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BLACKOUT HEADLAMP ILLUMINATES ONLY LOW SIGNS AND MARKINGS

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D. M. BEACH, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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HIGHWAY SIGNS AND MARKINGS FOR BLACKOUT CONDITIONS

BY THE DIVISION OF TRAFFIC AND SAFETY, OHIO DEPARTMENT OF HIGHWAYS AND THE DIVISION OF HIGHWAY TRANSPORT, PUBLIC ROADS ADMINISTRATION

Reported by GEORGE J. FISHER, Assistant Traffic Engineer, Ohio Department of Highways, and O. K. NORMANN, Highway Engineer-Economist, Public Roads Administration

Marking important highways so that essential vehicular traffic can move with comparative safety during blackouts may become one of the most critical traffic-control problems during the present emergency.

This report includes results of a study conducted during blackout conditions by driving passenger cars equipped with lights approved by the War Department over highways on which a large variety of standard and special signs and markings were installed.

A highway, either urban or rural, can be marked so that vehicles equipped with the approved blackout lighting system may be operated with comparative safety at speeds up to 20 miles per hour.

The need for most types of signs will be reduced during blackouts while the need for marking center-lines and hazardous objects within the roadway will be increased.

Signs, to be effective, must be either illuminated or reflectorized and mounted with their legends within 18 inches of the roadway elevation and as near the roadway as practicable. Pavement markings, to be effective, must be reflectorized.

THE complete elimination of all lights that would be visible at night to enemy aircraft has thus far been ordered by military authorities in very few sections of the United States and then only for relatively short periods. However, test blackouts to train Civilian Defense organizations and to make the necessary preparations in case frequent blackouts become necessary have been conducted in all sections of the country, especially in the coastal areas. While it may never be necessary to have blackouts over extended areas of the United States for long periods, present conditions warrant taking the necessary steps to insure that problems arising in blackouts can be handled quickly and efficiently.

One of the problems involved is the movement of essential vehicular traffic. Even during blackouts lasting for only short periods, certain military vehicles and emergency civilian vehicles must be in operation. In any area having frequent blackouts, it can also be assumed that vehicles carrying materials and workers to and from war production plants will be permitted to operate. Otherwise, production would be seriously curtailed.

Regulations governing traffic movement during blackouts, issued by the Office of Civilian Defense [1] and based on standards set by the War Department, specify that only vehicles equipped with blackout lights approved by the War Department will be permitted to operate.

The approved blackout lighting system for civilian vehicles, decided upon after extensive tests by the Blackout and Traffic Control Branch of the Engineer Board of the War Department, consists of one head lamp, two front clearance lamps, and a combination stop and tail lamp (fig. 1). The head lamp or driving lamp emits a beam that has only a small fraction of the intensity of an ordinary seal-beam headlight. It must be mounted as near the front of the vehicle as possible, between the left side and center of the vehicle and at a height of not less than 36 or more than 55 inches above the road surface. When properly adjusted, the visual cut-off of the top of the beam slopes down at the rate of 2 to 3 inches every 10 feet and illuminates a level road surface uniformly for 20 to 100 feet in front of the car. Beyond 100 feet, the illumination on the road surface gradually decreases until there are no light rays falling beyond 200 feet from the vehicle.

The two clearance lamps are mounted on the front fenders as far apart and as near the normal headlight height as possible. When viewed from less than 120 feet in front of the vehicle, two separate illuminated areas are visible in each lamp. Beyond this distance, the two separate illuminated areas in each lamp appear as a single light.

The combination stop and tail lamp must be mounted as near the left side as practicable and at a height of not less than 20 inches or more than 50 inches above the road. Only a single area is illuminated when the stop light is turned on, whereas four separate areas are illuminated in the tail lamp. The four individual areas can be seen up to a distance of 60 feet. Between 60 and 120 feet, the illuminated portion appears as two separate areas, while at distances over 120 feet the areas appear to merge and only one light is seen. This design feature is of assistance to a driver in estimating the distance to another vehicle when only the taillight is visible.

Lights used on the vehicle during normal conditions, including dash lights, are turned off when the switch for the blackout lights is turned to the ON position.

Recognizing the need of special devices to regulate, warn, and guide drivers of vehicles during blackouts, the Division of Traffic and Safety of the Ohio Department of Highways in cooperation with the Public Roads Administration conducted this study of the effectiveness of various highway signs and markings

[1] Blackout Requirements for Highway Movement, prepared under the direction of the Chief of Engineers, United States Army, by the Engineer Board, and published by United States Office of Civilian Defense.

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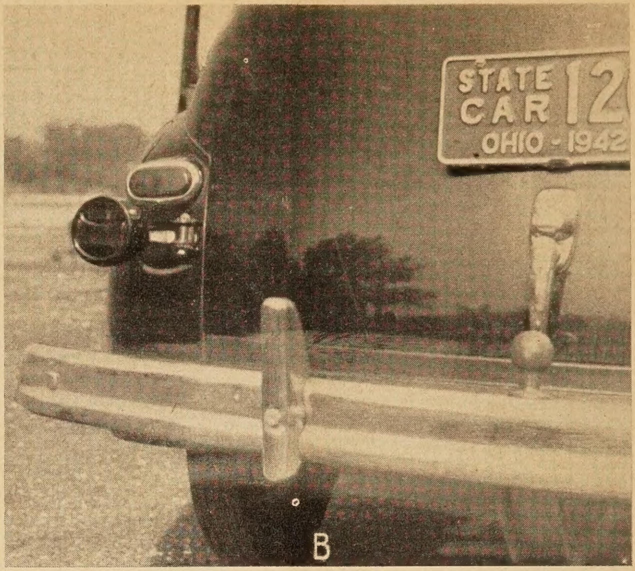

FIGURE 1.—AUTOMOBILE EQUIPPED WITH APPROVED BLACKOUT HEAD LAMP, MARKER LAMPS, AND COMBINATION STOP AND TAIL LAMP.

at the request of the Joint Committee on Uniform Traffic Control Devices.[2] These tests were designed to extend the comprehensive research already conducted by the Engineer Board of the War Department to conditions pertaining particularly to civilian driving.

TESTS CONDUCTED DURING BLACKOUT CONDITIONS

Valuable assistance in the conduct of the study was supplied by representatives of the War Department, the Office of Civilian Defense, and the Lamp Department of the General Electric Engineering Research Laboratories at Nela Park near Cleveland, Ohio. Lights approved by the War Department for use during blackouts were furnished by three manufacturers of these units[3] and installed on passenger cars of the State Highway Patrol, State Highway Department, and Public Roads Administration.

In order to determine the effectiveness of various traffic signs and markings, it was essential that this study be conducted during actual blackout conditions on highways having various surface widths, alinements, and a variety of other design features. A 3.5-mile section of U. S. Route 40 and a 6.2-mile section of State Route 79, both extending through the village of Hebron, Ohio, were selected as the highways along which the traffic control devices included in this study were located.

In addition to 27 existing signs and route markers, 12 standard signs, 45 special test signs, 8 interior-illuminated signs, 6 floodlighted signs, and 20 symbols were installed along the selected route. Outside of the limits of Hebron, 18 different center- and edge-line designs were used on 30 sections of highway, each at least 1,000 feet long, and delineators having plastic buttons as the reflecting units were installed along the outside of 4 curves.

Within the limits of Hebron, a large variety of pavement, curb, and object markings were used and the traffic signal at the intersection of routes 40 and 79 was equipped with a 27-volt transformer. Along the entire route, culvert and bridge headwalls, guardrails, and objects so near the roadway as to cause a possible traffic hazard were marked, employing a large variety of designs and materials such as plain paint, beaded paint, reflector buttons, and materials with reflectorized coatings.

All of the four barricades at the ends of the test sections were also marked to increase their visibility. One was reflectorized. At each of two barricades three red lanterns were used, and at the other barricade two lanterns meeting War Department specification[4] for blackout lighting were used. Four painted or reflectorized boards 10 inches by 10 feet and 33 truncated cones 8 inches in diameter and 6 inches high were used near the barricades to outline the area available for turning the vehicles. Figures 2 and 3 show the layout of the test course.

The first observations of the signs and markings under blackout conditions were made in the early morning hours on Monday, August 3, 1942. Five cars equipped with blackout lights and carrying State highway department personnel that were to act as guides and recorders during the succeeding tests were driven over the 19.4-mile test course (both directions over the 9.7 miles of highway). Traffic had been detoured from the test course by placing the necessary detour signs and stationing a standard barricade and two men from the State highway maintenance organization far enough beyond the barricades at the end of the test section to prevent the drivers of the test vehicles from seeing any normal headlights.

Immediately before the blackout signal sounded, the air-raid wardens of the Hebron Civilian Defense Organization went into action and saw that all street, house, and other lights in the neighborhood of the test route were extinguished or blacked out. State highway patrolmen kept traffic originating within the test area off the rural portions of the route and emergency police of the Civilian Defense Organization were stationed within Hebron to warn pedestrians and to control traffic. They were equipped with blackout flashlights, reflectorized leggings, and 3-foot broomsticks wrapped with reflectorized material.

[2] This committee consists of a total of 21 members appointed by the American Association of State Highway Officials, the Institute of Traffic Engineers, and the National Conference on Street and Highway Safety. It is charged with the responsibility of revising the "Manual on Uniform Traffic Control Devices" to cover war emergency conditions.

[3] Eleven sets of blackout lights were furnished, consisting of three sets by the Guide Lamp Division, General Motors Corporation, Anderson, Indiana; four sets by the Corcoran-Brown Lamp Company, Cincinnati, Ohio; and four sets by the C. M. Hall Lamp Company, of Detroit, Michigan.

[4] Blackout Flashlights, Lanterns, and Flares. War Department Specification.

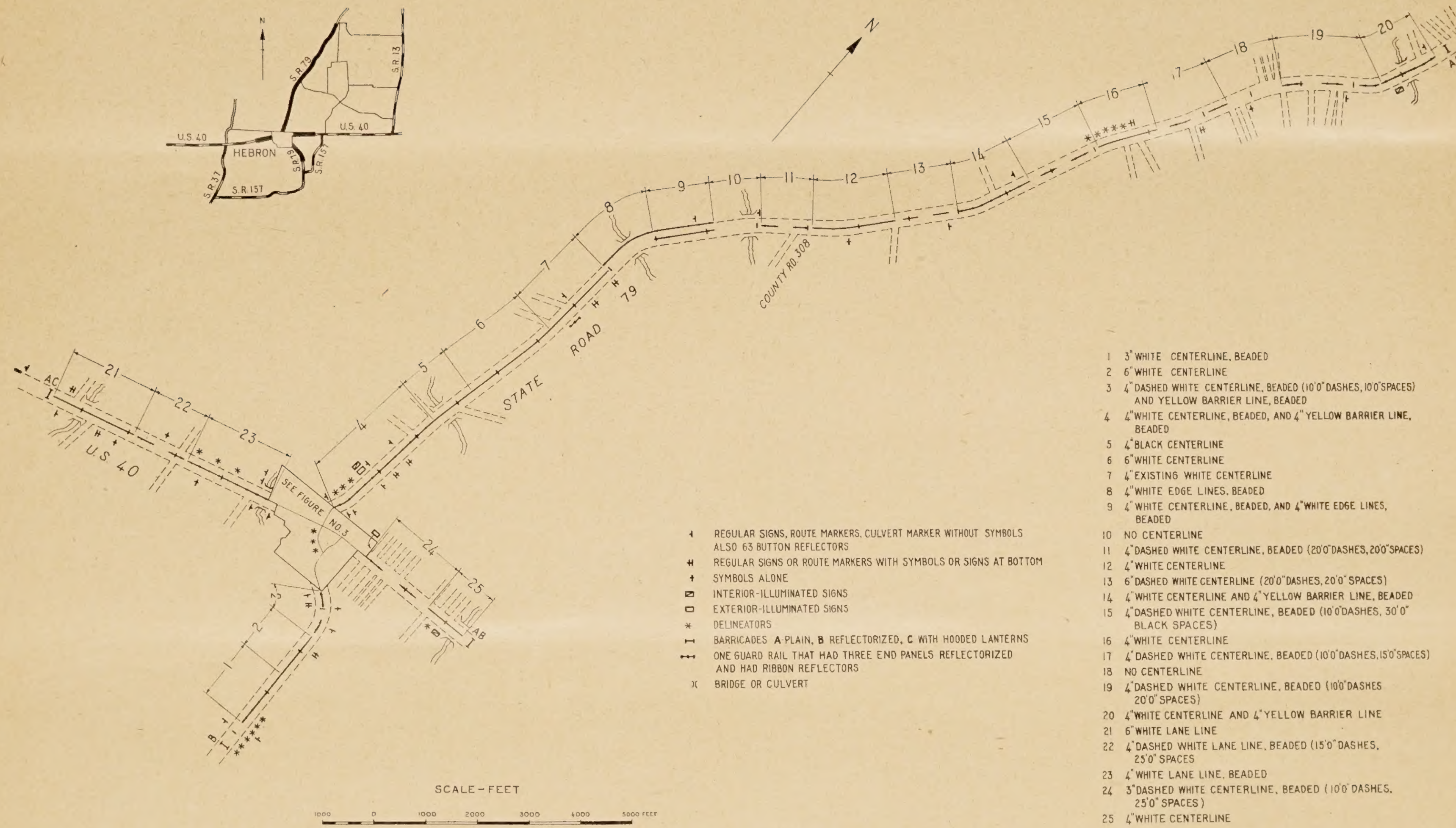

FIGURE 2.—CENTERLINES, PAVEMENT EDGE LINES AND SPECIAL MARKERS ON RURAL SECTIONS OF TEST ROUTE.

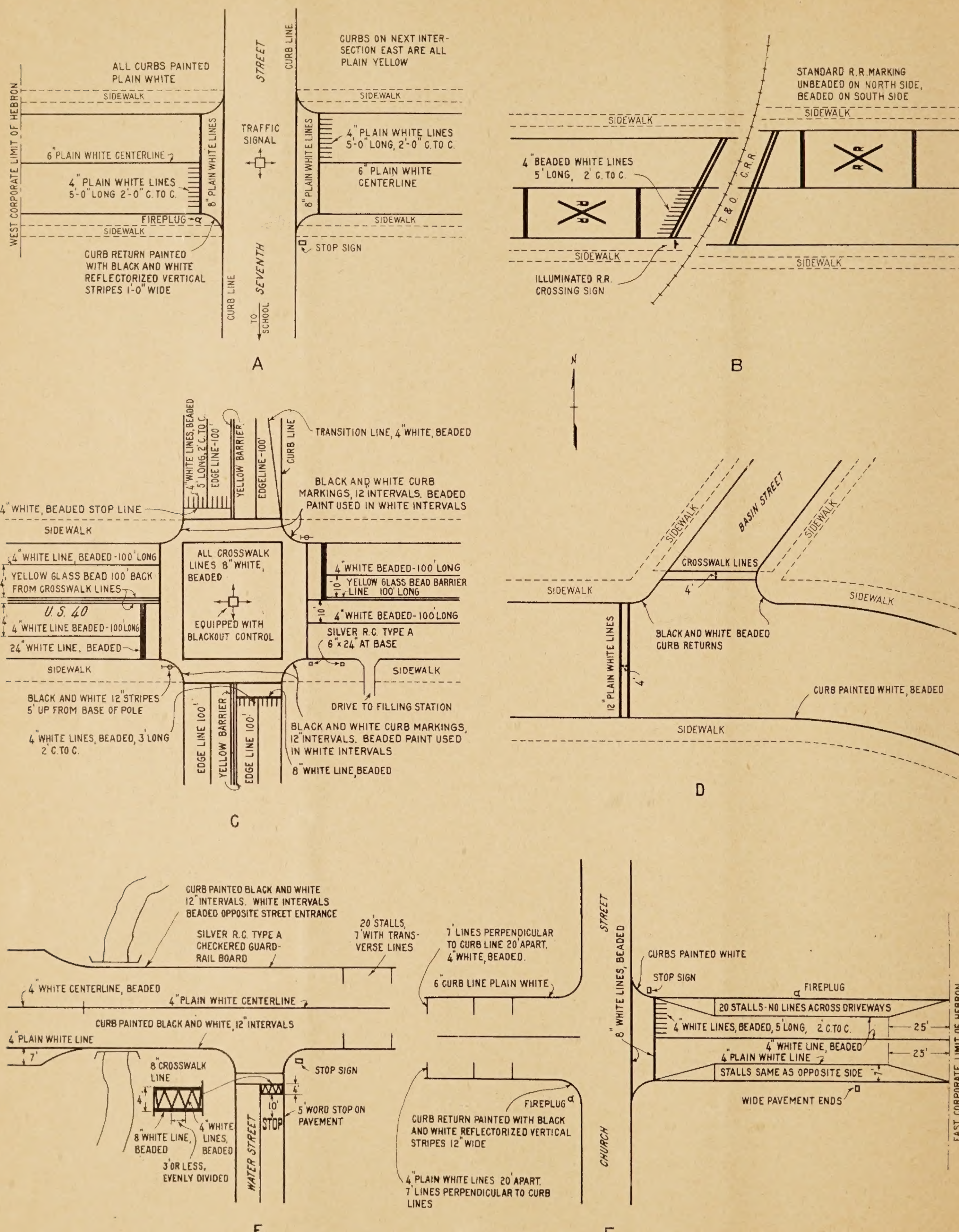

Figure 3.—Pavement and Special Markings on Urban Section of Test Route.

INVESTIGATION OF HIGHWAY MARKINGS AND SIGNS FOR BLACKOUT CONDITIONS

QUESTIONNAIRE FOR PEDESTRIAN OBSERVERS
(To be filled out by Auxiliary Policemen, Air Raid Wardens, etc.)

A. Effectiveness of Blackout:

1. Were all interfering lights extinguished at time of test? Yes ✓ No ___
Location of exceptions ___

2. How many pedestrians did you see that were not participating in test? 3
Did they know about blackout? 2 did
If not, did you caution them? yes Did they cooperate? yes

3. Were any unauthorized vehicles on the road? Yes ✓ No ___ How many? 1
Did they cooperate when informed? yes—took side road

B. Visibility of Blackout Cars:

4. Was there any difficulty in detecting the approach of a blackout car? No

5. What was your first warning of an approaching car?
(a) Headlight ✓ (c) Horn ___
(b) Marker Lights ___ (d) Motor Noise ___

6. Did you recognize the marker lights? Yes ✓ No ___ Distance 100 yards

7. Are vehicles with blackout equipment sufficiently visible to permit necessary pedestrians to move safely? Yes ✓ No ___

C. Movement of Vehicles Equipped with Blackout Equipment:

8. Did most drivers observe stop signs and signals? Yes ✓ No ___
Location and nature of violations None

9. Did cars appear to be driving dangerously fast? No

10. Did you notice any vehicles on wrong side of road? 2 at curve

D. Additional Comments: Name of Observer O. A. Burton
Where stationed during test Post #10
Assigned duties during test Police
Date 8-8-42

FIGURE 4.—QUESTIONNAIRE FORM FILLED OUT BY PEDESTRIAN OBSERVERS.

No data were recorded the first night except those obtained by having the emergency police and wardens fill out the pedestrian questionnaire (fig. 4). This preliminary test was valuable as a guide in determining the procedure to be followed during the succeeding tests and revealed a number of desirable changes in the markings and equipment, particularly in the adjustment of the blackout head lamps.

EXISTING SIGNS FOUND INADEQUATE

All head lamps were mounted with the horizontal slot in the mask 42 inches above the road surface and the center of the slot 11 inches to the left of the centerline of the vehicle, and were adjusted so that the top of the visual cut-off of the beam at a distance 10 feet ahead of the vehicle was 2 inches lower than the bottom of the horizontal slot in the head-lamp mask. With this adjustment, most of the pedestrian observers and drivers complained of being temporarily blinded by approaching test cars. Therefore, for subsequent tests the head lamps were adjusted so that the visual cut-off 10 feet ahead of the vehicle was between 2½ and 3 inches below the horizontal slot in the mask for a car with driver and one passenger in the front seat, and at least 2 inches below when there were also three people in the back seat. However, even with this adjustment, which was used during the following series of tests, it was not uncommon for a light beam to shine above the horizontal as the cars traveled along the relatively smooth surfaces of the test course, but this was a great improvement over the adjustment used during the preliminary test. Any further increase in the slope of the beam would have seriously affected the illumination provided by the head lamp.

The test runs conducted to record the driver's observations and reactions to the various signs and markings were made in the early morning hours on August 5 and 7. Fifteen trips over the test course were made on August 5 and eight trips on August 7. During the last seven

DATA FOR INVESTIGATION OF HIGHWAY SIGNS AND MARKINGS FOR BLACKOUT CONDITIONS

SHEET 1 - US 40 - WESTBOUND FROM SCHOOL TO BARRICADE

Log Miles	Description of Sign or Marking	LEGIBILITY (Check one) Good	Fair	Poor	Seen	Remarks
	Illuminated STOP sign at US 40	✓				
	Cross walk markings		✓			
0.00	Transition markings at corporation line-beaded		✓			
0.03	Exterior illuminated Keep Right sign		✓			
0.06	Culvert marker with 3 buttons (both sides of road	✓				
0.08	Distance sign				✓	
0.16	Delineator Yellow (edge of shoulder)	✓				
0.24	Delineator Silver (edge of shoulder)	✓				
0.33	Delineator Zebra (edge of shoulder)			✓		
0.33	End of 4" beaded lane marking	✓				
0.43	Cross Road symbol	✓				
0.56	End Dashed lane line-4" Beaded 15'-25' spaces		✓			Dashed line adequate on straight road
0.64	Scotchlite on mailbox post				✓	
0.82	a. Right Curve sign b. Right Curve symbol	✓				not seen
0.90	End 6" plain white lane line				✓	
0.96	US 40 route marker					Not seen
1.04	Barricade - a. Three approved blackout lanterns b. White beaded board		✓			Passed barricade
1.04	End no lane marking					Difficult to drive

TIME: Start 1:20 End 1:55 (Entire route)

NAME OF OBSERVER John Doe DATE 8-7-42

ADDRESS Columbus, Ohio BUSINESS CONNECTION Engineer

FIGURE 5.—FIRST SHEET OF 16-PAGE LOG USED TO RECORD DRIVER REACTION TO SPECIAL SIGNS AND MARKINGS.

trips on August 5, there was a quarter moon so the data obtained during these trips have been seggregated in the analyses. No brightness measurements were made on August 5 but those made by a representative of the General Electric Laboratories at 3 a. m. August 7 were as follows and indicate that the night was about as dark as any with starlight:

Object:	Footlamberts
Zenith sky	0.000076
Sky-45° to west	.000027
Concrete surface	.000010

The procedure followed was to assign a driver, guide, recorder, and one or two observers to each test car. The drivers and observers consisted of men from a large variety of occupations, none familiar with the test route. The guides and recorders were familiar with the test route. The guide sat alongside the driver and was present mainly for the purpose of showing the driver the course of the route, to warn the driver of pedestrians or dangerous locations if the speed was excessive and in general to see that the trip was made safely. The recorder, who rode in the back seat and was equipped with a very dim flashlight, entered the remarks made by the driver on a 16-page log (fig. 5) listing each traffic device, marking, or sign on the route. There were 260 listed items including such items as center-line markings that were listed twice. The drivers were not expected to rate or remark about all items but if they did, space was available on the form. No remarks made by the observers during the trip were recorded but both the drivers and observers filled out the form shown as figure 6 when the trip was completed.

