out of 282 vehicles observed passed through the stop sign without making any attempt to slow or stop. After the installation, 3 vehicles out of 351 observed passed without stopping. For "night" conditions, 2 out of 252 observed passed "before" as compared with one (1) out of the 311 observed "after." A test for significant difference in proportions, also at the 90% level, indicates that there is no significant difference in the passing "before" and "after" for day or night conditions.

CONCLUSIONS

No definite conclusions can be drawn from this study concerning the overall effectiveness of the use of red colored pavement, particularly since it deals with only one location. However, it is felt that this study gives some insight into the effect of the red colored pavement on approach speeds and lag acceptance and rejection. At this site, it appears that the red pavement may have a significant effect on causing the average approach speed at two of the three study points to be significantly less for "day" conditions. It also may have an effect on the variation of speeds at two of the study points, although the variation was less at one point "after" and greater at the other. It could be argued that the difference in average speeds was too small to be appreciable logically; however, it was appreciable statistically at the 90% level of significance. For "night" conditions, there was no change in the average "before" and "after" speeds statistically; since the red color was not discernible at night, this appears logical.

The red pavement apparently had no effect on the average lag accepted or rejected "after" the installation of the pavement as compared with "before" the installation for both "day" and "night" conditions.

Generally, it appears that the red colored pavement caused little, if any, change in the parameters studied. However, two major categories are yet to be studied, namely, (1) the materials evaluation and (2) the accident analysis.

Also, it must be kept in mind that the use of colored pavement to convey a definite meaning to the motoring public is new and little, if any attempt has been made to educate the public as to its use or meaning. Although this location was given wide newspaper and T.V. coverage, it is doubted if the majority of motorists passing through the location accept the red color to mean that a "stop" or "hazardous" condition is impending. Perhaps the better measure will be the accident evaluation.

Although the results of this study show little, if any, change in the parameters studied "after" the installation of the red pavement, it is not meant to infer that colored pavement cannot be an effective traffic control device. It is felt that colored pavement has the same potential to convey messages through its use of color as traffic signs. However, some means of educating the motoring public to the meanings of the various colors when used in pavements must be devised. Then the results of studies to evaluate its effectiveness will perhaps be more meaningful and give a better insight into its actual potential as a traffic control device.

A P P E N D I X

TABLE 1

SPEED DATA COLLECTION TIMES

DATE	DAY OR NIGHT	HOURS	SAMPLE SIZE
		Before	
5/4/67	Day	4:00 p.m. - 6:30 p.m.	286
5/4/67	Night	8:30 p.m. - 10:30 p.m.	297
		After	
7/27/67	Day	3:45 p.m. - 7:00 p.m.	603
7/27/67	Night	8:45 p.m. - 10:15 p.m.	402

TABLE 2

LAG DATA COLLECTION TIMES

DATE	DAY OR NIGHT	HOURS	SAMPLE SIZE *
		Before	
11/4/66	Day	1:30 p.m. - 3:00 p.m.	86
11/9/66	Night	6:30 p.m. - 8:00 p.m.	44
		After	
7/31/67	Day	1:40 p.m. - 3:10 p.m.	124
8/1/67	Night	8:45 p.m. - 10:15 p.m.	47

* For cars which are first in line only.

TABLE 3

BEFORE & AFTER SPEED DATA

SITE	DISTANCE FROM STOP SIGN	MEAN SPEED (MPH) BEFORE	MEAN SPEED (MPH) AFTER	SIGNIFICANT DIFFERENCE
		Day		
A	318'	38.7	37.6	Yes
B	200'	32.1	31.5	Yes
C	100'	24.1	23.9	No
		Night		
A	318'	37.4	37.1	No
B	200'	31.5	31.2	No
C	100'	23.9	23.6	No

D.W. GWYNN
J. SEIFERT

TABLE 4

LAG DISTRIBUTIONS

DAY

MIDPOINT VALUE (SEC.)	ACCEPTED Before	ACCEPTED After	REJECTED Before	REJECTED After
0.25	0	0	8	11
0.75	0	0	13	21
1.25	0	0	9	28
1.75	0	0	13	16
2.25	0	0	18	15
2.75	0	0	17	15
3.25	0	0	9	29
3.75	0	0	14	12
4.25	1	0	7	12
4.75	0	0	6	6
5.25	0	0	4	12
5.75	1	4	8	11
6.25	1	2	4	10
6.75	4	4	6	11
7.25	4	7	11	5
7.75	9	3	3	2
8.25	5	7	3	4
8.75	5	11	2	2
9.25	6	3	0	5
9.75	2	9	1	2
10.25	2	9	0	2
10.75	7	8	1	3
11.25	3	9	0	3
11.75	7	8	0	3
12.25	6	5	0	0
12.75	4	2	0	1
13.25	6	8	0	1
13.75	2	9	0	0
14.25	5	6	1	0
14.75	6	10	0	0
TOTAL	86	124	158	248
Over 15.00	157	190	0	2
Mean	10.52	10.72	3.70	3.97
Std. Dev.	2.65	2.57	2.53	2.90

NOTE: Means are computed using values of 15.00 seconds or less.