Prior to the start of the trip, the purpose of the tests and the procedure to be followed were explained to the drivers and observers. The drivers were requested to maintain a speed between 15 and 20 miles per hour and

QUESTIONNAIRE FOR OBSERVERS

Blackout Driving Tests, August 1942

PLEASE ANSWER ALL QUESTIONS

1. Were you able to follow the prescribed course with reasonable ease? Yes
2. What was your principal difficulty? Keeping on road without Centerline
   What remedy can you suggest? Marking a good centerline
3. What device was most helpful? Centerline and few signs
   Why? Only these are essential
4. (a) Which form of center line or striping was most useful? Continuous and reflectorized
   (b) How did the broken center lines compare with the solid lines? Fair but not as good especially on curves
   (c) Were any of the center line dashes spaced so widely as to cause difficulty?
   Yes ✓ No ___; How much difficulty? Center not defined on curves
   (d) What did you think of the pavement edge lines? Ok after one is familiar with them but dangerous if mistaken for centerline
   (e) Was the ordinary white painted center line adequate? Yes ___ No ✓
5. (a) Of roadside markers or delineators, which seemed most effective? Those with buttons
   (b) Which appeared to be inadequate? None
6. How would you rate the following in order of preference: (a) Reflecting button signs 2 (b) Reflecting background signs 1 (c) Other reflecting signs 3 (d) Painted signs 4.
7. (a) Is the self-illuminated sign superior to a good reflective sign? Yes ___ No ✓.
   (b) Were the "floodlighted" signs adequate? Yes ✓ No ___.
8. Can you suggest improvement in placement of signs? Not in test signs
9. Other remarks: Very interesting tour

Signed John Doe

Figure 6.—Questionnaire Form Filled Out by Drivers and Observers.

to remark about each traffic line, sign, or other device that they saw, and when possible to give a rating such as "good," "fair," or "poor," based on the visibility and effectiveness of the particular device. The eyes of everyone were "dark adapted" prior to starting over the test course. In addition, a night vision test was given most of the drivers and observers. This involved determining what line on an optometrist's chart, faintly illuminated, could be read by the subject at a distance of 10 feet in a blacked-out room. While this was a very rough test, it was desired to obtain some measure of the relative night vision of the various drivers.

Table 1 [5] shows the results of the observations made on standard signs placed, as to distance from the centerline and along the roadway, in the manner used for signing highways during normal conditions. The signs were along 2-lane highways with the exception of the railroad sign, which was on a 4-lane road, and the 3 signs placed 18 feet from the centerline which were on a 3-lane road. Most of the signs included were mounted at standard heights but a few were placed for this test as near the pavement elevation as possible.

In addition to the ratings of "good," "fair," and "poor" that were applied to signs that were legible, the rating "seen" was used when the observer saw the sign but could not read the legend. The rating "not seen" was applied when the driver made no mention of the sign as he passed it.

Rating factors are shown for each type of sign and placement classification in order to have a single figure for comparative purposes. They have been calculated on the basis that a sign rated as "good" by all drivers should have a rating factor of 100 and one not seen by any of the drivers should have a rating factor of 0. Since it was felt that a sign that could not be read, but that could be seen, has some value, some weight has been given to the "seen" ratings. Other methods of calculating a rating factor were also tried but for all those that seemed logical, approximately the same results were obtained.

SIGNS MUST BE PROPERLY REFLECTORIZED

Considering first the plain painted signs mounted at standard heights, table 1 shows that the route markers were not seen 72 percent of the time, the information signs were not seen 61 percent of the time, and the symbol signs were not seen 39 percent of the time. The majority of observers that did see signs in these three groups either could not distinguish the legends or rated the legibility as "poor." This resulted in rating factors of 10, 13, and 25 for the three groups of plain painted signs.

Reflectorizing the signs mounted at a standard height with either glass reflecting buttons or a reflectorized material improved their legibility very little as may be seen by the results for the "symbol," "WIDE PAVEMENT ENDS," and "railroad crossing" signs. However, the data for the few signs that were both reflectorized and mounted with their top edges within 2 feet of the elevation of the road surface indicate that this treatment resulted in a marked increase in the legibility of the standard signs. For example, the rating factor for the route markers increased from 10 to 38 (still too low for a sign to be effective) while the rating factor for the 24-inch "stop" sign was 81, a very high rating considering that the sign was on a 3-lane road and to receive a "good" rating the operator had to bring the vehicle to a stop before reaching a limit line directly opposite the sign.

Although the legibility ratings on table 1 and those on all succeeding tables regarding signs are generally lower for the moonlight condition (whenever there is an appreciable difference) than for the condition without moonlight, the results are not consistent. The moonlight on August 5 apparently had little or no effect on the legibility of signs as compared to the effect of other factors.

Thirty of the 42 signs made especially for this test by the Ohio Department of Highways were mounted along the shoulder on tangent sections of a 20-foot concrete road. All were placed 16 feet from the center line, at an angle of 10° toward the road from a line perpendicular to the centerline, and at a height so that the bottom edge of the sign was approximately at the same elevation as the road crown (fig. 7–A). All of these signs were 2 feet square and had legends consisting of four-letter words 6 inches high. By using different types and colors of materials and reflectorizing the letters on some and the background on others, 19 different combinations were used. Eleven signs were each duplicates of 1 of the other 19 except for the legend. In placing the signs, care was taken so that no sign could be seen from a vehicle on a curve or close enough to another sign to be visible while the other sign was still in view.

[5] As many materials as were available at the Ohio Highway Department's paint shop or could be obtained within the time permitted for this study were used to construct the signs. Table 1 shows that three types of reflecterized coatings (R. C.) were used. Types A and B designate the products of two different manufacturers and include reflectorized flexible materials that are applied to the face of the sign, while type C includes the coating obtained by the Ohio State Highway Department's sign shop by sprinkling glass beads over the surface of a freshly painted sign. The same designations apply when used in connection with other tables and the text of this report. Before or after these studies were made, products better suited for particular conditions may have been placed on the market by the same or other manufacturers.

TABLE 1.—*Legibility of standard signs*

Type of sign	Placement: Mounting height [1]	Placement: Distance from center of road	Color and material [2]: Letters	Color and material [2]: Background	Sky condition	Number of observations	Distribution of legibility ratings: Good	Fair	Poor	Seen	Not seen	Rating factor [3]
	Feet	*Feet*					*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Route markers	5	16	Black	White	Dark	150	2	3	11	13	71	11
					Moon	60	0	3	18	3	76	8
					Total	210	1	3	13	11	72	10
Do	2	16	do	do	Dark	45	4	7	27	16	46	21
					Moon	18	11	17	11	6	55	25
					Total	63	6	10	22	13	49	22
Do	2	16	do	Transparent R. C. type A.	Dark	45	16	22	20	29	13	41
					Moon	18	11	6	39	17	27	31
					Total	63	14	18	25	25	18	38
Information	4.5	16	do	White	Dark	45	2	2	27	11	58	15
					Moon	21	0	0	24	9	67	10
					Total	66	1	1	26	11	61	13
Symbol	4.5	16	do	Yellow	Dark	112	9	5	36	13	37	27
					Moon	56	5	4	27	20	44	21
					Total	168	8	5	33	15	39	25
Do	4.5	16	do	Yellow R. C. type B	Dark	15	33	7	13	20	27	46
					Moon	6	0	17	33	0	50	20
					Total	21	24	10	19	14	33	39
Do	4.5	16	Black with glass reflecting buttons.	Yellow	Dark	82	6	16	30	10	38	27
					Moon	42	3	9	26	14	48	20
					Total	124	5	14	29	11	41	25
Wide pavement ends	4.5	18	Black	Yellow R. C. type C	Dark	15	0	0	33	13	54	14
					Moon	6	0	0	14	0	86	5
					Total	21	0	0	27	9	64	11
Railroad crossing	4.5	28	Black with glass reflecting buttons.	Yellow	Dark	15	20	0	33	0	47	31
					Moon	6	0	28	0	14	58	18
					Total	21	14	9	23	5	49	28
Distance	2	16	Black	Silver R. C. type A	Dark	15	33	40	20	0	7	60
					Moon	6	33	33	17	17	0	60
					Total	21	33	38	19	5	5	60
30-inch stop	2.5	18	Silver R. C. type A with black border.	Yellow	Dark	15	27	13	14	13	33	42
					Moon	6	0	0	0	33	67	8
					Total	21	19	10	10	19	42	32
Keep right	2	0	Black with glass reflecting buttons.	White	Dark	8	63	13	0	12	12	73
24-inch stop	2	18	White with plastic reflecting buttons on black panel.	Yellow	Dark	15	80	7	0	0	13	84
					Moon	6	50	33	17	0	0	72
					Total	21	72	14	5	0	9	81

[1] To top of sign from crown of road.
[2] R. C. represents material with a reflectorized coating.
[3] Obtained by adding all of the percentage rated "good," one-half the percentage rated "fair," one-third the percentage rated "poor," and one-fourth the percentage rated "seen."

Table 2 shows the distribution of legibility ratings and rating factors for the special test signs. The legibility ratings of the plain painted signs (group 1) were all too low for any of these signs to be of material aid to a driver under blackout conditions.

Of the signs with plain black letters and a background made of material with a reflectorized coating (group 2, table 2), those with white material rated consistently higher than those with yellow material made by the same manufacturer although there was not a large difference. For both the white and yellow material, type A, type C, and type B rated first, second, and third, respectively, although the differences were slight. However, the most important finding was that the rating factor for the sign with the silver reflectorized coating (type A) was almost perfect and nearly twice as high as the average rating for any of the other materials.

Signs having letters constructed of a reflectorized material (group 3, table 2) and mounted on a black panel 8 inches high attached to a plain painted background all received comparatively high legibility ratings. It should be noted, however, that only the two reflectorized materials receiving the highest ratings in group 2 were used for the signs in group 3. Here again, the silver-colored material (type A) received higher ratings than the white material when both were on the same backgrounds. The signs with the white backgrounds rated higher than those with the yellow backgrounds when the letters were of the same material. The only explanation for this is that a white background provided a greater contrast with the black panel and increased the target value of the sign, thus helping to draw the driver's attention to the sign before the letters were fully illuminated.

None of the signs with reflector buttons received as

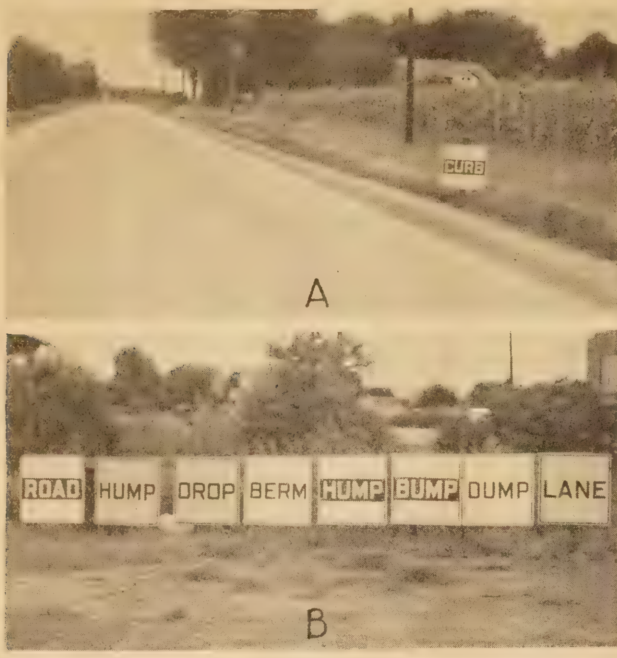

FIGURE 7.—SPECIAL SIGNS USED FOR TESTS; A, PLACED ALONG ROUTE; B, BATTERY OF SIGNS VIEWED FROM STATIONARY VEHICLE.

TABLE 2.—*Legibility of test signs, placed at an angle of 10° to the road, low, and 16 feet from the centerline*

GROUP 1—PLAIN PAINTED SIGNS

Color and material [1]: Letters	Color and material [1]: Background	Sky condition	Number of observations	Distribution of legibility ratings: Good	Fair	Poor	Seen	Not seen	Rating factor [2]
				Pct.	Pct.	Pct.	Pct.	Pct.	
Black	White	Dark	30	0	13	33	37	17	27
		Moon	12	0	8	50	34	8	29
		Total	42	0	12	38	36	14	28
Do	Yellow	Dark	37	3	13	41	35	8	32
		Moon	18	5	17	39	28	11	34
		Total	55	4	14	40	33	9	33
White on black panel.	White	Dark	15	7	20	47	26	0	39
		Moon	6	17	17	33	0	33	37
		Total	21	10	19	42	19	10	38
Do	Yellow	Dark	15	7	7	53	33	0	37
		Moon	6	0	17	67	0	16	31
		Total	21	5	9	57	24	5	35
	Combined	Dark	97	4	13	44	33	6	34
		Moon	42	6	15	47	16	16	33
		Total	139	5	14	44	28	9	34

GROUP 2—BACKGROUND OF MATERIAL WITH REFLECTORIZED COATING

Letters	Background	Sky condition	Number of observations	Good	Fair	Poor	Seen	Not seen	Rating factor
Black	Silver R. C. type A.	Dark	30	93	7	0	0	0	97
		Moon	12	92	8	0	0	0	96
		Total	42	93	7	0	0	0	97
Do	White R. C. type A.	Dark	15	33	33	27	0	7	59
		Moon	6	17	33	50	0	0	50
		Total	21	29	33	33	0	5	57
Do	Yellow R. C. type A.	Dark	15	33	27	27	0	13	56
		Moon	6	0	67	33	0	0	45
		Total	21	24	38	29	0	9	53

TABLE 2.—*Legibility of test signs, placed at an angle of 10° to the road, low, and 16 feet from the centerline*—Continued

GROUP 2—BACKGROUND OF MATERIAL WITH REFLECTORIZED COATING—Continued

Color and material: Letters	Color and material: Background	Sky condition	Number of observations	Distribution of legibility ratings: Good	Fair	Poor	Seen	Not seen	Rating factor
			Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Black	White R. C. type C.	Dark	30	27	36	10	20	7	54
		Moon	12	42	42	0	16	0	67
		Total	42	31	38	7	19	5	57
Do	Yellow R. C. type C.	Dark	30	24	30	20	13	13	49
		Moon	12	17	42	25	16	0	50
		Total	42	22	33	21	14	10	50
Do	White R. C. type B.	Dark	22	27	0	64	9	0	51
		Moon	12	17	33	42	0	8	48
		Total	34	23	12	56	6	3	49
Do	Yellow R. C. type B.	Dark	15	13	40	40	7	0	48
		Moon	6	0	67	33	0	0	45
		Total	21	9	48	38	5	0	47
	Combined	Dark	157	35	25	27	7	6	58
		Moon	66	26	42	26	5	1	57
		Total	223	33	30	26	6	5	58

GROUP 3—LETTERS OF MATERIAL WITH REFLECTORIZED COATING

Letters	Background	Sky condition	Number of observations	Good	Fair	Poor	Seen	Not seen	Rating factor
Silver R. C. type A.	Black panel on white.	Dark	15	86	7	0	7	0	91
		Moon	6	100	0	0	0	0	100
		Total	21	90	5	0	5	0	94
Do	Black panel on yellow.	Dark	7	57	29	0	0	14	72
		Moon	6	67	17	0	16	0	80
		Total	13	62	23	0	8	7	76
White R. C. type A.	Black panel on white.	Dark	30	63	27	7	3	0	80
		Moon	12	59	33	8	0	0	78
		Total	42	62	29	7	2	0	79
Do	Black panel on yellow.	Dark	30	37	50	3	3	7	64
		Moon	12	25	42	25	0	8	54
		Total	42	33	48	10	2	7	61
	Combined	Dark	82	61	28	3	3	5	77
		Moon	36	63	23	8	4	2	79
		Total	118	62	26	4	4	4	77

GROUP 4—LETTERS WITH GLASS REFLECTING BUTTONS

Letters	Background	Sky condition	Number of observations	Good	Fair	Poor	Seen	Not seen	Rating factor
Black with buttons.	White	Dark	30	43	47	3	7	0	70
		Moon	12	8	59	25	0	8	46
		Total	42	33	50	10	5	2	63
Do	Yellow	Dark	15	20	40	13	7	20	46
		Moon	6	16	50	17	0	17	47
		Total	21	19	43	14	5	19	47
White with buttons.	Black panel on white.	Dark	15	53	47	0	0	0	77
		Moon	6	33	67	0	0	0	67
		Total	21	48	52	0	0	0	74
Do	Black panel on yellow.	Dark	30	67	33	0	0	0	84
		Moon	12	42	50	8	0	0	70
		Total	42	60	38	2	0	0	80
	Combined	Dark	90	46	42	4	3	5	69
		Moon	36	25	57	12	0	6	58
		Total	126	40	46	7	2	5	66

[1] "R. C." represents material with a reflective coating.
[2] Obtained by adding all of the percentage rated "good", one-half the percentage rated "fair", one-third the percentage rated "poor", and one-fourth the percentage rated "seen".

high a rating factor as the best sign in either group 2 or group 3 and the yellow sign with black reflectorized letters had as low a rating as any of the reflectorized signs. One probable reason why the signs with reflector buttons as a group did not receive better legibility ratings was that they were all located in succession along the test route. The ratings, which were necessarily relative values, were made in comparison with other signs of the same group, and were therefore not as high as they might have been had they been placed in company with a number of less legible signs.

At one of the turn-around areas, eight test signs were mounted side by side just above ground level (fig. 7–B). As each test vehicle turned, the driver stopped with the car facing the battery of signs, and as far away as it was possible for him to read the legends on most of the signs. He then rated the signs in the order of preference.

The results for the test on the battery of signs are shown in table 3. The preference rating factors have been calculated so that if a particular sign had been preferred by all observers its rating factor would have been 8, and had it been considered the poorest sign by all observers it would have had a rating factor of 1. There was little difference in the factors for the three outstanding signs. They were: The sign with black letters on a white reflectorized background, the sign with silver reflectorized letters on a black panel, and the sign with white letters reflectorized with buttons on a black panel. The sign shown as receiving the highest rating in table 2 (black letters on a silver reflectorized background) was not included in this test. Signs with yellow backgrounds, either reflectorized or painted, did not receive as high rating factors as did those with white backgrounds.

The results of these tests definitely prove that the legibility of reflectorized signs when viewed either from a moving or stationary vehicle varies with the type of reflecting material used, the color combinations used in the sign, and the location of the sign with respect to the roadway.

Three phosphorescent signs, previously energized by 12 hours of daylight and sunlight, and mounted above the battery of signs were not noticed by the observers. Three reflectorized signs mounted at the standard height of 3½ feet above the road (to center of sign) but near the pavement edge were either not noticed or rated as "poor" by the observers.

MOUNTING AND PLACEMENT OF SIGNS IMPORTANT

Two types of illuminated signs meeting War Department Specifications for blackout conditions[6] were tested. One type (fig. 8–A) was an interior-illuminated sign in the shape of a box 19 inches long, 6 inches wide, and 4½ inches high. The transparent face of the sign was painted black with the exception of the legend which was of rounded letters 3 inches high made with a stroke ½ inch wide. Inside the box were a No. 6 dry cell battery and three 1.35-volt 0.06 ampere bulbs that will operate continuously for about 1 week with either a No. 6 dry cell or 10 standard flashlight batteries in parallel. Both ground glass and opal glass were used for the face of these signs. Three signs of each material were mounted along the test route at a height of 4½ to 6 feet above the pavement surface.

The other type of illuminated sign was provided by mounting a light 15 inches in front and slightly below

[6] Traffic Control During Blackouts, prepared under the direction of the Chief of Engineers, United States Army, by the Engineer Board.

TABLE 3.—*Relative legibility of test signs mounted low in front of stationary vehicle*

Color and material: Letters[1]	Color and material: Background	Sky conditions	Number of observations	Preference: 1st	2d	3d	4th	5th	6th	7th	8th	Preference rating factor[2]
				Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Black	White	Dark	15	0	7	0	7	0	13	73	0	2.7
		Moon	6	0	0	17	0	0	17	66	0	2.9
		Total	21	0	5	5	5	0	14	71	0	2.7
Do	Yellow	Dark	15	0	0	0	7	0	0	33	60	1.6
		Moon	6	0	0	17	0	17	32	17	17	3.2
		Total	21	0	0	4	4	5	10	29	48	2.0
White	Black panel on white	Dark	15	0	0	0	0	13	53	27	7	2.7
		Moon	6	0	0	0	17	17	17	17	32	2.7
		Total	21	0	0	0	5	14	43	24	14	2.7
Black	White R. C. type A	Dark	15	27	46	7	7	13	0	0	0	6.7
		Moon	6	33	17	33	0	17	0	0	0	6.5
		Total	21	29	38	14	5	14	0	0	0	6.6
Do	Yellow R. C. type A	Dark	15	0	7	33	40	20	0	0	0	5.3
		Moon	6	0	33	50	17	0	0	0	0	6.2
		Total	21	0	14	39	33	14	0	0	0	5.5
Do	Yellow R. C. type B	Dark	15	7	0	7	27	45	7	0	7	4.4
		Moon	6	0	0	0	17	17	17	17	32	2.7
		Total	21	5	0	5	24	37	10	5	14	3.9
Silver R. C. type A	Black panel on white	Dark	15	20	53	13	0	7	0	7	0	6.5
		Moon	6	32	0	17	17	17	0	17	0	5.5
		Total	21	24	37	14	5	10	0	10	0	6.2
White buttons	do	Dark	15	40	13	27	13	0	7	0	0	6.6
		Moon	6	17	33	33	17	0	0	0	0	6.5
		Total	21	33	19	29	14	0	5	0	0	6.6

[1] R. C. = reflectorized coating.
[2] Calculated by obtaining a summation of 8 times the percentage of the first preference, 7 times the percentage of the second preference, etc., and dividing by 100.

FIGURE 8.—TRAFFIC SIGNS TESTED UNDER BLACKOUT CONDITIONS. A, INTERIOR-ILLUMINATED BRIDGE SIGN; B, STANDARD STOP SIGN ILLUMINATED BY EXTERIOR LIGHT; C, ARROW SYMBOL WITH REFLECTORIZED COATING MOUNTED BELOW STANDARD SIGN; D, SIDE ROAD SYMBOL REFLECTORIZED WITH GLASS BUTTONS MOUNTED BELOW STANDARD SIGN.

the top of a standard nonreflectorized sign so that the legend was illuminated. The light consisted of a 1.35-volt, 0.06-ampere bulb with a flashlight reflector painted white. Two types of mountings were used. One consisted of a single-battery flashlight, with the lens removed, held in position by an arm extending out from the signpost (fig. 8–B). The other consisted of a curved metal arm with a clamp holding a No. 6 dry cell and light bulb that fastened to the top of the sign. Both the battery and light bulb were grounded on the metal arm thus requiring only one insulated wire to complete the electrical circuit.

Table 4 shows the results of tests with both types of illuminated signs. The interior-illuminated signs with opal glass were far superior to those with ground glass. They were also superior to the exterior-illuminated signs. Of the exterior-illuminated signs, the ones with black letters on a yellow background were better than those with black letters on a white background.

Table 5 shows the results obtained for a variety of special symbols mounted within 24 inches of the elevation of the pavement surface (figs. 8–C and 8–D). These symbols had no background and were made by cutting the particular shape desired from a piece of weatherproof composition board such as masonite and then painting or reflectorizing one surface. They were generally mounted farther from the pavement surface than the special test signs and were located on existing mail-box posts, telephone poles, or below standard signs along the test route. The rating factors for the symbols were much higher than for the standard signs and those for some of the symbols compare favorably with the ratings for the special test signs considering that the symbols were sometimes mounted at a greater lateral distance from the highway surface. Direct comparisons cannot be made for the different types of reflecting materials since there was such a large variation in the mounting locations.