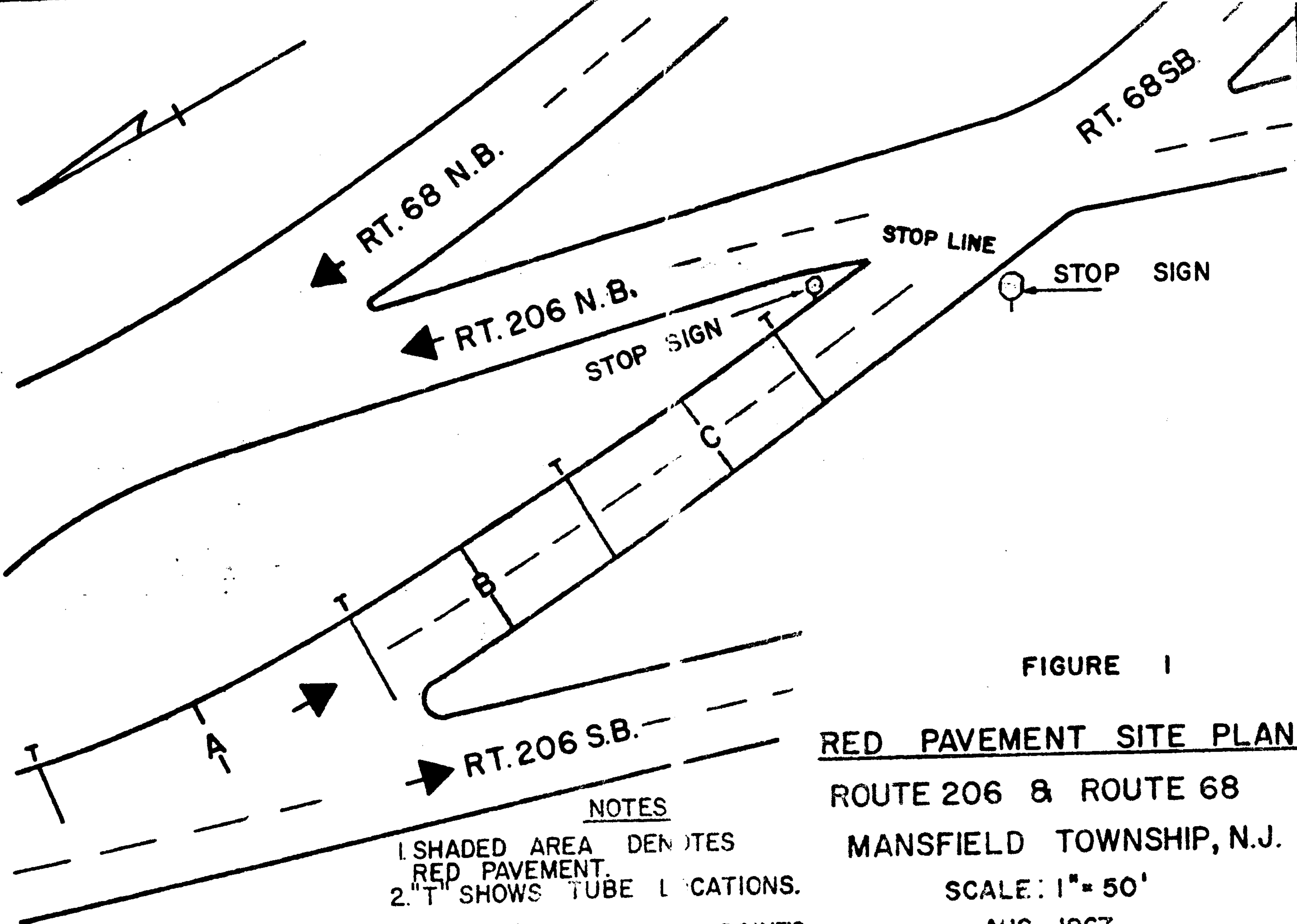
TABLE 5

LAG DISTRIBUTIONS

NIGHT

MIDPOINT VALUE (SEC.)	ACCEPTED Before	ACCEPTED After	REJECTED Before	REJECTED After
0.25	0	0	4	10
0.75	0	0	8	12
1.25	0	0	9	8
1.75	0	0	6	20
2.25	0	0	6	8
2.75	0	0	4	9
3.25	0	0	4	7
3.75	0	1	7	14
4.25	0	0	8	12
4.75	0	1	5	6
5.25	0	0	5	5
5.75	0	0	3	13
6.25	0	0	3	7
6.75	0	1	3	7
7.25	0	2	5	7
7.75	1	0	4	4
8.25	0	3	2	2
8.75	3	3	4	7
9.25	3	1	4	2
9.75	5	4	0	1
10.25	6	3	1	1
10.75	3	3	2	4
11.25	2	3	0	2
11.75	4	0	0	2
12.25	6	6	2	0
12.75	3	3	0	1
13.25	4	3	0	3
13.75	1	4	0	0
14.25	0	3	0	0
14.75	3	3	0	0
TOTAL	**44**	**47**	**99**	**174**
Over 15.00	**164**	**216**	**1**	**0**
Mean	**11.28**	**11.05**	**4.49**	**4.51**
Std. Dev.	**1.77**	**2.65**	**3.05**	**3.19**

NOTE: Means are computed using values of 15.00 seconds or less.



NOTES

1. SHADED AREA DENOTES RED PAVEMENT.
2. "T" SHOWS TUBE LOCATIONS.
3. "A", "B" & "C" ARE SPEED POINTS.

FIGURE 1

RED PAVEMENT SITE PLAN

ROUTE 206 & ROUTE 68

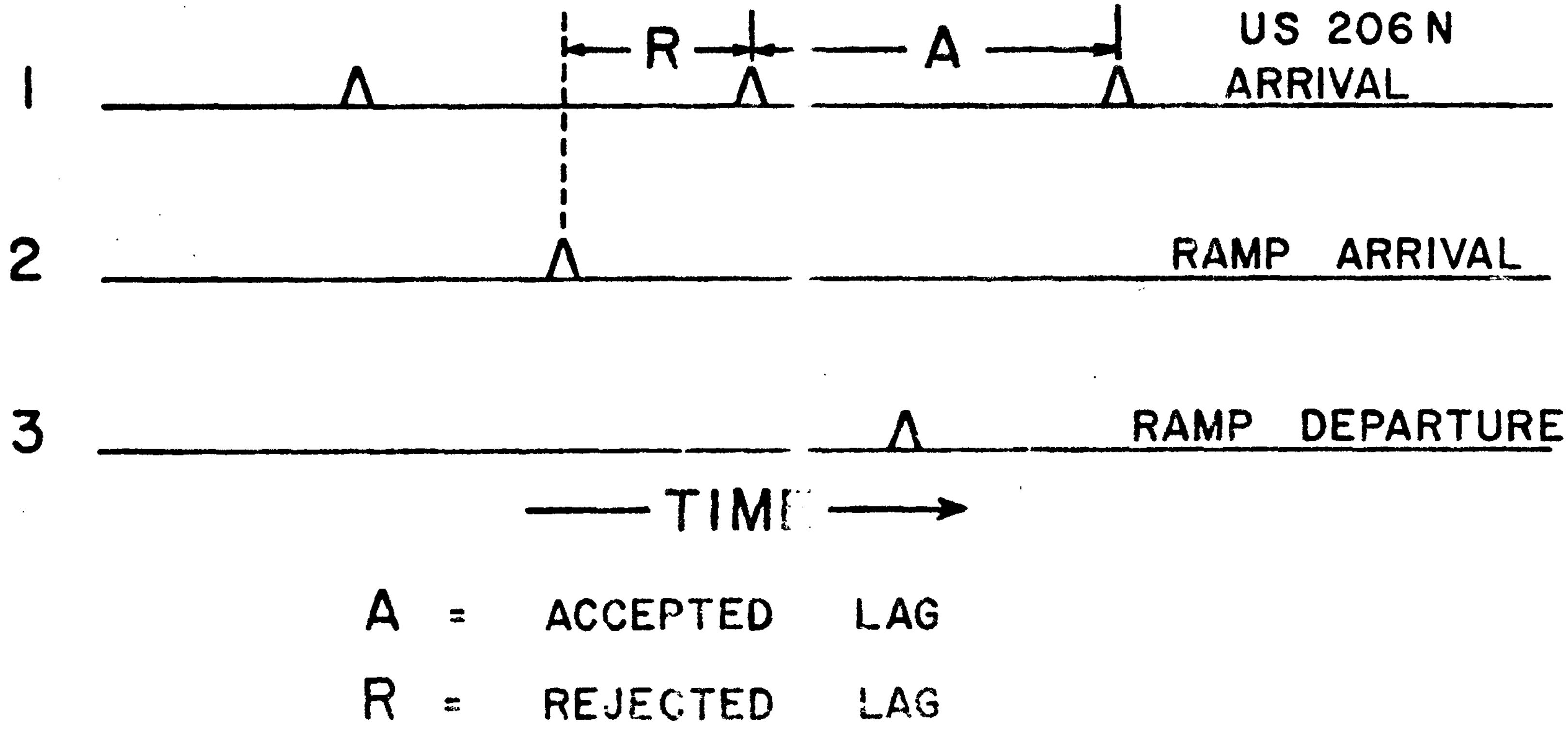
MANSFIELD TOWNSHIP, N.J.

SCALE: 1" = 50'