Prior to the installation of the special signs on the test route, tests were made at the General Electric Co. laboratory at Nela Park to determine the distance from a stationary vehicle that various signs were legible and the effect of mounting height, angularity, and transverse position upon legibility. The test signs

TABLE 4.—*Legibility of interior- and exterior-illuminated signs*

INTERIOR-ILLUMINATED SIGNS

Material used	Sky condition	Number of observations	Distribution of legibility ratings: Good	Fair	Poor	Seen	Not seen	Rating factor [1]
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	
Ground glass	Dark	45	35	27	22	7	9	58
	Moon	18	28	22	22	6	22	48
	Total	63	33	26	22	6	13	55
Opal glass	Dark	45	60	13	9	7	11	71
	Moon	18	55	39	0	6	0	76
	Total	63	59	21	6	6	8	73

EXTERIOR-ILLUMINATED PAINTED SIGNS

Material used	Sky condition	Number of observations	Good	Fair	Poor	Seen	Not seen	Rating factor [1]
Black on white	Dark	67	13	33	30	6	18	41
	Moon	30	27	33	14	3	23	49
	Total	97	17	33	25	5	20	43
Black on yellow	Dark	23	43	22	9	9	17	59
	Moon	6	17	67	0	16	0	55
	Total	29	38	31	7	10	14	58

[1] Obtained by adding all of the percentage rated "Good," one-half the percentage rated "Fair," one-third the percentage rated "Poor," and one-fourth the percentage rated "Seen."

TABLE 5.—*Visibility of special symbols mounted low*

CROSSROAD, SIDE ROAD, AND CURVE SYMBOLS

Color and material used	Sky condition	Number of observations	Distribution of visibility ratings: Good	Fair	Poor	Seen	Not seen	Rating factor [1]
			Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
Plain white paint	Dark	60	22	10	23	10	35	37
	Moon	24	21	12	21	0	46	34
	Total	84	22	11	22	7	38	37
Silver R. C. type A	Dark	45	60	11	4	0	25	67
	Moon	18	33	17	0	17	33	46
	Total	63	52	13	3	5	27	61
Glass reflecting buttons on white paint	Dark	60	57	15	8	12	8	70
	Moon	24	63	8	4	4	21	69
	Total	84	58	13	7	10	12	69
Glass reflecting buttons on yellow R. C. type A.	Dark	45	33	5	13	7	42	42
	Moon	18	17	17	11	5	50	30
	Total	63	29	9	12	6	44	40
Glass reflecting buttons on silver R. C. type A.	Dark	15	40	0	13	7	40	46
	Moon	6	0	67	0	0	33	34
	Total	21	29	19	9	5	38	43

NIGHT ARROW SYMBOLS

Color and material used	Sky condition	Number of observations	Good	Fair	Poor	Seen	Not seen	Rating factor [1]
Plain white paint	Dark	15	0	13	13	0	74	11
	Moon	6	0	33	33	0	34	28
	Total	21	0	19	19	0	62	16
Silver R. C. type A	Dark	15	27	0	0	13	60	30
	Moon	6	67	0	0	33	0	75
	Total	21	38	0	0	19	43	43
Glass reflecting buttons on white paint	Dark	15	27	6	20	20	27	42
	Moon	6	17	33	17	0	33	39
	Total	21	24	14	19	14	29	41
Glass reflecting buttons on yellow R. C. type A.	Dark	15	60	7	0	0	33	64
	Moon	6	50	0	0	17	33	54
	Total	21	57	5	0	5	33	61

[1] Obtained by adding all of the percentage rated "Good", one-half the percentage rated "Fair", one.third the percentage rated "Poor" and one-fourth the percentage rated "Seen".

were viewed from the driver's seat of one of the test vehicles with the blackout head lamp adjusted so that the visual cut-off of the top of the light beam sloped down ahead of the car at the rate of 2 inches every 10 feet from a height of 42 inches.

The results of these observations of signs viewed from a stationary vehicle were:

1. To be legible, a sign must be mounted within the range of the headlight beam.
2. For the 6-inch legend on a 24-inch square sign to be within the headlight beam, the maximum distance that the sign could be mounted ahead of the vehicle was 135 feet.
3. At a distance of 100 feet, the legend was illuminated when the bottom of the sign was 7 inches from the ground although better legibility was attained when the bottom of the sign was at ground level.
4. To be legible at 100 feet, a sign must be reflectorized. All reflectorized signs were not legible at 100 feet, however. (Some reflectorized signs with 6-inch letters are legible at distances exceeding 200 feet when the head-lamp beam is raised so that it strikes the sign.)
5. At a distance of 25 feet from the vehicle and 7 feet to the right of the centerline of the car, the 24-inch square reflectorized signs were legible when the bottom of the sign was placed anywhere from ground level to 26 inches above ground level, but the best legibility was obtained when 9 inches above ground level.
6. Sign legibility was not greatly affected by horizontal placement up to a distance of 18 feet to the right of the centerline of the vehicle (18 feet was the limit possible in the laboratory) when the sign was placed from 25 to 100 feet in front of the vehicle.
7. The best legibility was attained when the signs were turned so that they were normal to the line of sight of the observer.

The results of these tests were made use of when the special test signs were placed along the test route. However, since it is impossible to install signs so that they will always be normal to the driver's line of vision from a moving vehicle, and since the distance ahead of the vehicle that the signs were legible when placed at various distances from the edge of the road were not recorded, a separate study was made on August 12 to obtain information regarding:

1. The distance that signs suitable for use during blackouts are legible when viewed from a moving vehicle on both 2- and 4-lane highways.
2. The angle with both 2- and 4-lane roadways that signs should be mounted to obtain the best legibility from a moving vehicle.

INTERIOR-ILLUMINATED SIGNS FOUND MOST LEGIBLE

A level tangent section of two-lane highway with a smooth surface 20 feet wide was selected for this study. Normal traffic was detoured during the tests, and there were no lights in the neighborhood of the test section. A man with a number of test signs was stationed at each of eight locations (four on each side of the roadway) along the test section to change the sign at his particular location for each test run according to a prearranged schedule. The schedules were arranged so that direct comparisons could be made between similar signs placed at different angles with the roadway and between different signs placed at the same angle. None of the observers knew what sign was to be placed at a particular location.

FIELD SHEET

INVESTIGATION OF HIGHWAY SIGNS AND MARKINGS FOR BLACKOUT CONDITIONS

ANGULARITY TESTS

Date 8-12-42 Observer Eckhardt Recorder Holaday

(Record adjective rating and distance in feet)

RUN NO. 3 Direction south Side of centerline right

1. Legibility: Sign #1 Good-60' Sign #2 Good-60' Better sign #1 or #2 2
2. Legibility: Sign #3 Good-50' Sign #4 Good-40' Better sign #3 or #4 3
3. Which were better Signs #1 & #2 ✓ or Signs #3 & #4

RUN NO. 3 Direction North Side of centerline left

1. Legibility: Sign #1 Good-60' Sign #2 Good-80' Better sign #1 or #2 2
2. Legibility: Sign #3 Fair-40' Sign #4 Fair-40' Better sign #3 or #4 4
3. Which were better Signs #1 & #2 ✓ or Signs #3 & #4

RUN NO. 3 Direction South Side of centerline Right

1. Legibility: Sign #1 Fair-60' Sign #2 Good-60' Better sign #1 or #2 2
2. Legibility: Sign #3 Poor-40' Sign #4 Good-50' Better sign #3 or #4 4
3. Which were better Signs #1 & #2 ✓ or Signs #3 & #4

RUN NO. 3 Direction North Side of centerline left

1. Legibility: Sign #1 Good-70' Sign #2 Good-60' Better sign #1 or #2 1
2. Legibility: Sign #3 Fair-40' Sign #4 Fair-30' Better sign #3 or #4 3
3. Which were better Signs #1 & #2 Much better or Signs #3 & #4

FIGURE 9.—FORM USED IN RECORDING LEGIBILITY DISTANCE AND ADJECTIVE RATINGS FOR SIGNS PLACED AT DIFFERENT ANGLES.

All signs were mounted with their centers 2 feet outside the pavement edge. The mounting height from the elevation of the pavement crown to the center of the legend or symbol was 18 inches for the non-illuminated signs, 42 inches for the exterior-illuminated signs, and 54 inches for the interior-illuminated signs.

Figure 9 shows the form used to record the field data. The driver, as a sign was approached, called out the legend as soon as he could read it. The recorder immediately estimated the distance to the sign with the aid of small stakes covered with a reflecting material and located 30, 60, and 90 feet from the sign. While the driver may have actually been able to read the sign shortly before he called out the legend, his reaction time to do this was probably about the same as the time required for him to react in maneuvering the vehicle. In any case, the estimated distances were sufficiently accurate for this test.

After having passed the sign, the driver also gave the sign an adjective rating based on the distance that the sign remained legible and the relative legibility as compared with other signs. Although the signs that were legible from the greater distances generally received the higher adjective ratings, this did not always hold. For example, a sign that may have been legible for a long distance but was not outstanding at any distance may have been given a lower adjective rating than a sign that was very outstanding for a shorter distance. Data were obtained for both 2- and 4-lane highways by each observer driving over the test section twice for a particular sign installation, once to the right and once to the left of the centerline. Only the signs receiving the highest legibility ratings on the previous test route were included in this study.

Table 6 shows the legibility distances and ratings for the signs when at various angles with the roadway for 2- and 4-lane highways. The results, which were in line with but more conclusive than the previous sign tests, may be summarized as follows:

1. Interior-illuminated signs were the most legible. The average legibility distance was in excess of 100 feet whether the signs were 12 or 22 feet from the centerline of the roadway. The minimum legibility distance recorded was 50 feet, which is more than ample distance in which to stop a passenger car in good condition and traveling 20 miles per hour on a dry pavement.

2. The reflectorized symbols were identified at greater distances than were the legends on any type of sign except the interior-illuminated signs. It made little difference whether they were at 10° or 30° toward the road from a line perpendicular to the centerline or whether they were 12 or 22 feet from the centerline. The average legibility distances were about 80 feet and for only 2 out of 72 observations was the legibility distance less than 50 feet. Signs reflectorized with glass buttons were only slightly more effective than those with the reflectorized coatings used.

3. The exterior-illuminated signs were not legible for as great a distance as a number of the best reflectorized signs when both types were located 12 feet from the centerline. Since it made little difference where the exterior-illuminated signs were located, their legibility distances and ratings compared favorably with the best reflectorized signs when both were 22 feet from the center of the roadway. At greater distances, the exterior-illuminated signs would no doubt be the more legible.

Although about half of the observers read the four-letter legends at distances over 50 feet, the legibility distance was 30 feet or less for 21 percent of the observations, and, therefore, exterior-illuminated signs would not be effective at locations where a driver would be required to bring his vehicle to a stop from a speed of 20 miles an hour at a point adjacent to the sign after reading the legend. Where an immediate stop would not be required or where the sign could be located in advance of the stop, the legibility distance would be satisfactory. As with the interior-illuminated signs, the exterior-illuminated signs also have a target value, that is, they can be seen beyond the range of the headlamp beam. This feature, which was much more pronounced for the interior- than exterior-illuminated signs, may result in decreased speeds prior to reaching the point where the signs are legible.

It may be possible to increase the legibility distance for exterior-illuminated signs by using a flat finish. However, if this were required to obtain satisfactory legibility, one of the chief advantages of an exterior illuminated sign would be lost, namely, being able to utilize existing signs by attaching a simple light fixture.

4. Of the reflectorized signs, those with reflecting buttons were more satisfactory than those with reflectorized coatings when placed either 12 or 22 feet from the center of the roadway. This is not entirely consistent with the results obtained on the test route (table 2) where the legibility ratings were higher for the signs with reflectorized materials than for the signs with reflector buttons. The difference in either case, however, is not great. Since the signs were placed so that more direct comparisons could be made during the latter series of tests, these results (table 6) are more conclusive than the results for the test route (table 2). Final decision as to which type of sign to install should therefore, probably be based on the availability of materials and the particular local conditions involved. The average legibility distance

TABLE 6.—*Legibility distances of signs at various angles with the roadway observed from vehicles moving 15 to 20 miles per hour*

Color and material used			Angle with line perpendicular to roadway	For 2-lane road—12 feet from center of road								For 4-lane road—22 feet from center of road								
				Number of observations	Maximum legibility distance			Distribution of legibility ratings			Rating factor [1]	Number of observations	Maximum legibility distance			Distribution of legibility ratings				Rating factor [1]
Letters	Panel	Background			Maximum	Minimum	Average	Good	Fair	Poor			Maximum	Minimum	Average	Good	Fair	Poor	Seen	
			Degrees		*Ft.*	*Ft.*	*Ft.*	*Pct.*	*Pct.*	*Pct.*			*Ft.*	*Ft.*	*Ft.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
GROUP 1.—BACKGROUND OF MATERIAL HAVING A REFLECTORIZED COATING																				
Black paint		Silver R. C. type A	30	6	70	35	48	83	17	0	92	6	80	30	49	17	67	16	0	56
Do		White R. C. type A	10	16	75	35	52	50	50	0	75	8	60	0	24	13	25	12	50	42
Do		do	30	20	75	30	52	50	45	5	74	12	75	0	38	17	41	25	17	50
Do		do	45	14	60	25	41	0	64	36	44	14	40	0	15	7	14	22	57	36
Do		White R. C. type C	30	6	60	30	43	50	33	17	72	6	30	0	7	0	17	17	66	31
GROUP 2.—LETTERS OF MATERIAL HAVING A REFLECTORIZED COATING																				
Silver R. C. type A	Black	White paint	10	6	75	40	57	33	67	0	66	6	40	0	18	0	0	50	50	29
Do	do	do	30	6	75	30	47	67	33	0	84	6	70	30	47	17	50	33	0	53
Do	do	Yellow paint	30	6	70	40	49	67	33	0	84	6	60	0	35	50	17	17	16	68
White R. C. type A	do	White paint	30	6	70	30	46	67	33	0	84	6	60	25	39	34	33	33	0	62
GROUP 3.—LETTERS REFLECTORIZED WITH GLASS BUTTONS																				
Buttons on black paint		White paint	30	6	75	40	53	83	17	0	92	6	40	0	26	0	0	67	33	31
Do		Yellow paint	30	6	100	40	64	83	17	0	92	6	80	0	51	17	50	17	16	52
Buttons on white paint	Black	White paint	10	14	100	40	71	79	21	0	90	14	110	0	66	43	36	14	7	68
Do	do	do	30	14	100	50	71	93	7	0	96	6	100	30	71	83	17	0	0	92
Do	do	Yellow paint	30	6	90	40	57	100	0	0	100	6	75	0	41	17	50	17	16	52
GROUP 4.—EXTERIOR-ILLUMINATED SIGNS																				
Black paint		White paint	10	16	75	20	46	12	56	32	51	8	60	15	47	12	63	25	0	52
Do		do	30	8	75	20	51	25	63	12	60	---	---	---	---	---	---	---	---	---
Do		Yellow paint	10	8	80	30	51	25	38	37	56	8	90	30	59	25	63	12	0	61
GROUP 5.—INTERIOR-ILLUMINATED SIGNS																				
Opal glass		Black paint	10	16	150	70	116	100	0	0	100	8	150	50	108	100	0	0	0	100
GROUP 6.—REFLECTORIZED CROSSROAD SYMBOLS																				
Silver R. C. type A		None	10	14	110	40	75	86	14	0	93	14	100	50	78	71	29	0	0	86
Do		do	30	8	100	40	58	88	12	0	94	---	---	---	---	---	---	---	---	---
Buttons on white paint		do	10	8	110	50	74	75	25	0	88	8	100	60	79	88	12	0	0	94
Do		do	30	14	120	55	84	100	0	0	100	6	110	55	81	67	33	0	0	84

[1] Obtained by adding all of the percentage rated "good," one-half the percentage rated "fair," one-third the percentage rated "poor," and one-fourth the percentage rated "seen".

of a white sign with a black panel and reflector buttons in white letters was about 70 feet. Better legibility was obtained, especially, for the 4-lane highway condition, when the sign was mounted at an angle of 30° than at an angle of 10° toward the roadway from a line perpendicular to the centerline. The legibility distance when the sign was mounted at 30° was never less than 40 feet for the 2-lane highway condition and not less than 30 feet for the 4-lane highway condition.

5. The legibility of signs made with materials having reflectorized coatings was better, especially under 4-lane conditions, when the signs were placed at 30° toward the roadway from a line perpendicular to the centerline than when placed at either 10° or 45°. There was little difference between 10° and 30° for the 2-lane condition. With the same type of material, the results were about the same whether the background or letters were reflectorized. However the materials used had a marked effect on legibility. Reflectorized signs with the silver colored type A material were legible from an average distance of about 50 feet under either the 2- or 4-lane condition. To a few observers, some signs with reflectorized coatings were not legible from a distance of more than 30 feet for a 2-lane highway and except for the one material, were not legible to the majority of observers when placed 22 feet from the center of the roadway.

HEADLIGHT BEAM CHARACTERISTICS DISCUSSED

One of the most noticeable factors influencing the legibility distances of the various reflectorized signs was the variation in the height of the headlight beam at any distance from the car. Even though the surface was exceptionally smooth, the light beam was continually varying in height especially at the greater distances from the car. Even a slight acceleration or deceleration caused a considerable variation; in fact, enough so that it was more desirable to accelerate immediately after a sign was noticed than to decelerate (without applying brakes) in order to read the sign.

The vertical motion of the headlight beam was one of the primary reasons for greater legibility distance for the symbols and signs reflectorized with glass buttons as compared to the signs having reflectorized coatings. No sign or symbol was visible until illuminated by the light beam. However, the symbols could be identified and the legends on the signs reflectorized with buttons read with only intermittent

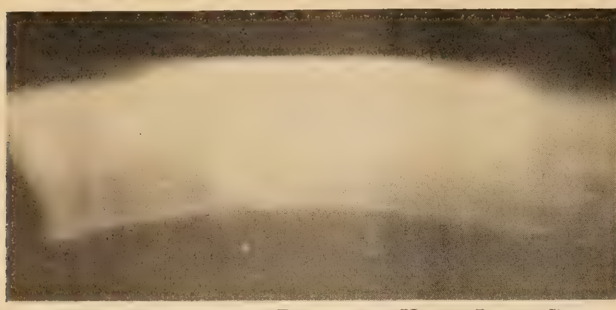

FIGURE 10.—PATTERN OF BLACKOUT HEAD LAMP BEAM ON VERTICAL SURFACE.

illumination, while the signs with reflectorized coatings were not legible until the vehicle was at least close enough to throw a continuous beam of light on the legend.

The effect of sign placement, including angularity, height above the road surface, and distance from the centerline of the roadway, and the effect of the type of reflecting materials on the legibility distance, can best be explained by a study of the headlight beam characteristics.

Figure 10 shows a blackout headlamp pattern on a vertical surface. It may be noticed that the top of the area has a very sharp cut-off and that the area just below the top and near the center is brighter than other portions of the pattern. At a distance of 10 feet from the lamp, the bright area is about 5 feet wide while the entire illuminated area is about 12 feet wide. Vertically, the illuminated area does not vary in intensity to any marked degree until about 5 inches below the top cut-off, then the intensity decreases until the illuminated area fades out 30 inches below the top cut-off. There was some variation in the illuminated areas for individual lights used during the road tests but the major difference was that the top of the illuminated area outside the bright area curved sharply downward in some cases and remained nearly horizontal in others. With the headlight adjusted so that the visual cut-off slopes down at the rate of 2½ inches in 10 feet (the lowest rate found to be practical in preventing the beam from shining above the vertical when the cars were traveling along a smooth, level road), the theoretical height of the beam at various distances ahead of a vehicle was as follows:

Distance from vehicle, feet	*Height of beam above road surface, inches*
0	44
20	39
40	34
60	29
80	24
100	19
120	14
140	9
160	4
176	0

Actually, however, as a vehicle traveled over a level highway, the beam varied in height. The variation was enough to cause intermittent illumination of the top of a sign legend 21 inches above the roadway at distances exceeding 120 feet, and usually the legend was not continuously illuminated until the vehicle was within 70 feet of the sign.

The bottom of the high-intensity area of the light beam hit the road surface about 60 feet ahead of the vehicle while the bottom of the beam fell about 15 feet ahead of the vehicle. The high-intensity area increased in width 5 feet every 10 feet from the vehicle and the entire illuminated area increased in width about 12 feet every 10 feet. However, the maximum widths of both were limited by the curvature of the top of the beam. Signs for blackout purposes should therefore be mounted as low and as close laterally to the pavement edge as practicable. Unless the legend of a reflectorized sign is within 18 inches of the elevation of the crown of the roadway, the sign will be of little value and practically worthless if above 24 inches. A difference of 6 inches in the mounting height will usually make a difference of about 24 feet in the legibility distance of the best reflectorized signs.

It is also important when reflectorized signs are used that the head lamp be properly mounted on the vehicle and that the signs be turned at an angle toward the road. The following are a few factors governing the intensity of the light reflected back to the driver of a vehicle:

1. The amount of light falling on the sign and the distance the driver is from the sign.
2. The particular characteristics of the reflecting material.
3. The angle between a line perpendicular to the face of the sign and a line from the head lamp to the sign (entrance or incidence angle).
4. The angle between the driver's line of sight to the sign and a line from the head lamp to the sign (divergence angle).

HEAD LAMP SHOULD BE MOUNTED NEAR DRIVER'S LINE OF SIGHT

Since the beam from the black out head lamp is very narrow, the amount of light falling on a sign will vary greatly with the distance to the sign from the head lamp and with its vertical and horizontal position along the roadway.

Although the characteristics of reflecting materials vary greatly, the intensity of the reflected light for any particular material generally decreases as both the entrance angle and divergence angles increase. Table 7 shows how these two angles vary for two different headlight mounting positions and a number of roadway conditions. For condition A the headlight is mounted as on the vehicles used for the road tests while for condition B an assumed mounting position is used. For both conditions the driver's eyes were 54 inches above

TABLE 7.—*Effect of head lamp mounting location and width of road on mounting angles and materials used for reflectorized signs*

ANGLE SIGNS MUST BE PLACED TO BE PERPENDICULAR TO HEAD LAMP BEAM (ZERO ENTRANCE ANGLE)

Distance from vehicle, feet	Sign 12 feet from centerline of roadway		Sign 22 feet from centerline of roadway	
	Condition A [1]	Condition B [2]	Condition A [1]	Condition B [2]
	° ′	° ′	° ′	° ′
100	5 06	5 43	10 43	11 19
50	10 07	11 19	20 44	21 48
30			32 14	33 42
20	24 02	26 34		

ANGLE BETWEEN LINE FROM DRIVER'S EYES TO SIGN AND LINE FROM HEAD LAMP TO SIGN (DIVERGENCE ANGLE)

Distance from vehicle, feet	Sign 12 feet from centerline of roadway, Condition A [1]	Sign 12 feet, Condition B [2]	Sign 22 feet from centerline of roadway, Condition A [1]	Sign 22 feet, Condition B [2]
	° ′	° ′	° ′	° ′
100	0 24	1 03	0 47	1 18
50	1 05	2 25	2 12	3 24
30			5 01	6 36
20	5 16	8 01		

[1] Head lamp mounted 44 inches above roadway and 11 inches to left of centerline of vehicle.
[2] Head lamp mounted 36 inches above roadway and 24 inches to left of centerline of vehicle.