AUG, 1967

FIGURE 2

RECORDER TAPE



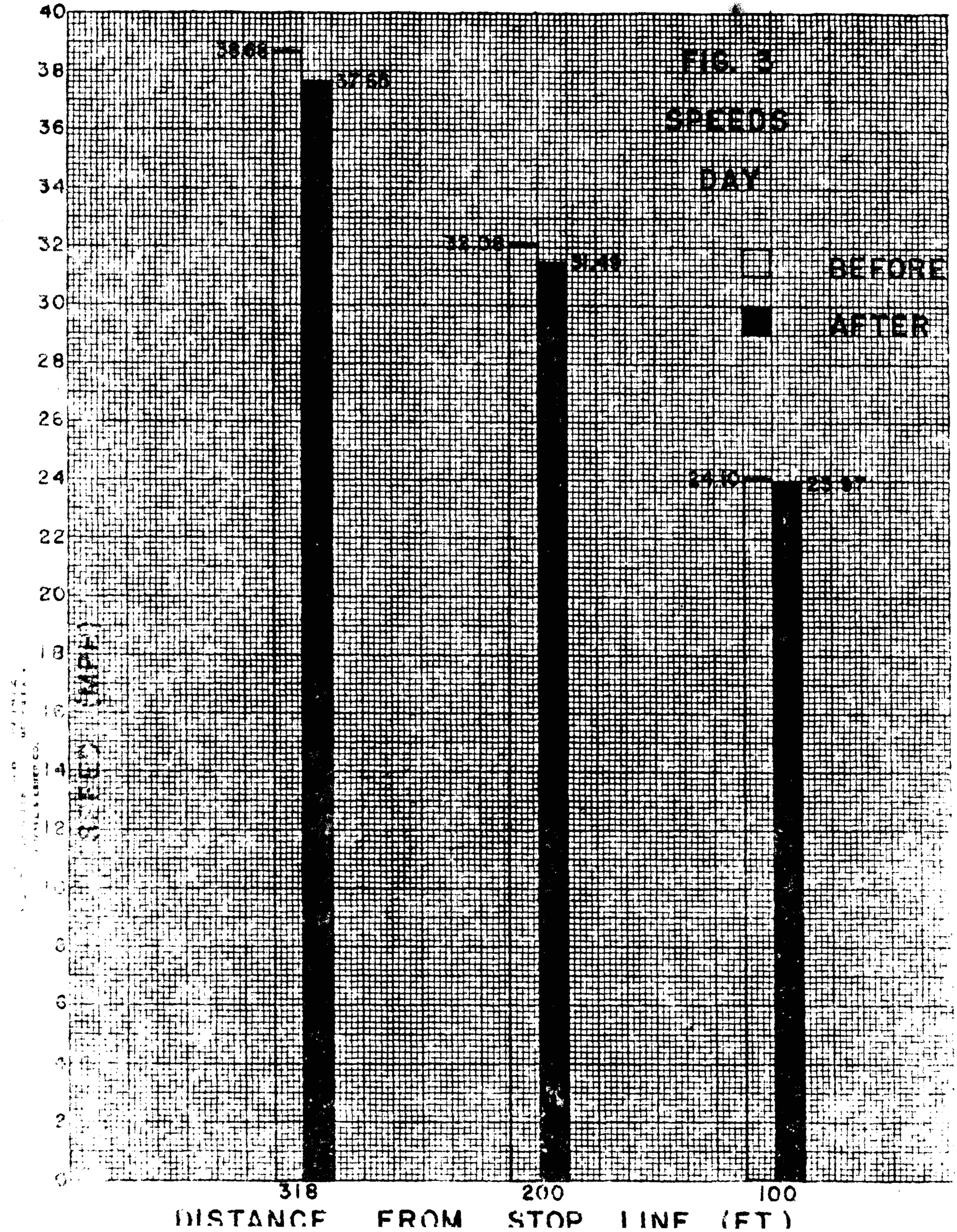


FIG. 3
SPEEDS
DAY
BEFORE
AFTER
38.68
37.55
32.08
31.49
24.10
23.97
SPEED (MPH)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
318
200
100
DISTANCE FROM STOP LINE (FT)