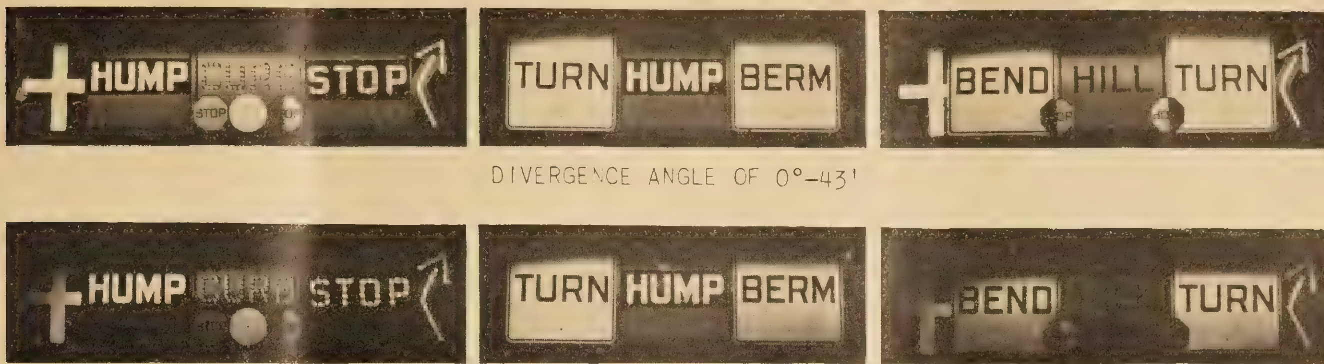

FIGURE 11.—EFFECT OF DIVERGENCE ANGLE ON VISIBILITY AND LEGIBILITY OF REFLECTORIZED SIGNS AND SYMBOLS ILLUMINATED BY BLACKOUT HEAD LAMP. (SAME EXPOSURE TIME USED IN ALL PICTURES.)

the pavement surface, 16 inches to the left of the centerline of the vehicle, and 7.5 feet behind the head lamp. The centerline of the vehicle was assumed to be 4 feet to the right of the center of the roadway (under blackout conditions, regardless of the width of the roadway, drivers try to keep just to the right of the centerline marking).

Values are shown for the 2-lane highway condition with the sign 100, 50, and 20 feet ahead of the vehicle and for the 4-lane condition with the sign 100, 50, and 30 feet ahead of the vehicle (10-foot lanes are assumed with the sign 2 feet beyond the edge). One hundred feet represents the maximum distance ahead of a vehicle that the headlight can be expected to illuminate a sign while 50 feet represents the minimum distance that a sign for use during black outs should be legible. The minimum distances at which enough light will fall on a sign to make it legible are 20 and 30 feet on 2- and 4-lane roadways, respectively.

Considering that there is a relatively small decrease in the brilliance of most reflectorized materials or glass reflecting buttons as the entrance angle increases from 0° to 10° as compared to the decrease in brilliance with a similar change at greater angles, it appears from table 7 and the results shown in table 6 that reflectorized signs should be mounted at about 15° with a line perpendicular to the centerline on a 2-lane roadway and at 25° on a 4-lane roadway.

Compared to the entrance angle, the divergence angle is much more critical. To be effective for use on signs a glass reflecting button or reflectorized material must be highly retrodirective, that is, it must return the light in approximately the same direction as the source of light. It is therefore common for the brilliance of a reflecting button to decrease more than 50 percent when the divergence angle increases from 1° to 2° (see fig. 11).

The importance of mounting the black out head lamp as near the driver's line of sight as possible is illustrated by the divergence angles for the two conditions shown in table 7. At distances over 50 feet ahead of the vehicle, the difference in the divergence angle due to the head lamp mounting location was greater than the change in the divergence angle caused by placing the sign 10 feet farther from the roadway. The values shown on table 7 also indicate that for signs that must be legible at least 50 feet away the best reflecting buttons or reflectorized materials are the ones that are most brilliant within entrance angles less than 10° and divergence angles in the neighborhood of 1° or 2°.

The answers on the 43 questionnaires filled out by the drivers and observers after they had been over the test route indicate that the illuminated signs were not superior to good reflectorized signs and that there was a slight preference for the signs reflectorized with glass buttons as compared with those made with reflectorized materials. In reply to the question "Is a self-illuminated sign superior to a good reflectorized sign?" 32 percent of the observers answered in the affirmative and 68 percent in the negative. To the question "Were the floodlighted signs adequate?" 42 percent of the observers answered "yes" and 58 percent "no." Fifty-four percent preferred the reflecting button signs and 46 percent the signs of materials with reflectorized coatings.

VISIBLE CENTERLINE MOST USEFUL MARKING IN BLACKOUTS

Seventy-seven percent of the drivers and observers felt that a visible centerline was the most useful highway marking during black out conditions. Table 8 shows the distribution of the visibility and effectiveness ratings and comparative rating factors for the 18 different types of center and edge lines studied. Most of the test route had an old centerline marking. To approach the "no line" condition, shown as the first two items in table 8, the existing line was covered with a paint as nearly as possible the same color as the pavement surface, but this marking was evidently visible to a few of the drivers.

TABLE 8.—*Visibility or effectiveness of centerline markings*

Type of line: Plain or beaded	Type of line: Color	Type of line: Width	Type of line: Solid or dashed	Length: Dashes	Length: Spaces	Sky condition	Number of observations	Distribution of visibility or effectiveness ratings: Good	Fair	Poor	Rating factor [1]
		Inches		*Feet*	*Feet*			*Percent*	*Percent*	*Percent*	
No line						Dark	58	9	9	82	14
						Moon	18	0	5	95	3
						Total	76	7	8	85	11
Do.[2]						Dark	10	0	60	40	30
						Moon	1	0	0	100	0
						Total	11	0	55	45	28
Plain—Old line	White	4	Solid			Dark	11	0	0	100	0
						Moon	4	0	0	100	0
						Total	15	0	0	100	0
Plain	Black	4	do			Dark	24	21	21	58	32
						Moon	11	18	18	64	27
						Total	35	20	20	60	30
Do	White	4	do			Dark	60	8	10	82	13
						Moon	27	11	0	89	11
						Total	87	9	7	84	13
Do.[2]	do	4	do			Dark	20	35	10	55	40
						Moon	16	19	6	75	22
						Total	36	28	8	64	32
Do	do	6	do			Dark	50	14	16	70	22
						Moon	18	6	17	77	15
						Total	68	12	16	72	20
Do.[2]	do	6	do			Dark	24	0	17	83	9
						Moon	9	0	56	44	28
						Total	33	0	27	73	14
Plain	do	6	Dashed	20	20	Dark	21	5	19	76	15
						Moon	8	13	25	62	26
						Total	29	7	21	72	18
Beaded [2]	do	3	Solid			Dark	22	73	18	9	82
						Moon	12	67	33	0	84
						Total	34	71	23	6	83
Do.[2]	do	3	Dashed	10	25	Dark	11	9	55	36	37
						Moon	11	36	18	46	45
						Total	22	23	36	41	41
Do	do	4	Solid			Dark	48	75	12	13	81
						Moon	20	70	15	15	78
						Total	68	74	13	13	81
Do.[2]	do	4	do			Dark	15	80	7	13	84
						Moon	7	100	0	0	100
						Total	22	86	5	9	89
Do	Yellow (no passing)	4	do			Dark	34	53	23	24	65
						Moon	22	50	18	32	59
						Total	56	52	21	27	63
Do.[2]	do	4	do			Dark	21	62	33	5	79
						Moon	10	60	20	20	70
						Total	31	61	29	10	76
Beaded edge lines only	White	4	do			Dark	24	63	25	12	76
						Moon	11	73	18	9	82
						Total	35	66	23	11	78
Beaded center and edge lines	do	4	do			Dark	25	84	4	12	86
						Moon	10	100	0	0	100
						Total	35	89	3	8	91
Beaded	do	4	Dashed	10	15	Dark	20	45	30	25	60
						Moon	10	50	40	10	70
						Total	30	47	33	20	64
Do	do	4	do	10	20	Dark	21	43	28	29	57
						Moon	9	44	45	11	67
						Total	30	43	34	23	60
Do	do	4	do	20	20	Dark	24	58	13	29	65
						Moon	10	60	20	20	70
						Total	34	59	15	26	67

TABLE 8.—*Visibility or effectiveness of centerline markings*—Continued

Type of line: Plain or beaded	Color	Width	Solid or dashed	Length: Dashes	Length: Spaces	Sky condition	Number of observations	Distribution of visibility or effectiveness ratings: Good	Fair	Poor	Rating factor [1]
		Inches		*Feet*	*Feet*			*Percent*	*Percent*	*Percent*	
Beaded	White	4	dashed	15	25	Dark	26	58	23	19	70
						Moon	11	64	27	9	78
						Total	37	60	24	16	72
Do.[2]	do	4	do	10	10	Dark	10	40	40	20	60
						Moon	5	60	20	20	70
						Total	15	47	33	20	64
Do	do	4	do	10 (white)	30 (black)	Dark	22	63	23	14	75
						Moon	9	67	33	0	84
						Total	31	64	26	10	77

[1] Obtained by adding all of the percentage rated "good" to one-half the percentage rated "fair."
[2] On bituminous surface. Others on concrete surface.

Based on the data in table 8 and answers on questionnaires filled out by the drivers and observers after completing a trip over the test course, the conclusions with respect to center and edge lines for blackout conditions may be summarized as follows:

1. Visible centerlines are the most useful marking and are essential.

2. Plain painted centerlines, not reflectorized, are of little value. Plain white centerlines, including those 6 inches in width, could not be seen by many of the drivers. Out of 44 observers, 33 stated that the ordinary white centerline was inadequate. On a concrete surface, a black centerline was rated as more effective than a plain white centerline.

3. White continuous centerlines either 3 or 4 inches wide and reflectorized with glass beads are very effective. Any greater width is unnecessary.

4. Yellow reflectorized lines are not as visible as white reflectorized lines, although the difference is not great.

5. Dashed centerlines are not as effective as continuous centerlines although they are adequate on tangent sections of highway (fig. 12). Out of 44 observers, 26 stated that the continuous line was definitely better, 13 stated that the continuous line was somewhat better, and 5 had no preference. When a dashed line is used, the dashes should be at least 10 feet long and the spaces not over 20 feet long. Although both designs require the same amount of paint, 10-foot dashes and spaces are preferable to 20-foot dashes and spaces, especially on curves. However, the remarks made by the observers indicate that a solid centerline should be used in place of a dashed centerline even on fairly flat curves.

6. Edge lines when used in conjunction with a centerline (fig. 12) are effective in helping to outline the road surface but are unnecessary and may be confused with lane lines. The comments of the 44 observers regarding the edge lines were as follows:

Comment	*Number of observers*
Good if used with centerline	16
Good	11
Confusing or dangerous	9
Confusing or dangerous without centerline	2
Some help to driving	4
Unnecessary	2

FIGURE 12.—TOP, 4-INCH BEADED WHITE CENTERLINE WITH 20-FOOT DASHES AND 20-FOOT SPACES; BOTTOM, 4-INCH BEADED WHITE CENTERLINE AND EDGE LINES.

A few drivers did mistake the 2-lane pavement with edge lines for a 3- or 4-lane pavement and drove off the paved surface. However, at some locations, such as short access roads that are narrow and have poor alinement, the use of edge lines in addition to a center line is desirable. Most drivers exceeded a speed of 20 miles per hour while on the sections with edge lines. Some believed edge lines would make it possible to travel at speeds up to at least 30 miles per hour with the blackout head lamp.

With the exception of the 6-inch line, the visibility of the plain painted centerlines was lower when there

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was some moonlight than when there was no moonlight, but moonlight increased the visibility of the beaded white centerlines. However, in either case the difference was slight.

The need for certain transverse pavement markings is increased during blackout conditions. For example, at stop signs and traffic signals meeting blackout requirements some type of visible pavement marking is needed to indicate the point where the stop should be made. Under black-out conditions it is exceedingly difficult for a driver to estimate the distance to a light, and the curbs and other objects normally used to define or outline an intersection are not visible. Unless there is some special marking to indicate an intersection, a driver may pass through the intersection without being aware of it. When transverse pavement lines such as stop lines are used, they generally require special treatment in addition to reflectorization or they will not be effective.

Table 9 shows the rating factors for a number of different transverse pavement markings, some being designs that as yet have not been used extensively for normal conditions. Since it was not possible to place all the transverse markings at similar locations, the rating factor for a particular marking was influenced to some extent by the drivers' speed when the marking was noticed and also affected to some extent by other pavement markings or signs at the intersection.

TABLE 9.—*Visibility of painted crosswalk and special limit lines*

Color	Width	Kind	Sky condition	Number of observations	Distribution of visibility and effectiveness ratings: Good	Fair	Poor	Rating factor [1]
	Inches				*Percent*	*Percent*	*Percent*	
White	8	Plain	Dark	15	25	8	67	29
			Moon	6	50	0	50	50
			Total	21	31	6	63	34
Do	12	do	Dark	15	33	17	50	42
			Moon	6	40	20	40	50
			Total	21	36	18	46	45
Do	8	Beaded	Dark	30	86	14	0	93
			Moon	12	100	0	0	100
			Total	42	89	11	0	95
Do	[2] 8	do	Dark	30	75	25	0	88
			Moon	12	100	0	0	100
			Total	42	86	14	0	93
Do	[3] 8	Plain	Dark	30	64	36	0	82
			Moon	12	83	17	0	92
			Total	42	71	29	0	86
Do	[3] 8	Beaded	Dark	15	82	18	0	91
			Moon	6	100	0	0	100
			Total	21	87	13	0	94
Do	[4] 8	do	Dark	15	70	30	0	85
			Moon	6	100	0	0	100
			Total	21	75	25	0	88
Do	[5] 8	do	Dark	15	70	30	0	85
			Moon	6	100	0	0	100
			Total	21	79	21	0	90

[1] Obtained by adding all of the percentage rated "good" to one-half the percentage rated "fair."
[2] With beaded limit line 24 inches wide placed 4 feet in advance of crosswalk line.
[3] With 4-inch beaded lines 5 feet long spaced 24 inches apart perpendicular to crosswalk line on the side of approaching traffic to form a "comb" effect.
[4] Special design of limit line consisting of a continuous V design, the open end of each V being 3 feet wide and the height being 4 feet. One end of the design was bordered by the 8-inch crosswalk line and the other end by a similar 8-inch white beaded line.
[5] With 4-inch beaded limit line having perpendicular beaded lines toward approaching traffic 5 feet long spaced 24 inches apart to form a "comb" effect and placed 4 feet in advance of crosswalk line.

LINES HAVING "COMB" DESIGN FOUND MOST EFFECTIVE TRANSVERSE MARKING

Considering the particular locations where these transverse markings were placed, the design with 4-inch lines 5 feet long spaced 2 feet center-to-center and placed perpendicular to a transverse line on the side of approaching traffic to give a "comb" effect (fig. 13) was the most effective transverse marking. Where it is necessary that the pavement marking be visible for 50 feet such as at wide, important intersections where there is a stop light, this design should be used. Increasing the length of the perpendicular bars will, to some extent, increase the visibility distance.

At the intersection of 2-lane highways where there is a blackout traffic signal or at any intersection where there is a stop sign visible for 50 feet or more, an 8-inch beaded line is sufficiently visible to indicate the stopping point since in either case the driver will have decreased his speed below 20 miles per hour before reaching the line. An 8-inch beaded line is also sufficiently visible for identifying intersections where there is apt to be little or no cross traffic.

Painting the curbs is another means of indicating to a driver that he is at an intersection and is of material assistance to the driver when making a turn but does not provide an advance warning so that a stop can be made before entering the intersection. Since the vertical faces of curbs are low, they are illuminated at greater distances than other surfaces and therefore are the most effective location for markings. Curbs in the direct line of traffic whether at intersections or around hazardous objects should be marked.

Table 10 shows the visibility ratings for the painted and reflectorized curbs along the test route. None of the observers noticed curbs at one intersection that had been painted yellow. The rating factor for the plain white curbs is nearly as high as that for the beaded curbs but is misleading since the rating factors in this table are based only on the adjective ratings given by the observers that noticed the painted curbs. Only 67 percent of the observers noticed the plain white curbs while all observers noticed the beaded curbs. If an adjective rating of "poor" were assumed each time the plain white curb was not seen, the rating factor would be

TABLE 10.—*Visibility of painted curbs at intersections*

Color	Kind	Sky condition	Number of observations	Distribution of visibility ratings: Good	Fair	Poor	Rating factor [1]
				Percent	*Percent*	*Percent*	
White	Plain	Dark	45	57	29	14	72
		Moon	18	83	0	17	83
		Total	63	65	20	15	75
Yellow	do	Dark	8	0	0	100	[2] 0
White	Beaded	Dark	15	71	29	0	86
		Moon	6	50	50	0	75
		Total	21	67	33	0	84
White & black	do	Dark	45	69	31	0	85
		Moon	18	67	17	16	76
		Total	63	69	26	5	82
Do. (straight curb at T-intersection).	do	Dark	30	91	9	0	96
		Moon	12	100	0	0	100
		Total	42	94	6	0	97

[1] Obtained by adding all of the percentage rated "Good" to one-half the percentage rated "Fair."
[2] None of the 8 observers saw this marking.

FIGURE 13.—BEADED WHITE PAVEMENT MARKINGS IN URBAN AREAS. LEFT, CENTERLINE, PARKING STALLS, AND "COMB" DESIGN AT CROSSWALK; RIGHT, PAVEMENT AND CURB MARKINGS AT T-INTERSECTION.

reduced from 75 to 40. The white curbs were, therefore, less than half as effective as the beaded curbs. The white beaded curbs with plain black vertical stripes were no more effective than the white beaded curbs.

At the railroad crossing within the limits of Hebron the standard railroad crossing marking was painted on the pavement surface with plain white paint for half the roadway width and with reflectorized paint for the other half. The comb design was also employed to emphasize the approach lines parallel with the tracks on the side that was reflectorized (see fig. 3). The reflectorized markings were rated as about 60 percent more effective than those made using plain white paint (table 11).

Parking stall lines if visible may be effective in helping prevent emergency vehicles from hitting parked cars especially when there are cars near the middle of a block but none near the intersections. However, their use for this purpose is very limited since, when the stalls are filled, the transverse lines will not be visible. Plain painted stalls were practically useless (table 10) unless the marking included a longitudinal line parallel with the curb (fig. 13) and even then they were only about half as effective as the beaded markings.

To warn a driver of the approach to an intersection on a 2-lane road an additional line may be placed alongside the centerline for 100 feet in advance of the intersection or when a dashed centerline is used it may be made continuous for 100 feet in advance of the intersection. Such markings are very effective (table 11). On 4-lane roads with a double centerline marking, the same principle may be applied by the use of an additional line near the centerline and by making lane lines solid instead of dashed. Double lines should never be used for lane lines since with the blackout light such a lane line on the left side of the lane may be mistaken for the centerline marking.

The only words marked on the pavement were located where the test drivers had reduced their speed in compliance with a good reflectorized or illuminated sign. At these locations, both beaded and plain painted words were fairly effective. Where vehicle speeds are not reduced below 20 miles per hour, words probably will not be effective. Their use is therefore very limited.

TWO TYPES OF ROAD-EDGE DELINEATORS TESTED

A traffic signal equipped with a 27-volt transformer was in operation during 2 of the 3 nights when the tests were made. It was very effective and probably more noticeable than are lights under normal conditions operating on 110 volts.

Some type of road-edge delineation is desirable at curves on unpaved roadways where the centerline cannot be marked, and necessary at sharp curves even though the centerline of the roadway is marked. The beam of the blackout lamp is so limited that practically no light falls on the centerline at sharp curves especially when the vehicle is on the outside of the curve. Two types of markers suitable for use as delineators were tested. One was constructed by wrapping 3-inch boards for 42 inches with a reflectorized material (fig. 14–A) and the other consisted of three sets of three plastic reflecting buttons mounted 1 foot apart on a 3-inch board. When these markers were installed in a vertical position 5 feet outside the pavement edge, the reflectorized material extended from 6 to 36 inches above the pavement elevation and the centers of the three sets of reflecting buttons were at 12, 24, and 36 inches above the pavement.

The outside of four horizontal curves and the tangents for about 80 feet in advance of and beyond the curves were delineated using the markers with reflecting buttons. The spacing was 40 feet on two curves, 20 feet on one curve, and 80 feet on the other curve during the first night that the drivers' reactions were recorded. Bidirectional units were used on one curve. On the second night, alternate markers on each curve were removed so that results for two different spacings would be obtained for the same curve. The markers with reflectorized material were placed individually along the route.

Conclusive data as to the most desirable spacing on curves were not obtained. However, three delineators were visible at all times only when spaced 40 feet on the more gradual curves (3° to 5°) and 20 feet on the one sharp curve (about 12°). The sets of buttons mounted 36 inches above the pavement were rarely visible, the sets 24 inches above the pavement were visible about half the time, and those at a height

TABLE 11.—*Visibility and effectiveness of various white urban pavement markings and blackout traffic signal*

Legend or marking	Kind	Width of line	Sky condition	Number of observations	Distribution of visibility and effectiveness ratings: Good	Fair	Poor	Rating factor [1]
RAILROAD GRADE CROSSING MARKINGS								
		Inches			*Percent*	*Percent*	*Percent*	
Railroad crossbuck [2]	Plain	Standard [3]	Dark	15	50	25	25	63
			Moon	6	20	60	20	50
			Total	21	33	45	22	56
Do.[2]	Beaded	do.[3]	Dark	15	100	0	0	100
			Moon	6	100	0	0	100
			Total	21	100	0	0	100
Lines parallel to and 10 feet from tracks	do	12	Dark	15	50	42	8	71
			Moon	6	25	75	0	63
			Total	21	44	50	6	69
Do.[4]	do	12	Dark	15	100	0	0	100
			Moon	6	100	0	0	100
			Total	21	100	0	0	100
WHITE PAINTED PARKING STALL LINES								
7-foot transverse lines	Plain	4	Dark	15	0	0	100	0
			Moon	6	50	0	50	50
			Total	21	12	0	88	12
Do	Beaded	4	Dark	15	80	20	0	90
			Moon	6	0	100	0	50
			Total	21	67	33	0	84
7-foot transverse lines with longitudinal line.	Plain	4	Dark	15	40	0	60	40
			Moon	6	33	33	34	50
			Total	21	38	12	50	44
Do	Beaded	4	Dark	15	86	0	14	86
			Moon	6	50	0	50	50
			Total	21	78	0	22	78
WHITE PAINTED LANE LINES EXTENDING 100 FEET BACK FROM INTERSECTIONS								
	Beaded	4	Dark	15	88	12	0	94
			Moon	6	75	25	0	88
			Total	21	83	17	0	92
WHITE PAINTED WORDS ON PAVEMENT								
Stop [2]	Plain		Dark	15	57	29	14	72
			Moon	6	0	100	0	50
			Total	21	44	45	11	67
Slow [2]	Beaded		Dark	16	50	50	0	75
BLACKOUT TRAFFIC SIGNAL								
			Dark	7	100	0	0	100
			Moon	6	100	0	0	100
			Total	13	100	0	0	100

[1] Obtained by adding all of the percentage rated "good" to one-half the percentage rated "fair."
[2] With 5-foot letters. Crossbuck 20 feet long and 8 feet wide.
[3] As given in Manual on Uniform Traffic Control Devices for Streets and Highways, by the A. A. S. H. O.
[4] With 4-inch beaded lines 5 feet long and 24 inches center to center perpendicular to line parallel to tracks on approach side to form a "comb" effect.

of 12 inches were visible all the time when they were within the light beam and not more than 120 feet ahead of the vehicle. When one set of three reflecting units is used on delineators, the set should be within 18 inches of the elevation of the road surface. However, one reflecting button at 12 inches, one at 18 inches, and one at 24 inches would probably be more effective especially on curves with considerable superelevation or where there also is a vertical curve.

The rating factor for the units wrapped with material having a reflectorized coating was not as high as for the units with plastic reflecting buttons (table 12) mainly because they were at individual locations and were approached unexpectedly. To be effective enough to warrant their installation as delineators, the reflectorized surface facing traffic should be at least 2 inches wide and 24 inches high with the bottom as close to the

(Continued on page 135)

VOLCANIC CINDERS SUITABLE FOR USE IN BASE COURSE CONSTRUCTION

BY THE DIVISION OF TESTS, PUBLIC ROADS ADMINISTRATION

Reported by EDWARD A. WILLIS, Associate Highway Engineer, HENRY AARON, Associate Highway Engineer, and RICHARD C. LINDBERG, Junior Highway Engineer

Volcanic cinders, a fragmental ash deposited as a result of volcanic eruptions, has been used for many years in constructing and maintaining local earth roads. Recently it has been used in the construction of road surfaces, base courses, and subbases on State highway systems.

A survey was recently made to obtain information on the service behavior of volcanic cinder roads in Arizona and to correlate the road condition with the physical characteristics of the cinders as determined by laboratory tests. Laboratory and circular track tests were made on cinders from five sources in Arizona and on "tufa" gravel.

The results of these studies disclose that volcanic cinders will prove satisfactory for use as base courses for thin bituminous surface treatments if they meet, with certain modifications, the requirements of A. A. S. H. O. specification M-56-38 for type C stabilized base-course materials. Even though the most satisfactory cinders are nonplastic, adequate compaction and density of base courses can be obtained by the judicious use of water during rolling.

"Tufa" gravel was not satisfactory as a base course because of an excess of fine-size material. "Tufa" gravel with a coarser gradation would probably serve satisfactorily as a base material. The investigation provided a direct correlation between circular track tests and field service behavior. It established the fact that suitable base-course materials will withstand concentrated traffic in the circular track with water 2½ inches above the top of the subbase but that water 4½ inches above the top of the subbase provides a condition more severe than can reasonably be expected under normal service conditions.

VOLCANIC CINDERS have been used for many years in the construction and maintenance of local earth roads in the southwestern United States. More recently this material has been utilized in the construction of road surfaces, base courses, and subbases on State highway systems. Since it is available in practically unlimited quantities in certain areas, its utilization in road building has considerable economic importance.

This report describes (1) a survey made by the Division of Tests in 1939 in cooperation with the Arizona State Highway Department and the Phoenix office of the Public Roads Administration to obtain information on the service behavior of roads constructed with volcanic cinders and to correlate the road condition with the physical characteristics of the cinders as determined by laboratory tests, and (2) laboratory and circular track tests on cinders from five sources and a "tufa" gravel, all selected by engineers in the Public Roads administration office at Phoenix in collaboration with the materials department of the Arizona Highway Department. One of the cinder materials tested in the circular track was similar to that used in the construction of Federal-aid project No. 105-C, surveyed in 1939. This provided a direct correlation between the track tests and observed service performance.

The cinders consist of a fragmental ash deposited in cone-shaped mounds or ridges as a result of volcanic eruptions. Figures 1-A and 1-B show a number of such cones and ridges in the vicinity of Flagstaff, Arizona. The fragments, ranging in size from fine sand grains to large boulders, have a honeycomb structure and are relatively light in weight. The material occurs as a compact deposit in the undisturbed condition and the sides of excavations will stand vertically, but as soon as it is dislodged it crumbles into a loose mass which is difficult to recompact. The character of the material, both undisturbed and dislodged, is shown in figures 1-C and 1-D.

The cinders vary considerably in color, both in the same deposit and in different deposits. Various shades of yellow, red, purple, and black are encountered. They all have practically the same granular texture, honeycomb structure and, unless mixed with clay, they are nonplastic. Small amounts of a calcareous material, known locally as caliche, are often present.

The deposits are generally covered with from 4 to 10 feet of overburden consisting of a friable, grayish silty soil containing rock fragments and calcareous material or a brownish red to red plastic clay in the upper part and red clay mixed with partially decomposed cinders in the lower part passing gradually into the unweathered cinders.

CONDITION SURVEY MADE OF ROADS IN SERVICE

The condition survey was made during April 1939. Samples taken at that time were tested in the Public Roads laboratory.

The roads covered in this survey are located in the vicinity of Showlow and Springerville in the east central part of the State and near Flagstaff in north central Arizona. They pass through areas of rolling topography at elevations exceeding 7,000 feet and are subject to heavy snowfall during the winter.

A total of about 83 miles of road were inspected, of which approximately 20 miles were of the bituminous surface-treated type and the remainder was untreated. The untreated surfaces were maintained in uniformly good condition as illustrated in figure 2-A. Since no variation in condition could be observed, no detailed studies were made of the untreated roads.

Bituminous treatments were used on FAP 105-C and FAP 95-J located, respectively, on U S 60 west of Springerville and on U S 89 north of Flagstaff. Failures were observed on short sections of FAP 105-C. FAP 95-J was in good condition throughout its length. Both sections were constructed in 1937.

FIGURE 1.—VOLCANIC CINDER DEPOSITS IN ARIZONA. CINDER CONES NORTH OF FLAGSTAFF (A AND B); CINDER PIT EAST OF SHOWLOW (C), AND WEST OF FLAGSTAFF (D).

The bituminous surface treatment consisted of from 0.75 to 1.00 gallon of liquid asphalt (SC–2) applied to a previously sprinkled, rolled, and properly shaped surface. No cover material was spread unless the asphalt was not entirely absorbed. The loose material developed in blading the road during the reshaping process was used for the cover material when required. The asphalt was placed in two applications, the first consisting of 0.5 gallon per square yard and the second varying from 0.25 to 0.50 gallon. The character of the surface obtained in this manner is illustrated in figures 2–B and 2–C.

The base course referred to in the discussion of service performance is the layer of cinders on which the asphaltic surface treatment was applied. This layer was about 5 inches thick on the two projects surveyed. The penetration of the bituminous material had formed a mat approximately 1 inch thick. Figure 3 shows a section through the mat and base course.

The base course rested on a cinder sub-base consisting of pit run material designated "imported borrow." The depth of this material was not uniform as it was varied during construction in accordance with the subgrade soil encountered. In many instances, shallow fills from 2 to 3 feet high were composed entirely of cinders.

Excellent drainage was provided in all cases. The cross-sections and grades were adequate to remove any surface water and there were no indications of subsurface water.

The surveying and sampling consisted of (1) making a condition survey of the bituminous surface, (2) measuring the thickness of the base and subbase, (3) examining the subgrade soils, and (4) obtaining samples of the base course, sub-base, and subgrade from locations corresponding to the variations in road condition.

Samples were obtained from the base and subbase after removing the portion penetrated by bituminous material. In all cases care was taken not to include any subbase material with the base-course samples, and likewise not to include any subgrade with the subbase samples.

The thickness of base and subbase was measured and the subgrade soil was examined at each sampling point. Each type of subgrade encountered was sampled.

For convenience of analysis, the results of the condition survey and the mechanical analyses and physical tests performed on the base-course samples are summarized in table 1. The base thickness shown in this table includes the portion penetrated by the bituminous material, which amounted to approximately 1 inch. The characteristics of the subbase and subgrade material are shown by the test results given in tables 2 and 3, respectively.

Three variations in surface condition were encountered. They have been designated (1) intact, (2) cracked and scaled, and (3) badly cracked and rutted. Figures 2–B and 2–C are views of the surface condition corresponding to the designation "intact." Cracked and scaled surface is illustrated in figure 4–B and a badly cracked and rutted section is shown in figure 4–A.

The similarity of the subbase cinders on both projects is illustrated in table 2. They were granular, nonplastic materials and, referring to table 1, it will be seen that they compare favorably in grading with the base-course materials on which no failures occurred. Table 1 also shows that the thickness of subbase was just as great or greater under the failed areas as under the intact areas.

The subgrade soils were stony loams and sandy loams containing calcareous material in various amounts The results of tests shown in table 3 indicate that the soils had physical properties of both the A–2 and A–5

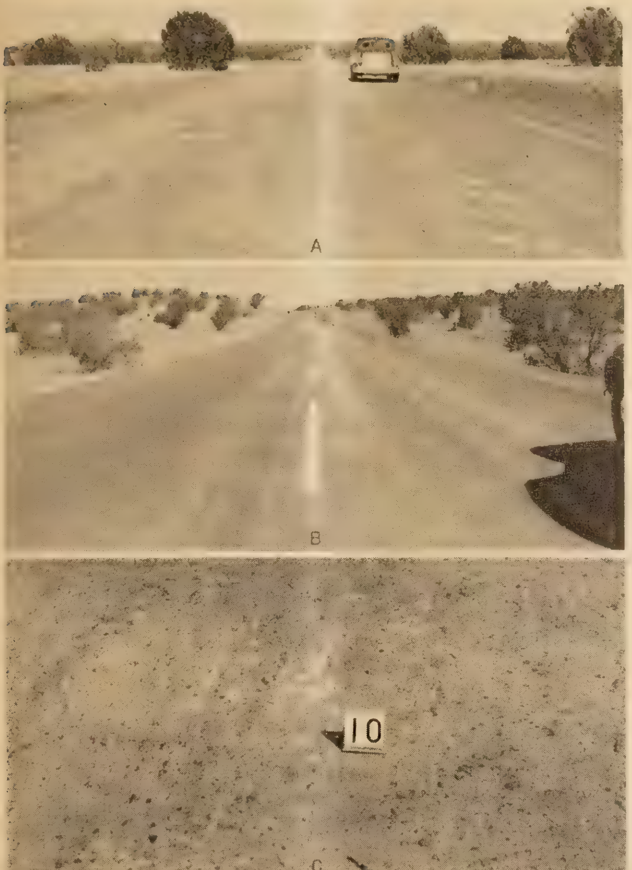

FIGURE 2.—VOLCANIC CINDER ROADS. A, UNTREATED CINDER ROAD TYPICAL OF ALL SUCH ROADS INSPECTED; B, BITUMINOUS TREATED CINDER ROAD IN GOOD CONDITION (FAP 95-J); C, TEXTURE OF ROAD SURFACE SHOWN IN B.

subgrade groups. The same type of subgrade was encountered under both the intact sections and the locations where failures occurred.

The base course was uniformly 5 inches thick except at the cracked and scaled location where base-course sample S-12653 was obtained. The 13 inches recorded at this point probably consisted of 5 inches of base course and 8 inches of subbase, but no difference in character of the material could be detected for the full depth. The subgrade at this location was the same as that where base-course sample S-12647 was taken and where the total thickness of base and subbase equalled 14 inches.

The good condition of all but a few short sections indicated that the base-course thickness of 5 inches was adequate for the traffic carried on these projects provided the base-course materials were satisfactory. Since the failed areas were interspersed between the intact sections, both the character and volume of traffic on the intact portions were the same as on the sections where cracking, scaling, and rutting occurred. The average daily traffic on the two projects as counted in 1937 and 1940 is given in table 4.

ROAD CONDITION RELATED TO GRADATION AND PHYSICAL PROPERTIES OF BASE COURSES

The results of the condition survey and laboratory tests summarized in table 1 indicate that the difference in road condition is directly related to the character of the base-course materials. The base-course samples

FIGURE 3.—SECTION THROUGH BITUMINOUS PENETRATION MAT AND BASE COURSE. BOTTOM OF EXCAVATION IS TOP OF SUBBASE.

taken from the locations where no failures occurred were nonplastic and had liquid limits not exceeding 30. In contrast, the samples from the failed sections had plasticity indexes of 7 and 14 and corresponding liquid limits of 33 and 37.

TABLE 1.—*Summary of results of condition survey and mechanical analysis and physical tests performed on base course samples*

F. A. project No.	105-C	105-C	105-C	105-C	105-C	95-J	95-J
Sample No.	S-12647	S-12650	S-12653	S-12654	S-12656	S-12657	S-12659
Surface condition	Intact	Intact	Cracked scaled	Badly cracked, rutted	Intact	Intact	Intact
Thickness:							
Base .... inches	5	5	13	5	5	5	5
Subbase .... do	9	14	[1] 0	[2] 15+	[3] 0	[2] 18+	11
Grading:							
Passing 1½-inch sieve ..... percent	100	100	100	100	100	100	100
Passing 1-inch sieve ..... percent	96	100	97	100	100	98	100
Passing ¾-inch sieve ..... percent	82	93	94	99	99	95	99
Passing ⅜-inch sieve ..... percent	70	84	86	90	91	91	95
Passing No. 4 sieve ..... percent	61	74	66	76	73	77	85
Passing No. 10 sieve ..... percent	53	62	57	58	53	61	74
Passing No. 40 sieve ..... percent	45	50	47	50	39	44	64
Passing No. 200 sieve ..... percent	18	19	29	32	21	21	18
Analysis of material passing No. 10 sieve:							
Sand, 2.0-0.25 millimeter ..... percent	16	20	18	13	26	28	14
Sand, 0.25-0.05 millimeter ..... percent	57	53	37	37	40	41	67
Silt .... do	21	17	32	35	28	23	9
Clay .... do	6	10	13	15	6	8	10
Colloids .... do	2	5	2	4	0	0	2
Dust ratio [4]	40	38	62	64	54	48	28
Tests on material passing No. 40 sieve:							
Liquid limit	30	30	33	37	29	24	20
Plasticity index	[5] NP	[5] NP	7	14	[5] NP	[5] NP	[5] NP
Shrinkage limit	24	25	20	16	25	20	....
Shrinkage ratio	1.6	1.6	1.7	1.8	1.6	1.7	....
Centrifuge moisture equivalent	23	22	28	28	19	19	10
Field moisture equivalent	31	31	31	28	31	26	25
Specific gravity	2.76	2.72	2.73	2.72	2.74	2.79	2.87
Subbase sample No. [6]	S-12648	S-12651	....	S-12655	....	S-12658	S-12660
Subgrade sample No. [7]	S-12649	S-12652	S-12649	....	....	....	S-12661

[1] Base and subbase of same material.
[2] Sampled on fill section. Entire fill composed of cinders. Figures indicate depth sampled.
[3] No subbase. Fill of coarse rock fragments and loamy soil similar to subgrade sample No. S-12652, table 3.
[4] Dust ratio $=100\left[\frac{\text{percentage passing No. 200 sieve}}{\text{percentage passing No. 40 sieve}}\right]$.
[5] NP is used to denote nonplastic materials which do not have a plastic limit, in contrast to those which have a plastic limit equal to the liquid limit and therefore a plasticity index of zero.
[6] Refers to samples in table 2.
[7] Refers to samples in table 3.

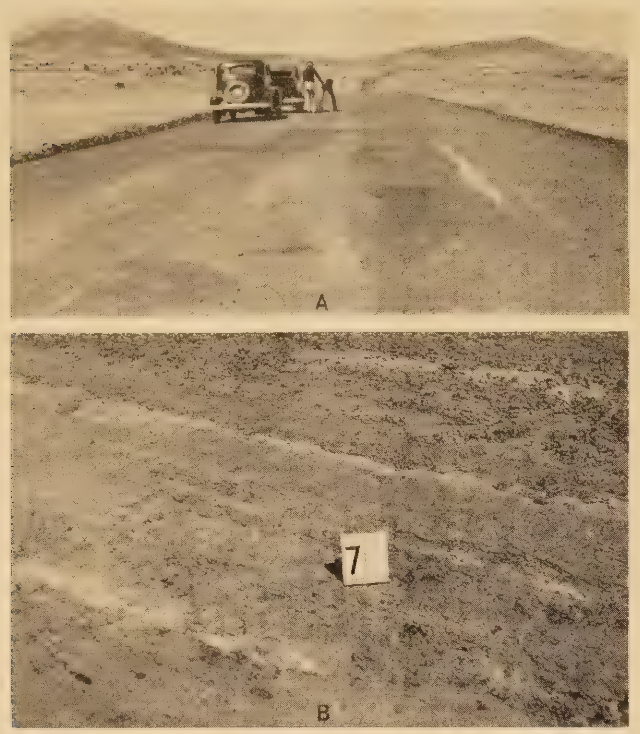

FIGURE 4.—A, FAILED SECTION OF FAP 105-C THAT WAS BADLY CRACKED AND RUTTED; B, CRACKED AND SCALED PORTION OF FAP 105-C.

TABLE 2.—*Results of mechanical analyses and physical tests performed on subbase samples*

F. A. project No.	105-C	105-C	105-C	95-J	95-J
Sample No.	S-12648	S-12651	S-12655	S-12658	S-12660
Grading:					
Passing 1½-inch sieve...percent	100	88	80	100	100
Passing 1-inch sieve...do	99	88	72	98	100
Passing ¾-inch sieve...do	95	86	68	97	99
Passing ⅜-inch sieve...do	86	84	58	94	94
Passing No. 4 sieve...do	70	74	47	82	89
Passing No. 10 sieve...do	56	61	38	63	83
Passing No. 40 sieve...do	40	43	31	49	71
Passing No. 200 sieve...do	14	16	8	21	14
Analysis of material passing No. 10 sieve:					
Sand, 2.0–0.25 millimeter...percent	29	29	19	23	14
Sand, 0.25–0.05 millimeter...do	53	49	64	49	71
Silt...do	13	15	13	24	10
Clay...do	5	7	4	4	5
Colloids...do	2	2	2	2	1
Dust ratio [1]	35	37	26	43	20
Tests on material passing No. 40 sieve:					
Liquid limit	22	24	21	27	18
Plasticity index	[2] NP	[2] NP	[2] NP	[2] NP	[2] NP
Shrinkage limit	-----	23	-----	24	-----
Shrinkage ratio	-----	1.6	-----	1.6	-----
Centrifuge moisture equivalent	10	16	7	19	9
Field moisture equivalent	31	31	34	33	28
Specific gravity	2.78	2.71	2.78	2.75	2.87

[1] Dust ratio $=100\left[\frac{\text{percentage passing No. 200 sieve}}{\text{percentage passing No. 40 sieve}}\right]$.

[2] NP is used to denote nonplastic materials which do not have a plastic limit, in contrast to those which have a plastic limit equal to the liquid limit and therefore a plasticity index of zero.

With respect to gradation the samples from the failed areas had 29 and 32 percent passing the No. 200 sieve as compared to a maximum of 21 for the samples from the locations where no failures occurred. No significant difference existed in the coarser fractions of the samples from the various locations.

In general, the survey showed that there were cinders from widely separated sources eminently suitable for road construction and indicated that it would be possible to select materials by means of the mechanical analysis and plasticity tests. However, since there are many other types of cinders available which had not been used in road construction, it was considered advisable to conduct a series of tests on such materials in the circular track with the particular purpose of determining whether they were satisfactory for use as base courses under a thin bituminous surface treatment. Accordingly, a sufficient quantity of cinders from each of five sources was procured. A quantity of material known locally as a "tufa" gravel with sand was also submitted and included in the tests.

TABLE 3.—*Results of mechanical analyses and physical tests performed on subgrade samples*

F. A. project No.	105-C	105-C	95-J
Sample No.	S-12649	S-12652	S-12661
Grading:			
Passing 1½-inch sieve...percent	84	81	56
Passing 1-inch sieve...do	81	79	50
Passing ¾-inch sieve...do	79	76	47
Passing ⅜-inch sieve...do	75	68	43
Passing No. 4 sieve...do	69	63	39
Passing No. 10 sieve...do	63	57	35
Passing No. 40 sieve...do	60	49	30
Passing No. 200 sieve...do	39	30	14
Analysis of material passing No. 10 sieve:			
Sand, 2.0–0.25 millimeter...do	4	14	15
Sand, 0.25–0.05 millimeter...do	44	41	53
Silt...do	33	25	24
Clay...do	19	20	8
Colloids...do	5	6	2
Dust ratio [1]	65	61	47
Tests on material passing No. 40 sieve:			
Liquid limit	44	42	35
Plasticity index	1	12	3
Shrinkage limit	21	22	26
Shrinkage ratio	1.7	1.6	1.6
Centrifuge moisture equivalent	30	30	24
Field moisture equivalent	33	36	34
Specific gravity	2.71	2.70	2.76

[1] Dust ratio $=100\left[\frac{\text{percentage passing No. 200 sieve}}{\text{percentage passing No. 40 sieve}}\right]$.

TABLE 4.—*Average daily traffic on Federal-aid projects 105-C and 95-J for the years 1937 and 1940*

Project No.	Average daily traffic			
	1937		1940	
	Total	Trucks and busses	Total	Trucks and busses
105-C	95	25	125	38
95-J	210	35	474	64

"Tufa" gravel is a porous concretionary formation of calcium carbonate deposited frequently around springs. The material submitted, however, was not calcareous and is in reality a pumiceous tuff, a product of volcanic action and very similar to the cinders. Since it is known locally as "tufa" gravel that designation has been retained throughout this report.

In each case, all material larger than 1 inch was removed, crushed to pass a 1-inch sieve and recombined with the fraction passing the 1-inch sieve. The identification and source of the six materials tested in the track are shown in table 5.

The circular track used in this investigation was the same as that used in the studies of water-retentive chemicals as admixtures with nonplastic road-building materials which have been reported previously.[1] The

[1] Studies of Water-Retentive Chemicals with Nonplastic Road-Building Materials, by E. A. Willis and C. A. Carpenter. PUBLIC ROADS, vol. 20, No. 9, November 1939.

TABLE 5.—*Identification and source of materials tested in circular track*

Circular track section No.	Description and source
1	"Tufa" gravel with sand. From pit 0.5 mile right of station 48, FAP 81-B.
2	Red cinders. From pit 1.0 mile right of station 235, F. H. 17-B2.
3	Black cinders. From pit 600 feet left of station 2695 south approach road to Grand Canyon National Park.
4	Red cinders. From pit 600 feet right of station 881, FAP 89-D.
5	Red cinders. From pit 1,500 feet right of station 1909, FAP 105-C. This project inspected and surveyed in 1939.
6	Red cinders. From pit 2,200 feet right of station 431, F. H. 30-B.

tire equipment was size 30×5 of the high-pressure type, requiring an inflation pressure of 80 pounds per square inch.

Distributed traffic, which was used for compacting the base course and the surface treatment, was obtained by gradually shifting the rotating beam longitudinally with respect to its axis of rotation. Concentrated traffic, which was used after the surface treatment had been constructed, was obtained by locking the sliding pivot of the beam in such a position that the wheels pursued two concentric courses whose centerlines were about 2½ inches on either side of the centerline of the test sections.

Each of the six sections tested in the track was 18 inches wide, 6 inches deep, and approximately 6.3 feet long. All the sections were laid over a crushed stone subbase through which water introduced from below could pass. The grading and soil constants of the 6 materials tested in the circular track are given in table 6.

TABLE 6.—*Grading and soil constants of materials tested in circular track*

	Track section No.—					
	1	2	3	4	5	6
Sieve analysis of total sample:						
Passing 1-inch sieve .... percent	100	100	100	100	100	100
Passing ¾-inch sieve .... do	100	99	100	100	99	98
Passing ⅜-inch sieve .... do	100	90	89	96	95	87
Passing No. 4 sieve .... do	98	85	68	83	81	78
Passing No. 10 sieve .... do	92	81	43	60	60	64
Passing No. 40 sieve .... do	67	59	17	33	34	39
Passing No. 200 sieve .... do	40	24	9	19	19	12
Dust ratio [1]	60	41	53	58	56	31
Analysis of material passing No. 10 sieve:						
Sand, 2.0–0.25 millimeter .... percent	34	31	67	53	49	53
Sand, 0.25–0.05 millimeter .... do	30	40	17	20	26	33
Silt .... do	28	18	12	17	18	10
Clay .... do	8	11	4	10	7	4
Colloids .... do	1	2	1	3	2	1
Physical constants of material passing No. 40 sieve:						
Liquid limit	26	35	17	23	18	22
Plasticity index	[2] NP	[2] NP	[2] NP	[2] NP	[2] NP	[2] NP
Shrinkage limit	23	------	------	------	------	------
Shrinkage ratio	1.6	------	------	------	------	------
Centrifuge moisture equivalent	14	18	13	17	14	6
Field moisture equivalent	28	40	18	27	24	29
Specific gravity	2.64	2.58	2.98	2.96	2.78	2.80

[1] $\text{Dust ratio} = 100\left[\frac{\text{Percentage passing No. 200 sieve}}{\text{Percentage passing No. 40 sieve}}\right]$.