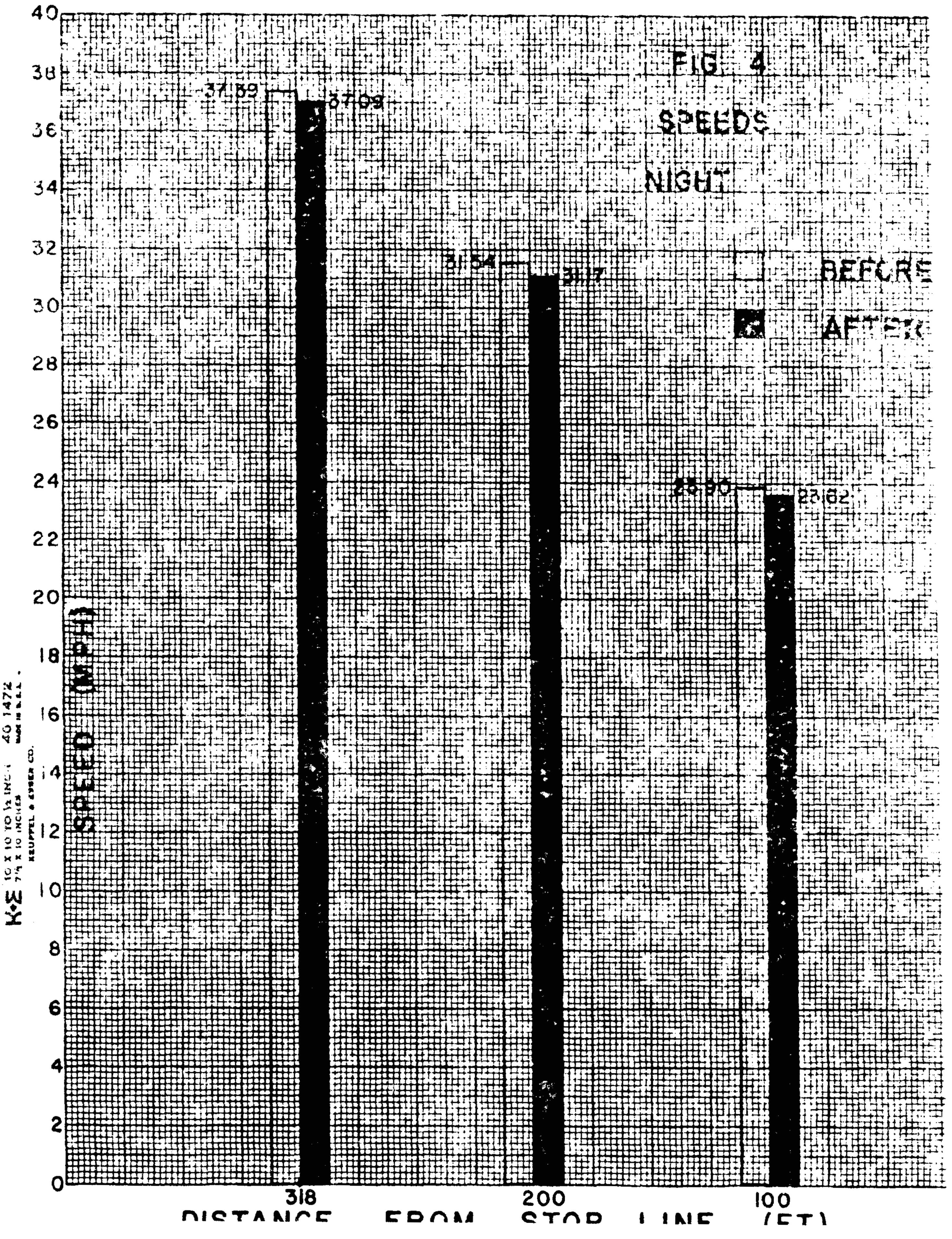


FIG. 4
SPEEDS
NIGHT
BEFORE
AFTER
37.39
37.09
31.54
31.17
23.90
23.62
SPEED (MPH)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
318
200
100
DISTANCE FROM STOP LINE (FT)