[2] NP = Nonplastic.

In constructing the test sections sufficient water was mixed with the dry material so that, when squeezed in the hand, a firm ball would be formed. Mixing was continued to distribute the moisture thoroughly. The dampened materials were then placed in the track in two approximately equal layers. The bottom layer was first tamped into place with hand tamps and then compacted with 1,000 wheel-trips of distributed traffic. The top layer was then placed and hand tamped, and compaction with distributed traffic was continued until a total of 20,000 wheel-trips was completed.

The compacted base was made ready for a surface treatment by trimming the sections smooth and priming with 0.3 gallon of light tar. After curing, the surface treatment was constructed. It consisted of 0.4 gallon of hot bituminous material and a cover of 50 pounds per square yard of ¾-inch maximum size stone. This surface treatment was consolidated by 20,000 wheel-trips of distributed traffic. At the end of this period the surface was well sealed and showed no movement.

DIFFICULTY EXPERIENCED IN COMPACTING SECTION 3

The behavior of the materials was judged on the basis of the appearance of the sections at various stages of the test, supplemented by measurements of vertical displacement of the surface. Previous reports have described the transverse[2] and longitudinal[3] profilometers with which the measurements were made.

The area between the initial and each succeeding transverse profile was measured by a planimeter. The measured area divided by the track width, 18 inches, gave the vertical displacement, and the average for the two stations on the section gave the average vertical displacement for that section.

The area between the initial and each succeeding longitudinal profile made in that wheel lane was measured for each section and the area of vertical displacement determined. That area divided by the length of the wheel lane gave the depth of rutting and the average for the two wheel lanes gave the average depth of rutting for the section.

Figure 5 shows changes in behavior of the various sections under altered test conditions. The abrupt changes in the slopes of the displacement curves coincide with the increased severity of test conditions brought about by changing from distributed to concentrated traffic or by raising the ground-water level.

The schedule of traffic applications with notations on the behavior of the six test sections is given in table 7. Initial profile measurements were made at 40,000 wheel-trips. From 40,000 to 60,000 wheel-trips, the sections were subjected to distributed traffic, and the ordinates at 60,000 wheel-trips (fig. 5) represent displacements at the end of such traffic. At 60,000 wheel-trips, concentrated traffic was begun and continued to the end of the test.

Section 1 was quite spongy during the early stages of compaction and material in the section tended to shove up onto the curbs. Light scarifying and raking was necessary to keep the section smooth. After 18,000 wheel-trips, the material in section 1 began to knit together and by 20,000 wheel-trips it was firm and stable.

Much difficulty was experienced in compacting section 3. The cinders placed in this section were moistened and subjected to the same treatment accorded all the other sections. It did not set up readily, however, and additional water was sprinkled on the surface in an effort to aid compaction. This was ineffectual. The upper portion of the section was so loose that traffic had to be applied at slow speed in order to prevent the material from being thrown out of the trough. Under

[2] Circular Track Tests on Low-Cost Bituminous Mixtures, by C. A. Carpenter and J. F. Goode, PUBLIC ROADS, vol. 17, No. 4, June 1936.

[3] A Study of Sand-Clay-Gravel Materials for Base-Course Construction, by C. A. Carpenter and E. A. Willis, PUBLIC ROADS, vol. 20, No. 1, March 1939.

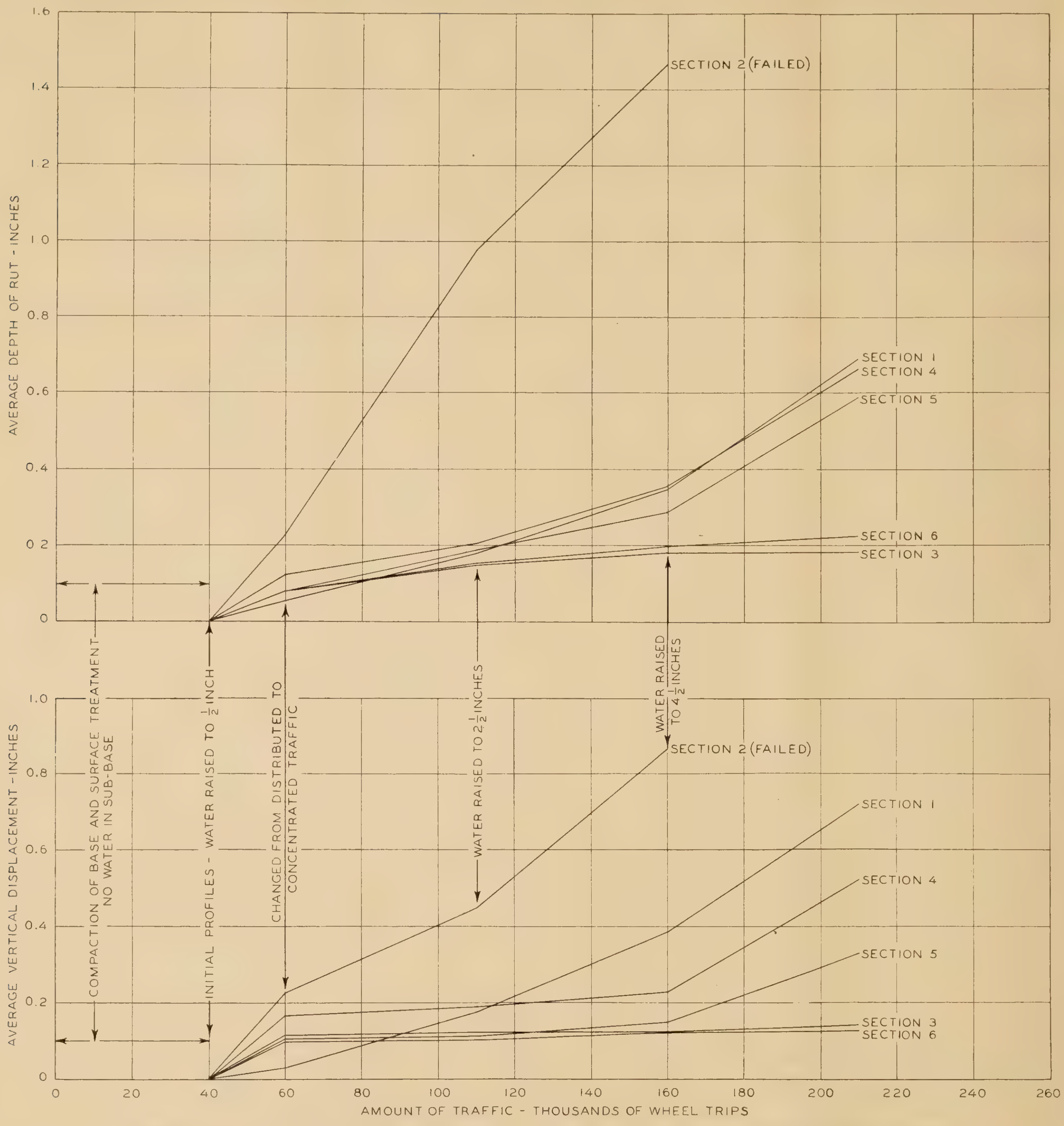

FIGURE 5.—RATE OF SURFACE DISPLACEMENT OF CIRCULAR TRACK TEST SECTIONS UNDER TRAFFIC.

continued traffic and as the cinders in section 3 dried out, the material gradually consolidated.

At 6,800 wheel-trips, it was possible to increase the speed of traffic to that normally used in testing. At this time the material had dried out a great deal, and compaction seemed to take place more rapidly. At 12,700 wheel-trips, section 3 was in good condition and only a very light sprinkling was necessary from time to time during the remainder of the compaction period to keep the surface from dusting and loosening. Light sprinkling was necessary also on sections 1 and 5 to prevent the surface from becoming loose.

All other sections compacted readily under distributed traffic with no water in the subbase.

The density of each track section was measured at 20,000 wheel-trips or just before the application of the surface treatment. The results of these and later determinations are shown in table 8.

Water was admitted and the level raised to ½ inch above the top of the subbase at 40,000 wheel-trips. The following 20,000 wheel-trips of distributed traffic under this condition did not develop any failures and all sections were firm and stable. Profiles taken at the end of this period showed that all sections had under-

TABLE 7.—*Schedule of operations and behavior of test sections*

Operation	Traffic	Water level above top of subbase	Behavior					
			Section No. 1	Section No. 2	Section No. 3	Section No. 4	Section No. 5	Section No. 6
	Wheel-trips	*Inches*						
Placing and compacting base	0-20,000	[1] 0	Good	Good	Good	Good	Good	Good.
Compacting treated surface	20,000-40,000	[1] 0	do	do	do	do	do	Do.
Testing with distributed traffic	40,000-60,000	½	do	do	do	do	do	Do.
Testing with concentrated traffic	60,000-110,000	½	Slightly unstable	Unstable	do	do	do	Do.
Do	110,000-160,000	2½	Became more unstable.	Failed	do	Slightly unstable	do	Do.
Do	160,000-210,000	4½	Unstable		do	Unstable	Slightly unstable	Do.

[1] No water in subbase.

gone further compaction. Sections 2 and 4 experienced the most compaction during this interval (see fig. 5).

TABLE 8.—*Comparison of moisture contents and densities obtained by laboratory compaction and in the track sections*

Method of compaction	Section No.	Moisture content based on weight of dry soil	Density	
			Dry weight per cubic foot	Solids by volume
		Percent	*Lb. per cu. ft.*	*Percent*
Track sections at end of initial compaction period (40,000 wheel-trips).	1	13.2	103.8	63.0
	2	14.4	61.5	38.2
	3	4.4	124.1	66.7
	4	11.5	85.0	46.1
	5	6.5	93.9	54.1
	6	6.6	97.9	56.1
Track sections at time of failure (sec. 2, 160,000 wheel-trips) or at end of test (210,000 wheel-trips).	1	16.8	108.0	65.6
	2	31.7	64.4	39.1
	3	9.8	122.2	65.6
	4	24.7	114.6	62.1
	5	18.1	92.3	53.2
	6	14.9	94.1	53.9
Standard compaction test on fraction passing No. 4 sieve.[1]	1	16.5	102.5	62.2
	2	25.2	85.5	58.1
	3	16.5	110.2	59.4
	4	21.0	100.0	54.2
	5	21.0	101.8	58.8
	6	20.4	99.8	57.1

[1] Results shown are the optimum moisture content and maximum density determined by the standard compaction test.

Testing with concentrated traffic was begun at 60,000 wheel-trips with the ground-water elevation remaining at ½ inch. At 83,680 wheel-trips movement was noticed in sections 1 and 2. The remaining sections at this time were in excellent condition. At 110,000 wheel-trips, the conclusion of testing with ground water ½ inch above the top of the subbase, the surfacing in section 2 had been ruptured in two places. At this time the surface of section 1 was in distress and rutting of the surface had begun. Profiles taken at 110,000 wheel-trips showed that sections 2, 4, and 1 had undergone the most displacement, in the order named. The rest of the sections exhibited negligible amounts of displacement between 60,000 and 110,000 wheel-trips as shown in figure 5.

Water was raised to 2½ inches above the top of the subbase at 110,000 wheel-trips and testing with concentrated traffic was resumed. At 120,000 wheel-trips, movement under the wheel loads was noticed in section 4. Increased rutting took place in sections 1 and 2. At the completion of 50,000 wheel-trips of concentrated traffic at this ground-water elevation (making a total of 160,000 wheel-trips) section 2 had failed. Profiles taken at this time showed that sections 1 and 4 had undergone much displacement during this period of the test. Figure 6 shows the condition of the sections at the conclusion of 160,000 wheel-trips.

SECTIONS 3 AND 6 REMAINED IN GOOD CONDITION THROUGHOUT SEVERE TEST

Water was temporarily drained from the subbase at this time while samples were being taken from section 2 for final density determinations. The results obtained are shown in table 8. In order to continue the testing of the five remaining sections, a bituminous cold patch material was used to level the surface of section 2. No profile measurements were made on this section after 160,000 wheel-trips.

Testing was continued with the ground-water elevation raised to 4½ inches above the top of the subbase. The severity of these test conditions soon caused sections 1 and 4 to become very rough and unstable. At 174,160 wheel-trips, section 4 had developed deep ruts and the surfacing had broken in one wheel rut, exposing the brownish-red volcanic cinder base. Figure 7–C shows the condition of this section at 210,000 wheel-trips, the end of the test.

At 174,160 wheel-trips, section 1 had practically reached a point of failure, and the tufa gravel material was exposed between the wheel ruts. At the end of 210,000 wheel-trips, section 1 had definitely failed. Figure 7–A shows the appearance of this section at the end of the test.

Section 5, which had remained in good condition previously, began to show some movement in the base. By the end of the test considerable displacement had occurred as shown in figure 7–D. The displacement curves, figure 5, show clearly that there was a marked increase in the rate of surface displacement in section 5 after the ground-water elevation had been raised to 4½ inches above the top of the subbase. Comparison of figures 6–E and 7–D show the difference in behavior of this section under altered test conditions.

Sections 3 and 6 remained in excellent condition throughout the track tests. Very little surface displacement took place after 60,000 wheel-trips (see fig. 5). Figures 7–B and 7–E show the appearance of sections 3 and 6, respectively, at the end of the tests. Comparison with figures 6–C and 6–F shows changes in appearance since that at 160,000 wheel-trips. The smooth appearance of the wheel ruts is caused by material carried from sections 1 and 2 where the surfacing had failed.

The density of each track section was measured at the time of failure or at the end of the testing period. The results of these determinations as well as those obtained after compaction are shown in table 8 together with the densities obtained in the standard compaction test on the fraction of the material passing the No. 4 sieve.

No consistent relationship was found between the densities measured by the laboratory compaction test and those obtained in the track either after the initial

Figure 6.—Appearance of Circular Track Test Sections After 160,000 Wheel-Trips of Traffic. A, Surfacing of Section 1 Failed Between Wheel Ruts Because of Movement in Base; B, Base-Course Material of Section 2 Shoved up Through Surface Treatment Between Wheel Ruts; C, Little Displacement Occurred on Section 3, Surface Treatment in Excellent Condition; D, Some Movement Took Place in Section 4; E, Little Displacement Occurred on Section 5, Surface Treatment in Excellent Condition; F, Base and Surface of Section 6 in Excellent Condition.

compaction period or at the end of the test. Although profiles taken at the end of 20,000 wheel-trips of distributed traffic (interval from 40,000 to 60,000 wheel-

Figure 7.—Appearance of Circular Track Test Sections After 210,000 Wheel-Trips (End of Test). A, Section 1 Had Failed; Section 2 (Not Shown) Had Previously Failed; B, Section 3 Remained in Good Condition (Compare With Fig. 6–C); C, Section 4 Rutted and Surface Broke, Exposing Base; D, Considerable Displacement Occurred on Section 5 (Compare With Fig. 6–E); E, Section 6 Remained in Good Condition (Compare With Fig. 6–F).

trips) showed that appreciable compaction had taken place in all sections, the determinations made at the end of the test showed that sections 3, 5, and 6, which exhibited the least movement under traffic, were slightly less dense than at the end of the initial compaction period. It is probable that a major part of the measured displacement occurring under distributed test traffic was due to further consolidation of the surface treatment. Increases in density were noted in sections 1, 2, and 4 which failed or were unstable at the end of the test.

This investigation makes possible a direct correlation between the circular track tests and service performance since the material tested in section 5 of the track came from the same source as the cinders used in constructing FAP 105–C, a project which was included in the field condition survey.

The mechanical analyses and physical constants of the five samples taken from FAP 105–C together with the respective surface condition ratings appear in table 1. The grading and constants of the material tested in section 5 are given in table 6. The behavior of this section under test is summarized in table 7.

The laboratory tests on samples from FAP 105–C showed that the base courses in areas where no failure occurred were nonplastic, that they had liquid limits of 30 or less, and that the amount of material passing the No. 200 sieve did not exceed 21 percent. Where failures occurred, liquid limits of 33 and 37, plasticity indexes of 7 and 14, and percentages passing the No. 200 sieve of 29 and 32, were determined by tests on base-course samples.

The cinders tested in section 5 of the circular track were nonplastic. The liquid limit was 18 and the amount passing the No. 200 sieve was 19 percent. It can be inferred, therefore, that the section 5 material would have proved entirely satisfactory for use as a base course under field service conditions.

SECTION 2 ONLY MATERIAL REVEALED UNSATISFACTORY BY TRACK TEST

In reports of previous circular track investigations, it has been stated that an average vertical displacement of 0.25 inch was sufficient to cause marked damage to the bituminous wearing course. Furthermore, it was found that, with the ground water elevation ½ inch above the top of the subbase, concentrated traffic provided a condition sufficiently severe to enable the identification of the definitely unsatisfactory materials. In the present investigation and under these test conditions, section 5 gave excellent performance. Satisfactory behavior with average vertical displacements below 0.20 inch was also observed while testing with water at the 2½-inch elevation. (See table 7 and figs. 5 and 6–E).

It was not until the ground water had been raised to 4½ inches above the top of the subbase or within about 1½ inches of the surface that section 5 showed excessive movement. Since section 5 was constructed of material having known satisfactory characteristics, it is evident that the test conditions imposed near the end of the investigation were more severe than are normally encountered in service. Using a criterion that definitely unsatisfactory materials will not withstand concentrated traffic with water ½ inch above the top of the subbase without excessive vertical displacements and that wholly satisfactory materials will withstand concentrated traffic with water 2½ inches above the top of the subbase without excessive movement, the five cinders and the tufa gravel tested in the circular track are rated as shown in table 9.

Section 1 was slightly unstable with water at the ½-inch level and is rated as poor. Section 2 was definitely unstable under this condition and failed completely with water at the 2½-inch level. It is, therefore, considered unsatisfactory. Sections 3, 5, and 6 did not exhibit excessive movement with water at the 2½-inch level and are rated as satisfactory. Section 4 gave good service with water at the ½-inch level but became slightly unstable when the water was raised an additional 2 inches. It is rated as fair although it is believed that under reasonably good drainage conditions in the field it would give satisfactory service.

TABLE 9.—*Rating of sections after testing under concentrated traffic with water elevation 2½ inches above the top of the subbase*

Section No.	Composition	Service rating
1	Tufa gravel with sand	Poor.
2	Red cinders	Unsatisfactory.
3	Black cinders	Satisfactory.
4	Red cinders	Fair.
5	do	Satisfactory.
6	do	Do.

Figure 8 shows the grading curves for samples Nos. S–12653 and S–12654 (table 1), which were the two samples taken from points where failures had occurred on FAP 105–C, and for the materials from sections 1 and 2 which showed excessive movement in the circular track tests with water 2½ inches above the top of the subbase. The shaded band in the figure was drawn to include the grading curves of all materials investigated which had shown satisfactory performance as base courses in roads or in the circular track.

The grading curve for the tufa gravel tested in section 1 falls almost entirely outside the shaded band, being finer than any of the other materials investigated. The other three materials that gave unsatisfactory service have grading curves which fall outside the shaded band in the vicinity of the No. 200 sieve size.

Section 4 was unstable and section 5 was slightly unstable at the end of the test under the extremely severe conditions which were imposed. The materials tested in these two sections have gradings which fall entirely within the band of satisfactory materials. Likewise, the materials tested in sections 3 and 6, which gave excellent service throughout all phases of the testing, have grading curves falling within the band. An examination of the analyses of material passing the No. 10 sieve given in table 6 shows that for the section 3 and 6 materials only 4 percent of the soil mortar was clay while the clay content of section 5 was 7 percent and that of section 4 was 10 percent. Similarly, the silt plus clay contents of sections 3 and 6 were respectively 16 and 14 percent, that of section 5 was 25 percent, and that of section 4 was 27 percent. It is possible that the larger amount of very fine material present in the soil mortar fraction was responsible for the adverse behavior of sections 4 and 5 under the extremely severe testing conditions.

Samples Nos. S–12653 and S–12654 taken from failed locations on FAP 105–C had plasticity indexes of 7 and 14 respectively. All other base-course materials included in this investigation were nonplastic. This investigation did not furnish sufficient information to determine the maximum allowable plasticity index for base-course materials.

CONFORMITY OF MATERIALS WITH SPECIFICATION FOR STABILIZED BASE-COURSE MATERIALS STUDIED

A. A. S. H. O. specification M 56–38 gives requirements for materials for stabilized base course. Volcanic cinders are not included within the three types of materials covered by the specification. However, they most closely resemble the type C materials (gravel, stone or slag screenings, or sand) and a comparison of the results of tests on the cinders with the type C specification requirements is, therefore, of interest.

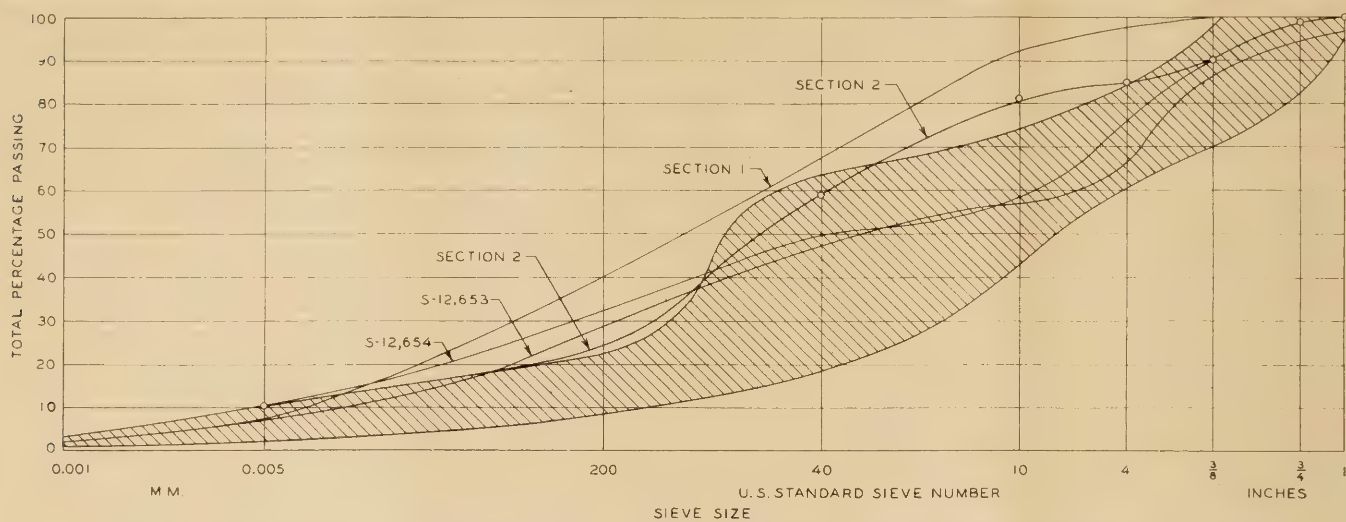

Figure 8.—Grading Band of Satisfactory Cinders and Grading Curves of Unsatisfactory Cinders.

The requirements for type C materials contained in the specification are as follows:

Passing—	*Percentage by weight*
¾-inch sieve	100
No. 4 sieve	70–100
No. 10 sieve	35–80
No. 40 sieve	25–50
No. 200 sieve	8–25

The fraction passing the No. 200 sieve shall be less than one-half of the fraction passing the No. 40 sieve. The fraction passing the No. 40 sieve shall have a liquid limit not greater than 25 and a plasticity index not greater than 3.

All of the samples from locations designated as intact in table 1 were somewhat coarser than required by the specification since in each case there was less than 100 percent passing the ¾-inch sieve. Sample No. S–12647 had only 61 percent passing the No. 4 sieve as compared to the minimum of 70 percent contained in the specification for this size. In all other respects, the samples from intact locations conformed to the grading requirements of the A. A. S. H. O. Samples No. S–12647, S–12650, and S–12656 had liquid limits greater than 25 but not greater than 30.

Samples Nos. S–12657 and S–12659 had liquid limits less than 25 as required by the specification. All five of the samples under discussion were nonplastic.

In four cases the percentage passing the No. 200 sieve was less than one-half of the percentage passing the No. 40 sieve while in the case of sample No. S–12656 this ratio was 0.54.

The samples from areas where distress was noted (table 2) also had maximum-size particles larger than is covered by the specification. These two samples, S–12653 and S–12654, failed to meet the grading requirements of the specification in another respect since the percentages passing the No. 200 sieve were 29 percent and 32 percent respectively as compared to a maximum permissible percentage of 25. The liquid limits, the plasticity indexes, and the ratios of the percentage passing the No. 200 sieve to the percentage passing the No. 40 sieve are all too high for these two samples to conform to the specification.

In the circular track tests, section 1 was rated as poor (see table 9). The material used in the construction of this section failed to meet the A. A. S. H. O. type C requirements because it had too large percentages of material passing the Nos. 10, 40, and 200 sieves, and because it had a liquid limit greater than 25 and a dust ratio greater than 0.50. Section 2 material was rated as unsatisfactory. It failed to meet the specifications because the percentages passing the No. 10 and No. 40 sieves were too large and the liquid limit was 35. Section 4 material was rated as fair and met the requirements in all respects except that the dust ratio was greater than one-half.

Sections 3, 5, and 6 were rated as satisfactory in the circular track tests. Section 3 failed to meet the specification requirements in that it had too small an amount of material passing the No. 4 and No. 40 sieves and had a dust ratio of 0.53. The cinders used in sections 5 and 6 had a small amount of material retained on the ¾-inch sieve but otherwise met the specification except that the section 5 material had a dust ratio slightly greater than one-half.

CONCLUSIONS

Based on the results of the field condition survey and the circular track tests, the following conclusions appear to be justified:

1. There is adequate evidence to show that volcanic cinders having the proper characteristics can be used successfully as base-course material for thin bituminous surface treatments.

2. The investigations reported indicate strongly that volcanic cinders will prove satisfactory for use as base courses for thin bituminous surface treatments if they meet the A. A. S. H. O. specification M 56–38 for type C stabilized base-course materials with the following modifications:

a. The maximum size may be increased from ¾ inch to 1½ inches.

b. The amount of material passing the No. 200 sieve should not exceed 20 percent.

c. If the fraction passing the No. 40 sieve is nonplastic, the maximum permissible liquid limit may be increased from 25 to 30.

d. The percentage passing the No. 200 sieve may be less than 0.6 of the fraction passing the No. 40 sieve.

3. The base thickness of 5 inches appears to be adequate for the conditions existing on the two projects studied in the field. It should be noted that in most instances where examinations were made, a cinder subbase having a minimum thickness of 8 inches was encountered.

4. Failure occurred in a plastic base course on project 105–C even though this base course rested on a nonplastic cinder subbase.

5. Even though the most satisfactory cinders are nonplastic, adequate compaction and density of base course can be obtained by the judicious use of water during rolling.

6. There was no evidence on the projects studied in the field or in the circular track to indicate that, as a result of manipulation with water, the cinders undergo sufficient change in gradation or physical characteristics to influence their performance as base courses.

7. The one tufa gravel investigated in the circular track did not give satisfactory service as a base course, and this could be explained on the basis of an excess of fine-size material. Tufa gravel with a coarser gradation would probably serve satisfactorily as a base material.

8. This investigation provided a direct correlation between circular track tests and field service behavior. It established the fact that suitable base-course materials will withstand concentrated traffic in the circular track with water 2½ inches above the top of the subbase but that water 4½ inches above the top of the subbase provides a condition more severe than can reasonably be expected under normal service conditions.

(Continued from page 124)

pavement elevation as practicable, preferably within 6 inches. Small pieces of reflectorized material fastened to miscellaneous posts and trees along the roadway are not satisfactory where it is necessary to delineate the alinement of a highway.

TABLE 12.—*Effectiveness of road edge delineators*

Reflecting material	Spacing	Sky condition	Number of observations	Distribution of visibility and effectiveness ratings: Good	Fair	Poor	Rating factor [1]
	Feet			*Percent*	*Percent*	*Percent*	
R. C. type A.[2]	(3)	Dark	52	53	40	7	73
		Moon	24	20	60	20	50
		Total	76	45	45	10	68
Plastic buttons [4]	20	Dark	15	100	0	0	100
		Moon	6	100	0	0	100
		Total	21	100	0	0	100
Do.[4]	40	Dark	37	87	13	0	94
		Moon	18	67	33	0	84
		Total	55	81	19	0	91
Do.[4]	80	Dark	7	71	29	0	86
		Moon	6	75	25	0	88
		Total	13	73	27	0	87
Do.[4]	160	Dark	16	75	25	0	88

[1] Obtained by adding all of the percentage rated "good" to one-half the percentage rated "fair."
[2] Constructed of 1 inch x 3 inch board wrapped with material having a reflective coating for 42 inches and placed 5 feet from pavement edge.
[3] Individual markers.
[4] Delineators constructed of 1 inch x 3 inch black board with three units of reflecting buttons (each unit containing 3 buttons) mounted 1 foot, 2 feet, and 3 feet above and 5 feet outside the pavement edge

Table 13 shows the rating factors for a number of devices used to mark guardrails and culvert headwalls along the test route. All of the markings were about equally effective, except for the guardrail that was painted white and reflectorized with glass beads which was particularly outstanding (fig. 14–B). For traffic to move with any degree of safety during blackouts, all bridge piers, abutments, and other objects within the roadway or so near as to constitute traffic hazards should be marked either with a cluster of reflecting buttons or a reflectorized sign within 18 inches of the elevation of the roadway surface, or reflectorized with beaded paint or reflectorized materials from a point as close to the pavement surface as practicable to a height of 36 inches, or lanterns suitable for blackout purposes should be used.

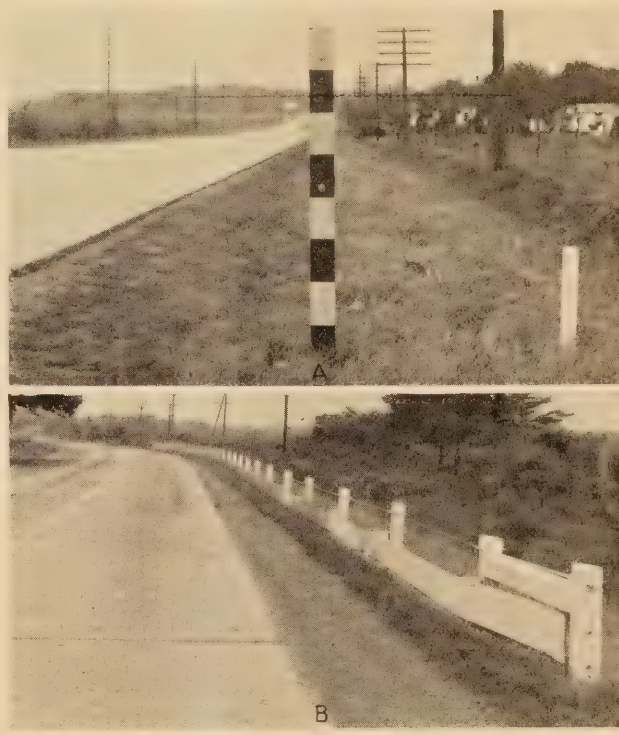

FIGURE 14.—A, 3-INCH BOARD COVERED WITH REFLECTORIZED MATERIAL SUITABLE FOR USE AS A MARKER OR DELINEATOR; B, END PANELS OF GUARDRAIL REFLECTORIZED WITH BEADED WHITE PAINT.

CONCLUSIONS

The main conclusions regarding highway signs and markings for blackout conditions based on the results of this study conducted under actual road and operating conditions may be summarized as follows:

1. Both urban and rural highways can be marked so that vehicles equipped with the approved blackout lighting system may be operated with comparative safety at speeds up to at least 20 miles per hour.

2. The need for highway signs, especially of the informational type, is greatly reduced while the need for pavement and object markings is increased.

3. Signs used during normal illumination are of little value. To be effective they must be either illuminated or reflectorized and mounted close to the roadway at

Table 13.—*Visibility or effectiveness of various devices to mark location of guardrails or culverts*

Type of device	Sky condition	Number of observations	Distribution of effectiveness and visibility ratings: Good	Fair	Poor	Rating factor [1]
			Percent	*Percent*	*Percent*	
Guardrail painted white	Dark	15	27	46	27	50
	Moon	6	25	50	25	50
	Total	21	26	47	27	50
Reflecting buttons on end post of guardrail.	Dark	45	13	60	27	43
	Moon	18	20	40	40	40
	Total	63	15	55	30	43
Reflecting buttons along steel ribbon of guardrail (1 for each 8-foot section).	Dark	30	46	31	23	62
	Moon	12	40	20	40	50
	Total	42	44	28	28	58
Reflecting buttons on steel ribbon and near top of every fourth post.	Dark	15	40	30	30	55
	Moon	6	25	50	25	50
	Total	21	36	36	28	54
White beaded paint on 3 end panels of guardrail.	Dark	15	70	20	10	80
	Moon	6	100	0	0	100
	Total	21	82	12	6	88
Reflecting material (8 inches x 12 inches) on end post.	Dark	30	21	50	29	46
	Moon	12	60	20	20	70
	Total	42	32	42	26	53
Culvert marker with black and white stripes and 3 reflecting buttons at different heights.	Dark	30	23	77	0	62
	Moon	12	25	50	25	50
	Total	42	24	70	6	59

[1] Obtained by adding all of the percentage rated "good" to one-half the percentage rated "fair."

the proper angle, with the top of their 6-inch legends within 18 inches of the elevation of the road surface.

4. Interior-illuminated signs are the most effective type and must be used whenever a legibility distance in excess of 75 feet is required.

5. Exterior-illuminated signs are most desirable where the same sign must be effective for both normal and blackout conditions. They are satisfactory on 2- and 4-lane highways where a target value in excess of 75 feet is desired and where there is no need of an average legibility distance in excess of 50 feet.

6. Reflectorized signs can be made that will be legible to drivers on both 2- and 4-lane highways, when properly placed, for a distance of at least 50 feet, which is adequate for most locations where a sign is necessary.

7. Reflectorized symbols are effective when properly placed; they are relatively inexpensive and should be used in advance of curves or intersections requiring a reduction in speed below 20 miles per hour.

8. Pavement and object markings to be effective must be reflectorized.

9. Visible centerlines are the most effective and necessary marking. They should be continuous on curves. Dashed centerlines are adequate on tangent sections of highways, providing the dashes are at least 10 feet long and the spaces do not exceed 20 feet.

10. Curbs and objects within the direct line of traffic must be marked.

11. Effort at the present time with respect to highway marking should be directed primarily toward installing markings that are most effective and necessary for both normal and blackout conditions.

INDEX TO PUBLIC ROADS, VOLUME 22, NOW AVAILABLE

The index to PUBLIC ROADS, volume 22, is now available. A chronological list of articles and a list of authors are included with the index. The index will be sent free to subscribers to PUBLIC ROADS requesting it. Requests should be addressed to the Public Roads Administration, Federal Works Agency, Washington, D. C.

Indexes to volumes 6 to 8 and 10 to 21, inclusive, are also available and will be sent to PUBLIC ROADS subscribers upon request. Indexes to volumes 1 to 5, inclusive, have never been prepared. The supply of the index to volume 9 is exhausted.

DISPOSITION OF STATE MOTOR-FUEL TAX RECEIPTS - 1941

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES

STATE	NET TOTAL RECEIPTS OF CALENDAR YEAR	ADJUSTMENTS DUE TO UNDISTRIBUTED FUNDS, ETC. 1/	NET TOTAL FUNDS DISTRIBUTED 2/	EXPENSES OF COLLECTION AND ADMINISTRATION	FOR OTHER ADMINISTRATIVE PURPOSES 3/	FOR STATE HIGHWAY PURPOSES: CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION: ON STATE HIGHWAYS 4/	CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION: ON STATE PARK AND FOREST ROADS, ETC. 5/	STATE HIGHWAY POLICE	SERVICE OF STATE HIGHWAY OBLIGATIONS: STATE HIGHWAY BONDS AND NOTES	SERVICE OF STATE HIGHWAY OBLIGATIONS: REIMBURSEMENT OBLIGATIONS 6/	SERVICE OF STATE HIGHWAY OBLIGATIONS: TOTAL	TOTAL FOR STATE HIGHWAY PURPOSES 5/	FOR LOCAL ROADS AND STREETS: FOR WORK ON COUNTY AND LOCAL ROADS 4/ 7/	FOR WORK ON CITY STREETS 8/	SERVICE OF LOCAL HIGHWAY OBLIGATIONS	TOTAL	FOR NONHIGHWAY PURPOSES: TO GENERAL FUNDS 9/: INSPECTION FEES, DEALERS LICENSES, ETC.	TO GENERAL FUNDS 9/: MOTOR-FUEL TAX	FOR RELIEF OF UNEMPLOYMENT OR DESTITUTION	FOR EDUCATION	FOR OTHER PURPOSES 10/	TOTAL	STATE
	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	
ALABAMA	18,401	-119	18,282	24	78	6,562	39	-	1,949	-	1,949	8,550	9,505	125	-	9,630	-	-	-	-	-	-	ALABAMA
ARIZONA	5,362	-	5,362	69	-	3,541	-	134	-	-	-	3,675	*1,618	-	-	1,618	-	-	-	-	-	-	ARIZONA
ARKANSAS	13,219	-	13,219	341	3	3,824	-	28	7,043	-	7,043	10,895	1,416	97	373	1,886	94	-	-	-	-	94	ARKANSAS
CALIFORNIA	58,094	-1,771	56,323	203	-	33,020	-	-	-	-	-	33,020	*15,927	4,430	-	20,357	-	-	2,743	-	-	2,743	CALIFORNIA
COLORADO	8,833	-263	8,570	86	28	4,342	-	268	1,563	-	1,563	6,173	2,283	-	-	2,283	-	-	-	-	-	-	COLORADO
CONNECTICUT	11,804	-105	11,699	43	-	10,247	-	-	-	1,409	1,409	11,656	-	-	-	-	-	-	-	-	-	-	CONNECTICUT
DELAWARE	2,504	-	2,504	8	-	4/ 868	-	201	91	299	390	1,459	(4/)	-	-	-	-	1,037	-	-	-	1,037	DELAWARE
FLORIDA	30,397	-7	30,390	34	139	17,414	-	1	-	8,132	8,132	25,547	-	-	-	-	385	2,132	-	2,130	23	4,670	FLORIDA
GEORGIA	26,086	-2,396	23,690	782	-	11,575	-	-	77	-	77	11,652	4,971	-	-	4,971	33	1,932	-	4,320	-	6,285	GEORGIA
IDAHO	5,218	45	5,263	18	1	3,712	-	12	112	-	112	3,836	*1,407	1	-	1,408	-	-	-	-	-	-	IDAHO
ILLINOIS	45,261	-31	45,230	197	304	14,425	-	-	-	-	-	14,425	11,200	13,474	905	25,579	194	-	4,531	-	-	4,725	ILLINOIS
INDIANA	29,244	-	29,244	80	110	14,838	-	760	-	-	-	15,598	9,754	2,230	-	11,984	590	882	-	-	-	1,472	INDIANA
IOWA	15,400	-151	15,249	151	-	3,198	-	10	-	3,268	3,268	6,476	*8,616	6	-	8,622	-	-	-	-	-	-	IOWA
KANSAS	11,389	-	11,389	363	118	7,386	-	136	230	686	916	8,438	2,470	-	-	2,470	-	-	-	-	-	-	KANSAS
KENTUCKY	16,180	509	16,689	46	-	14,703	-	253	-	-	-	14,956	1,687	-	-	1,687	-	-	-	-	-	-	KENTUCKY
LOUISIANA	21,562	83	21,645	74	107	6,446	-	-	7,706	-	7,706	14,152	-	-	-	-	-	3,107	1,169	1,518	1,518	7,312	LOUISIANA
MAINE	6,654	-	6,654	17	-	4,157	-	198	1,753	-	1,753	6,108	529	-	-	529	-	-	-	-	-	-	MAINE
MARYLAND	13,070	-	13,070	32	-	7,090	-	-	18	-	18	7,108	1,691	3,821	418	5,930	-	-	-	-	-	-	MARYLAND
MASSACHUSETTS	22,536	143	22,679	50	25	5,196	11/ 1,026	455	12/ 2,558	-	2,558	9,235	11,325	-	12/ 1,387	12,712	24	-	12/ 628	-	5	657	MASSACHUSETTS
MICHIGAN	35,504	-	35,504	255	-	25,688	-	-	3,000	-	3,000	28,688	*6,561	-	-	6,561	-	-	-	-	-	-	MICHIGAN
MINNESOTA	19,055	53	19,108	71	74	12,299	-	314	-	-	-	12,613	*6,307	-	-	6,307	43	-	-	-	-	43	MINNESOTA
MISSISSIPPI	13,753	-2	13,751	123	10	5,680	13/ 483	-	1,765	-	1,765	7,928	*5,689	1	-	5,690	-	-	-	-	-	-	MISSISSIPPI
MISSOURI	14,451	-	14,451	58	49	9,253	-	335	4,572	68	4,640	14,228	-	-	-	-	116	-	-	-	-	116	MISSOURI
MONTANA	5,471	24	5,495	23	4	5,413	-	-	55	-	55	5,468	-	-	-	-	-	-	-	-	-	-	MONTANA
NEBRASKA	12,357	39	12,396	123	56	6,227	5	-	-	-	-	6,232	*3,178	352	-	3,530	36	-	2,419	-	-	2,455	NEBRASKA
NEVADA	1,708	-	1,708	11	24	1,670	3	-	-	-	-	1,673	-	-	-	-	-	-	-	-	-	-	NEVADA
NEW HAMPSHIRE	3,716	1	3,717	(14/)	-	2,432	-	-	815	-	815	3,247	238	-	15/ 232	470	-	-	-	-	-	-	NEW HAMPSHIRE
NEW JERSEY	26,306	-222	26,084	201	-	9,003	230	356	2,509	-	2,509	12,098	3,982	-	890	4,872	-	-	7,289	485	1,139	8,913	NEW JERSEY
NEW MEXICO	5,102	-	5,102	145	3	3,012	-	-	1,942	-	1,942	4,954	-	-	-	-	-	-	-	-	-	-	NEW MEXICO
NEW YORK 16/	74,520	-5,453	69,067	115	-	6,510	464	627	3,549	-	3,549	11,150	8,729	1,861	-	10,590	-	47,212	-	-	-	47,212	NEW YORK 16/
NORTH CAROLINA	31,931	18	31,949	(17/)	92	4/ 24,329	-	-	5,989	128	6,117	30,446	(4/)	-	-	-	1,248	-	-	-	163	1,411	NORTH CAROLINA
NORTH DAKOTA	3,625	-1	3,624	46	83	2,615	-	-	-	-	-	2,615	874	-	-	874	-	6	-	-	-	6	NORTH DAKOTA
OHIO	18/ 58,113	-79	58,034	175	-	24,030	-	-	-	-	-	24,030	10,680	8,010	-	18,690	-	15,139	-	-	-	15,139	OHIO
OKLAHOMA	18,976	-57	18,919	459	85	10,697	-	-	-	-	-	10,697	*4,351	763	-	5,114	231	2,333	-	-	-	2,564	OKLAHOMA
OREGON	13,011	-95	12,916	49	-	8,453	16	245	1,966	8	1,974	10,688	*2,064	4	-	2,068	-	-	-	-	111	111	OREGON
PENNSYLVANIA	64,872	-	64,872	217	-	32,910	87	2,264	2,876	-	2,876	38,137	*10,246	-	-	10,246	-	16,216	-	-	56	16,272	PENNSYLVANIA
RHODE ISLAND 19/	4,275	-	4,275	15	-	1,326	-	126	141	-	141	1,593	28	-	-	28	-	2,639	-	-	-	2,639	RHODE ISLAND 19/
SOUTH CAROLINA	16,060	-	16,060	50	19	10,379	-	-	2,131	482	2,613	12,992	*2,643	95	-	2,738	261	-	-	-	-	261	SOUTH CAROLINA
SOUTH DAKOTA	4,617	-12	4,605	43	-	3,834	12	43	16	-	16	3,905	578	-	-	578	79	-	-	-	-	79	SOUTH DAKOTA
TENNESSEE	25,399	879	26,278	410	87	7,226	39	-	4,764	542	5,306	12,571	6,772	-	-	6,772	1,369	-	-	-	5,069	6,438	TENNESSEE
TEXAS	52,768	-168	52,600	714	-	24,869	-	530	-	9,146	9,146	34,545	*4,387	-	-	4,387	-	17	-	12,937	-	12,954	TEXAS
UTAH	4,370	-71	4,299	17	13	4,004	-	265	-	-	-	4,269	-	-	-	-	-	-	-	-	-	-	UTAH
VERMONT	2,930	-	2,930	3	-	1,592	7	-	21	-	21	1,620	1,012	-	280	1,292	-	-	-	-	15	15	VERMONT
VIRGINIA	22,896	-66	22,830	(17/)	37	4/ 21,537	-	478	362	-	362	22,377	4/ 352	64	-	416	-	-	-	-	-	-	VIRGINIA
WASHINGTON	19,334	-	19,334	47	-	7,661	-	-	12/ 142	53	195	7,856	*7,367	2,663	12/ 194	10,224	-	-	12/ 1,207	-	-	1,207	WASHINGTON
WEST VIRGINIA	11,559	-	11,559	16	-	4/ 6,801	-	10	4,732	-	4,732	11,543	(4/)	-	-	-	-	-	-	-	-	-	WEST VIRGINIA
WISCONSIN 20/	22,926	-	22,926	88	189	6,892	165	-	-	2,260	2,260	9,317	5,756	922	-	6,678	-	6,654	-	-	-	6,654	WISCONSIN 20/
WYOMING	3,014	-	3,014	12	-	2,103	-	60	81	-	81	2,244	758	-	-	758	-	-	-	-	-	-	WYOMING
DISTRICT OF COLUMBIA	3,479	1	3,480	(21/)	-	-	-	-	-	-	-	-	-	3,480	-	3,480	-	-	-	-	-	-	DISTRICT OF COLUMBIA
TOTAL	957,312	-9,274	948,038	6,104	1,738	460,989	2,576	8,109	64,528	26,481	91,009	562,683	176,951	42,399	4,679	224,029	4,703	99,306	19,986	21,390	8,099	153,484	TOTAL

1/ AMOUNTS DISTRIBUTED DURING THE CALENDAR YEAR OFTEN DIFFER FROM ACTUAL COLLECTIONS BECAUSE OF UNDISTRIBUTED FUNDS AND LAG BETWEEN ACCOUNTS OF COLLECTING AND EXPENDING AGENCIES.

2/ IN MANY STATES THE PROCEEDS OF HIGHWAY-USER TAXES ARE PLACED IN A COMMON FUND FROM WHICH A DISTRIBUTION IS MADE. THE AMOUNTS SO DISTRIBUTED HAVE BEEN PRORATED IN PROPORTION TO THE RECEIPTS NOT OTHERWISE DEDICATED. SEE TABLES MV-3 AND MC-2.

3/ WHERE REPORTED SEPARATELY FROM COLLECTION EXPENSES, FUNDS ALLOTTED FOR MOTOR-FUEL INSPECTION, ADMINISTRATION OF MOTOR VEHICLE DEPARTMENT, AND REGULATION OF MOTOR VEHICLES ARE SHOWN IN THIS COLUMN. SEE TABLE SF-9 FOR ADDITIONAL DETAIL OF COLLECTION COSTS.