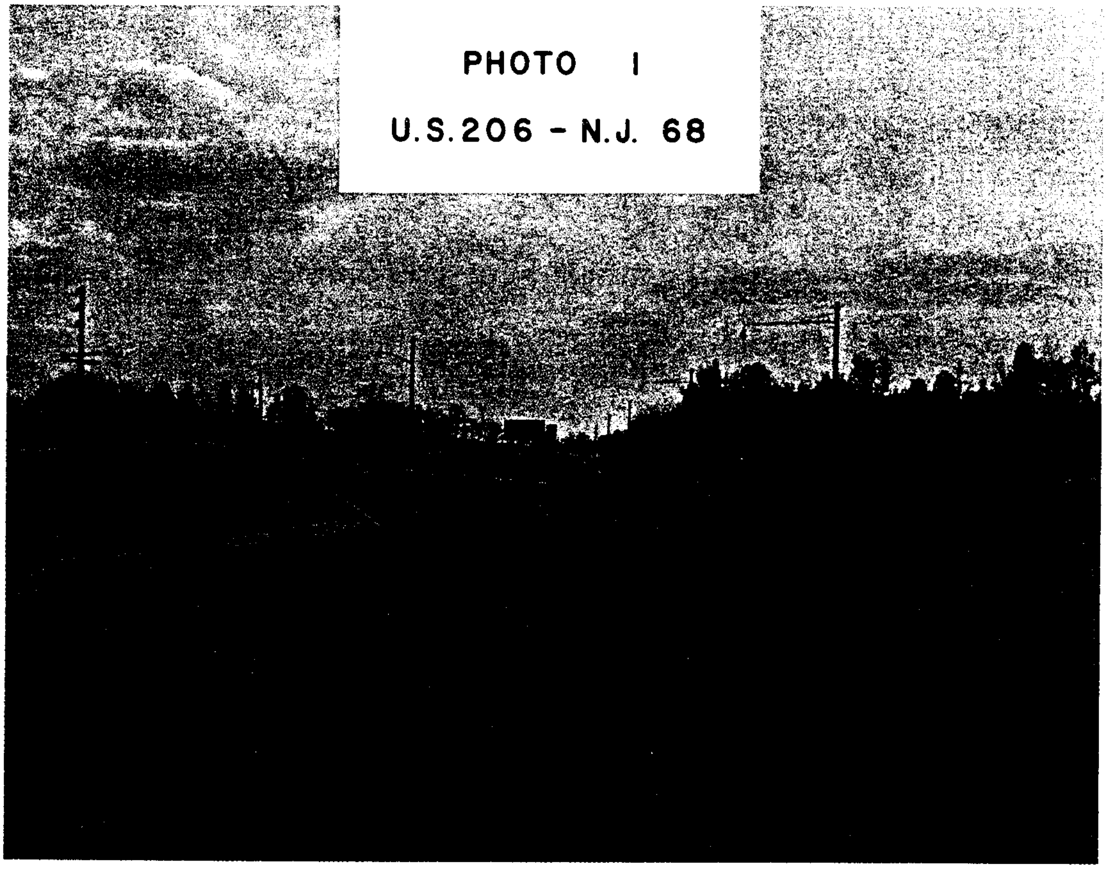


PHOTO 1

U.S. 206 - N.J. 68

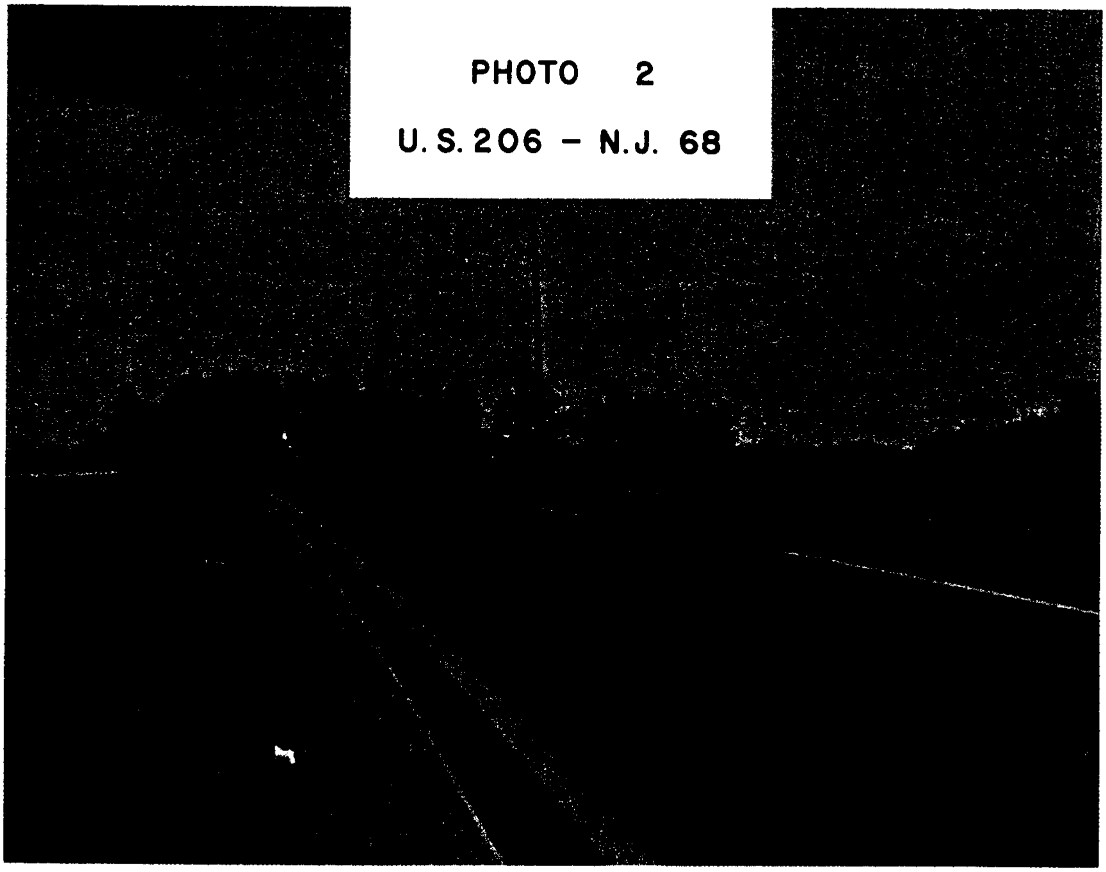


PHOTO 2

U.S. 206 - N.J. 68