4/ THE FOLLOWING AMOUNTS FOR CONSTRUCTION AND MAINTENANCE OF COUNTY ROADS UNDER STATE CONTROL ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES: DELAWARE, $322,000; NORTH CAROLINA, $8,229,000; VIRGINIA, $8,579,000; WEST VIRGINIA, $2,309,000. THE THREE COUNTIES IN VIRGINIA WHICH HAVE COUNTY ROADS NOT UNDER STATE CONTROL RECEIVED $352,000.

5/ AMOUNTS DISTRIBUTED FOR STATE PARK AND FOREST ROADS, ETC. WERE LISTED SEPARATELY, RATHER THAN UNDER "STATE HIGHWAY PURPOSES" ON TABLE G-3 FOR YEARS PRIOR TO 1940.

6/ REIMBURSEMENT TO COUNTIES AND LOCAL UNITS OF GOVERNMENT FOR AMOUNTS SPENT ON ROADS NOW ON STATE SYSTEM.

7/ IN STATES INDICATED BY STAR (*) LAW PROVIDES THAT THESE FUNDS MAY ALSO BE USED FOR SERVICE OF LOCAL HIGHWAY OBLIGATIONS. AMOUNTS SO USED NOT REPORTED SEPARATELY. IN COLORADO FUNDS MAY BE USED ON BOTH STATE AND LOCAL ROADS.

8/ THIS COLUMN SHOWS SPECIFIC ALLOTMENTS FOR CITY STREETS. WHERE REPORTED SEPARATELY, FUNDS ALLOTTED FOR URBAN EXTENSIONS OF STATE HIGHWAY SYSTEM ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES.

9/ TO STATE GENERAL FUNDS EXCEPT AS FOLLOWS: LOUISIANA, 1 CENT OF TAX TO PARISHES; WISCONSIN, $2,346,000 PAYMENT TO TOWNS, CITIES, AND VILLAGES IN LIEU OF PERSONAL PROPERTY TAXES FORMERLY IMPOSED ON MOTOR VEHICLES. ALLOCATIONS TO COUNTY OR LOCAL GENERAL FUNDS MAY HAVE BEEN USED IN PART FOR HIGHWAYS, BUT SUCH AMOUNTS WERE NOT REPORTED.

10/ FOR THE FOLLOWING PURPOSES: FLORIDA, AVIATION; LOUISIANA, HARBOR IMPROVEMENT; MASSACHUSETTS, RIVER AND HARBOR IMPROVEMENT; NEW JERSEY, DEBT SERVICE ON INSTITUTIONAL CONSTRUCTION BONDS, $243,000, BOARD OF COMMERCE AND NAVIGATION, $376,000, DEFENSE COUNCIL, $500,000, VARIOUS COMMISSIONS, $20,000; NORTH CAROLINA, STATE PROBATION AND PAROLE COMMISSIONS; OREGON, STATE PARKS; PENNSYLVANIA, AVIATION, $51,000, COOPERATIVE WORK OTHER DEPARTMENTS, $5,000; TENNESSEE, DEBT SERVICE ON NONHIGHWAY BONDS; VERMONT, DEBT SERVICE ON NONHIGHWAY PORTION OF FLOOD RELIEF BONDS.

11/ TO METROPOLITAN DISTRICT COMMISSION FOR PARKWAYS AND BOULEVARDS.

12/ INCLUDES DEBT SERVICE CHARGES ON EMERGENCY RELIEF BOND ISSUES, PRORATED IN PROPORTION TO USE OF PROCEEDS FOR STATE HIGHWAYS, LOCAL ROADS AND STREETS, AND NONHIGHWAY PURPOSES.

13/ INCLUDES $287,000 TO GULF COAST COUNTIES FOR SEA-WALL PROTECTION OF STATE HIGHWAYS.

14/ COST OF COLLECTING MOTOR-FUEL TAX WAS NOT REPORTED. EXPENSE OF ADMINISTERING REFUNDS, $4,000, WAS PAID FROM MOTOR-VEHICLE FUNDS.

15/ INCLUDES $116,000 PAID ON HIGHWAY RELIEF BONDS ISSUED BY STATE FOR LOCAL ROADS, AND $116,000 ON PRO-RATA SHARE OF HIGHWAY FLOOD BONDS.

16/ APPROPRIATIONS FOR HIGHWAY PURPOSES OUT OF STATE GENERAL FUND HAVE BEEN CREDITED AGAINST PAYMENTS OF MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES TO THE GENERAL FUND AND PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS NOT OTHERWISE DEDICATED.

17/ INCLUDED WITH MOTOR-VEHICLE COLLECTION EXPENSES.

18/ TAX OF $627,000 ON NON-MOTOR-VEHICLE FUELS NOT INCLUDED.

19/ EXPENDITURES FOR HIGHWAY PURPOSES HAVE BEEN CREDITED AGAINST PAYMENTS OF MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES TO THE STATE GENERAL FUND AND PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS NOT OTHERWISE DEDICATED.

20/ MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES ARE PAID INTO HIGHWAY ACCOUNT OF STATE GENERAL FUND, AND ARE USED FOR ANY PURPOSE, INCLUDING HIGHWAYS. EXPENDITURES FOR HIGHWAY PURPOSES HAVE BEEN CREDITED AGAINST RECEIPTS FROM MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES, PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS.

21/ PAID OUT OF GENERAL REVENUE. AMOUNT NOT REPORTED.

DISPOSITION OF STATE MOTOR-VEHICLE RECEIPTS - 1941

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES

STATE	NET TOTAL RECEIPTS OF CALENDAR YEAR	ADJUSTMENTS DUE TO UNDISTRIBUTED FUNDS, ETC. 1/	NET TOTAL FUNDS DISTRIBUTED 2/	EXPENSES OF COLLECTION AND ADMINISTRATION 3/	FOR OTHER ADMINISTRATIVE PURPOSES 4/	FOR STATE HIGHWAY PURPOSES: CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION			SERVICE OF STATE HIGHWAY OBLIGATIONS			TOTAL FOR STATE HIGHWAY PURPOSES 6/	FOR LOCAL ROADS AND STREETS				FOR NONHIGHWAY PURPOSES					STATE
						ON STATE HIGHWAYS 5/	ON STATE PARK AND FOREST ROADS, ETC. 6/	STATE HIGHWAY POLICE	STATE HIGHWAY BONDS AND NOTES	REIMBURSEMENT OBLIGATIONS 7/	TOTAL		FOR WORK ON COUNTY AND LOCAL ROADS 5/ 8/	FOR WORK ON CITY STREETS 9/	SERVICE OF LOCAL HIGHWAY OBLIGATIONS	TOTAL	TO GENERAL FUNDS 10/	FOR RELIEF OF UNEMPLOYMENT OR DESTITUTION	FOR EDUCATION	FOR OTHER PURPOSES 11/	TOTAL	
	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	
ALABAMA	6,431	17	6,448	519	-	2,201	13	669	1,597	-	1,597	4,480	181	266	-	447	1,002	-	-	-	1,002	ALABAMA
ARIZONA	1,352	-29	1,323	291	-	992	-	38	-	-	-	1,030	2	-	-	2	-	-	-	-	-	ARIZONA
ARKANSAS	3,935	283	4,218	92	-	2,107	-	207	1,531	-	1,531	3,845	-	53	228	281	-	-	-	-	-	ARKANSAS
CALIFORNIA	31,927	-1,476	30,451	2,955	35	4,429	-	3,172	3,604	-	3,604	11,205	*4,430	-	-	4,430	11,826	-	-	-	11,826	CALIFORNIA
COLORADO	2,953	-147	2,806	462	-	844	-	52	304	-	304	1,200	1,144	-	-	1,144	-	-	-	-	-	COLORADO
CONNECTICUT	8,249	-192	8,057	992	-	3,511	-	725	-	483	483	4,719	2,346	-	-	2,346	-	-	-	-	-	CONNECTICUT
DELAWARE	1,456	-	1,456	199	-	5/ 437	-	101	46	151	197	735	(5/)	-	-	-	522	-	-	-	522	DELAWARE
FLORIDA	9,463	-	9,463	1,050	-	-	-	559	-	-	-	559	-	-	-	-	15	-	7,839	-	7,854	FLORIDA
GEORGIA	2,951	43	2,994	243	-	1,688	-	799	53	-	53	2,540	114	-	-	114	97	-	-	-	97	GEORGIA
IDAHO	1,542	-108	1,434	82	-	108	-	126	-	-	-	234	1,118	-	-	1,118	-	-	-	-	-	IDAHO
ILLINOIS	26,567	-12	26,555	1,726	-	12,341	-	1,337	9,667	-	9,667	23,345	*1,290	-	-	1,290	194	-	-	-	194	ILLINOIS
INDIANA	11,628	140	11,768	1,170	-	5,525	-	283	-	-	-	5,808	3,632	830	-	4,462	328	-	-	-	328	INDIANA
IOWA	14,231	150	14,381	1,257	-	4,854	-	438	-	4,959	4,959	10,251	2,864	9	-	2,873	-	-	-	-	-	IOWA
KANSAS	4,743	-206	4,537	710	-	2,582	-	62	80	240	320	2,964	863	-	-	863	-	-	-	-	-	KANSAS
KENTUCKY	6,076	-1	6,075	609	-	2,397	-	41	-	-	-	2,438	936	-	-	936	2,092	-	-	-	2,092	KENTUCKY
LOUISIANA	3,486	17	3,503	169	-	2,503	-	630	201	-	201	3,334	-	-	-	-	-	-	-	-	-	LOUISIANA
MAINE	4,434	-14	4,420	214	-	2,634	-	126	1,111	-	1,111	3,871	335	-	-	335	-	-	-	-	-	MAINE
MARYLAND	7,830	-	7,830	363	53	3,191	-	546	699	-	699	4,436	-	1,290	-	1,290	1,688	-	-	-	1,688	MARYLAND
MASSACHUSETTS	7,905	295	8,200	1,581	70	1,507	12/ 297	132	13/ 742	-	742	2,678	3,285	-	13/ 402	3,687	-	13/ 182	-	2	184	MASSACHUSETTS
MICHIGAN	27,163	1,444	28,607	2,141	-	314	-	744	-	-	-	1,058	*25,408	-	-	25,408	-	-	-	-	-	MICHIGAN
MINNESOTA	19,530	-7,851	11,679	840	-	6,622	-	169	2,120	1,762	3,882	10,673	-	-	-	-	166	-	-	-	166	MINNESOTA
MISSISSIPPI	3,433	-36	3,397	208	-	44	-	298	-	-	-	342	*2,847	-	-	2,847	-	-	-	-	-	MISSISSIPPI
MISSOURI	11,713	-27	11,686	653	-	7,174	-	260	3,546	53	3,599	11,033	-	-	-	-	-	-	-	-	-	MISSOURI
MONTANA	1,797	-83	1,714	70	-	-	-	253	-	-	-	253	1,342	49	-	1,391	-	-	-	-	-	MONTANA
NEBRASKA	3,195	11	3,206	272	8	915	-	228	-	-	-	1,143	1,783	-	-	1,783	-	-	-	-	-	NEBRASKA
NEVADA	405	-	405	83	-	239	-	5	78	-	78	322	-	-	-	-	-	-	-	-	-	NEVADA
NEW HAMPSHIRE	3,291	-	3,291	209	4	2,506	-	206	1	-	1	2,713	245	-	14/ 120	365	-	-	-	-	-	NEW HAMPSHIRE
NEW JERSEY	24,349	239	24,588	2,133	-	10,430	266	414	2,906	-	2,906	14,016	4,612	-	1,031	5,643	-	1,493	563	740	2,796	NEW JERSEY
NEW MEXICO	2,213	53	2,266	202	120	736	-	239	-	-	-	975	254	37	-	291	678	-	-	-	678	NEW MEXICO
NEW YORK 15/	53,978	483	54,461	2,822	-	11,197	798	1,078	6,104	-	6,104	19,177	*10,247	5,042	-	15,289	17,173	-	-	-	17,173	NEW YORK 15/
NORTH CAROLINA	9,777	492	10,269	16/ 558	-	5/ 7,093	-	835	1,746	37	1,783	9,711	(5/)	-	-	-	-	-	-	-	-	NORTH CAROLINA
NORTH DAKOTA	2,025	-29	1,996	111	-	919	-	148	-	-	-	1,067	818	-	-	818	-	-	-	-	-	NORTH DAKOTA
OHIO	33,421	-1,834	31,587	3,167	-	8,403	-	873	-	-	-	9,276	*14,102	4,743	-	18,845	-	-	-	299	299	OHIO
OKLAHOMA	7,086	2	7,088	1,023	-	1,399	-	847	-	-	-	2,246	*2,818	786	-	3,604	-	-	215	-	215	OKLAHOMA
OREGON	4,416	-233	4,183	512	-	2,411	5	70	561	2	563	3,049	*589	1	-	590	-	-	-	32	32	OREGON
PENNSYLVANIA	41,326	865	42,191	2,130	-	32,691	87	2,249	2,856	-	2,856	37,883	2,123	-	-	2,123	-	-	-	55	55	PENNSYLVANIA
RHODE ISLAND 17/	3,425	-	3,425	254	-	987	-	93	105	-	105	1,185	21	-	-	21	1,965	-	-	-	1,965	RHODE ISLAND 17/
SOUTH CAROLINA	2,749	-	2,749	240	-	1,502	-	686	235	69	304	2,492	3	14	-	17	-	-	-	-		SOUTH CAROLINA
SOUTH DAKOTA	1,879	31	1,910	79	-	355	1	4	2	-	2	362	1,394	-	-	1,394	75	-	-	-	75	SOUTH DAKOTA
TENNESSEE	7,077	-5	7,072	842	-	4,947	-	402	-	-	-	5,349	-	-	-		881	-	-	-	381	TENNESSEE
TEXAS	26,671	-	26,671	1,918	-	9,688	-	207	-	-	-	9,895	*13,368	-	-	13,368	1,118	-	372	-	1,490	TEXAS
UTAH	1,335	-369	966	136	-	13	-	-	14	-	14	27	463	337	-	800	3	-	-	-	3	UTAH
VERMONT	2,750	1	2,751	84	-	1,389	5	115	19	-	19	1,528	883	-	244	1,127	-	-	-	12	12	VERMONT
VIRGINIA	8,363	60	8,423	16/ 593	-	7,319	-	271	204	-	204	7,794	-	36	-	36	-	-	-	-	-	VIRGINIA
WASHINGTON	5,461	183	5,644	514	-	3,262	2	1,671	-	-	-	4,935	9	-	-	9	-	-	-	186	186	WASHINGTON
WEST VIRGINIA	7,180	1	7,181	155	-	5/ 3,949	-	6	3,071	-	3,071	7,026	(5/)	-	-	-	-	-	-	-	-	WEST VIRGINIA
WISCONSIN 18/	14,862	-	14,862	1,004	-	4,217	101	-	-	1,383	1,383	5,701	3,522	564	-	4,086	4,071	-	-	-	4,071	WISCONSIN 18/
WYOMING	652	10	662	15	-	357	-	10	280	-	280	647	-	-	-	-	-	-	-	-	-	WYOMING
DISTRICT OF COLUMBIA	1,985	-	1,985	199	-	-	-	-	-	-	-	-	-	1,786	-	1,786	-	-	-	-	-	DISTRICT OF COLUMBIA
TOTAL	490,666	-7,832	482,834	37,851	290	184,929	1,575	22,424	43,483	9,139	52,622	261,550	109,391	15,843	2,025	127,259	43,894	1,675	8,989	1,326	55,884	TOTAL

1/ AMOUNTS DISTRIBUTED DURING THE CALENDAR YEAR OFTEN DIFFER FROM ACTUAL COLLECTIONS BECAUSE OF UNDISTRIBUTED FUNDS AND LAG BETWEEN ACCOUNTS OF COLLECTING AND EXPENDING AGENCIES.

2/ IN MANY STATES THE PROCEEDS OF HIGHWAY-USER TAXES ARE PLACED IN A COMMON FUND FROM WHICH A DISTRIBUTION IS MADE. THE AMOUNTS SO DISTRIBUTED HAVE BEEN PRORATED IN PROPORTION TO THE RECEIPTS NOT OTHERWISE DEDICATED. SEE TABLES G-3 AND MC-2.

3/ COLLECTION EXPENSES IN MANY STATES INCLUDE SERVICE CHARGES DEDUCTED BY COUNTY AND LOCAL COLLECTORS. SEE TABLE SF-9 FOR DETAILS OF AMOUNTS INCLUDED IN THIS COLUMN.

4/ WHERE REPORTED SEPARATELY FROM COLLECTION EXPENSES, MISCELLANEOUS EXPENSES OF MOTOR-VEHICLE, MOTOR-FUEL, AND MOTOR-CARRIER REGULATION ARE SHOWN IN THIS COLUMN.

5/ THE FOLLOWING AMOUNTS FOR CONSTRUCTION AND MAINTENANCE OF COUNTY ROADS UNDER STATE CONTROL ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES: DELAWARE, $162,000; NORTH CAROLINA, $2,399,000; WEST VIRGINIA, $1,034,000.

6/ AMOUNTS DISTRIBUTED FOR STATE PARK AND FOREST ROADS, ETC., WERE REPORTED SEPARATELY, RATHER THAN UNDER "STATE HIGHWAY PURPOSES" ON TABLE MV-3 FOR YEARS PRIOR TO 1940.

7/ REIMBURSEMENT TO COUNTIES AND LOCAL UNITS OF GOVERNMENT FOR AMOUNTS SPENT ON ROADS NOW ON STATE SYSTEM.

8/ IN STATES INDICATED BY STAR (*) LAW PROVIDES THAT THESE FUNDS MAY ALSO BE USED FOR SERVICE OF LOCAL HIGHWAY OBLIGATIONS. AMOUNTS SO USED NOT REPORTED SEPARATELY. IN COLORADO FUNDS MAY BE USED ON BOTH STATE AND LOCAL ROADS.

9/ THIS COLUMN SHOWS SPECIFIC ALLOTMENTS FOR CITY STREETS. WHERE REPORTED SEPARATELY, FUNDS ALLOTTED FOR URBAN EXTENSIONS OF STATE HIGHWAY SYSTEM ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES.

10/ TO STATE GENERAL FUNDS EXCEPT IN THE FOLLOWING STATES: ALABAMA, COUNTY AND MUNICIPAL GENERAL FUNDS; CALIFORNIA, COUNTY AND MUNICIPAL GENERAL FUNDS, $9,461,000; NEW MEXICO, COUNTY GENERAL FUNDS, $424,000; WISCONSIN, $1,436,000 TO TOWNS, CITIES, AND VILLAGES IN LIEU OF PERSONAL PROPERTY TAX FORMERLY IMPOSED ON MOTOR VEHICLES. ALLOCATIONS TO COUNTY OR LOCAL GENERAL FUNDS MAY HAVE BEEN USED IN PART FOR HIGHWAYS, BUT SUCH AMOUNTS WERE NOT REPORTED.

11/ FOR THE FOLLOWING PURPOSES: MASSACHUSETTS, RIVER AND HARBOR IMPROVEMENT; NEW JERSEY, DEBT SERVICE ON INSTITUTIONAL CONSTRUCTION BONDS, $281,000, BOARD OF COMMERCE AND NAVIGATION, $436,000, VARIOUS COMMISSIONS, $23,000; OHIO, CARE OF INDIGENT PERSONS INJURED IN MOTOR-VEHICLE ACCIDENTS; OREGON, STATE PARKS; PENNSYLVANIA, AVIATION, $50,000, COOPERATIVE WORK OTHER DEPARTMENTS, $5,000; VERMONT, DEBT SERVICE ON NONHIGHWAY PORTION OF FLOOD RELIEF BONDS.

12/ TO METROPOLITAN DISTRICT COMMISSION FOR PARKWAYS AND BOULEVARDS.

13/ INCLUDES DEBT SERVICE CHARGES ON EMERGENCY RELIEF BOND ISSUES, PRORATED IN PROPORTION TO USE OF PROCEEDS FOR STATE HIGHWAYS, LOCAL ROADS AND STREETS, AND NONHIGHWAY PURPOSES.

14/ DEBT SERVICE ON HIGHWAY RELIEF BONDS, A STATE OBLIGATION INCURRED FOR IMPROVEMENT OF LOCAL ROADS.

15/ APPROPRIATIONS FOR HIGHWAY PURPOSES OUT OF STATE GENERAL FUND HAVE BEEN CREDITED AGAINST PAYMENTS OF MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES TO THE GENERAL FUND AND PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS NOT OTHERWISE DEDICATED.

16/ INCLUDES EXPENSES OF COLLECTING MOTOR-FUEL TAX.

17/ EXPENDITURES FOR HIGHWAY PURPOSES HAVE BEEN CREDITED AGAINST PAYMENTS OF MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES TO THE STATE GENERAL FUND AND PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS NOT OTHERWISE DEDICATED.

18/ MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES ARE PAID INTO HIGHWAY ACCOUNT OF STATE GENERAL FUND, AND ARE USED FOR ANY PURPOSE, INCLUDING HIGHWAYS. EXPENDITURES FOR HIGHWAY PURPOSES HAVE BEEN CREDITED AGAINST RECEIPTS FROM MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES, PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS.

DISPOSITION OF STATE MOTOR-CARRIER TAX RECEIPTS - 1941

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES

STATE	NET TOTAL RECEIPTS OF CALENDAR YEAR	ADJUSTMENTS DUE TO UNDISTRIBUTED FUNDS, ETC. 1/	NET TOTAL FUNDS DISTRIBUTED 2/	EXPENSES OF COLLECTION AND ADMINISTRATION	FOR STATE HIGHWAY PURPOSES: CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION: ON STATE HIGHWAYS 3/	FOR STATE HIGHWAY PURPOSES: CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION: ON STATE PARK AND FOREST ROADS, ETC. 4/	FOR STATE HIGHWAY PURPOSES: STATE HIGHWAY POLICE	FOR STATE HIGHWAY PURPOSES: SERVICE OF STATE HIGHWAY OBLIGATIONS: STATE HIGHWAY BONDS AND NOTES	FOR STATE HIGHWAY PURPOSES: SERVICE OF STATE HIGHWAY OBLIGATIONS: REIMBURSEMENT OBLIGATIONS 5/	FOR STATE HIGHWAY PURPOSES: SERVICE OF STATE HIGHWAY OBLIGATIONS: TOTAL	FOR STATE HIGHWAY PURPOSES: TOTAL FOR STATE HIGHWAY PURPOSES 4/	FOR LOCAL ROADS AND STREETS: FOR WORK ON COUNTY AND LOCAL ROADS 3/ 6/	FOR LOCAL ROADS AND STREETS: FOR WORK ON CITY STREETS 7/	FOR LOCAL ROADS AND STREETS: SERVICE OF LOCAL HIGHWAY OBLIGATIONS	FOR LOCAL ROADS AND STREETS: TOTAL	FOR NONHIGHWAY PURPOSES: TO STATE GENERAL FUNDS	FOR NONHIGHWAY PURPOSES: FOR EDUCATION	FOR NONHIGHWAY PURPOSES: FOR STATE PARKS	FOR NONHIGHWAY PURPOSES: TOTAL	STATE
	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	
ALABAMA	422	3	425	67	329	2	-	-	-	-	331	27	-	-	27	-	-	-	-	ALABAMA
ARIZONA	225	-21	204	42	155	-	6	-	-	-	161	1	-	-	1	-	-	-	-	ARIZONA
ARKANSAS	4	-1	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ARKANSAS
CALIFORNIA	3,888	-82	3,806	517	133	-	-	-	-	-	133	1	-	-	1	3,155	-	-	3,155	CALIFORNIA
COLORADO	859	-18	841	101	281	-	17	101	-	101	399	341	-	-	341	-	-	-	-	COLORADO
CONNECTICUT	337	-8	329	74	126	-	-	-	17	17	143	-	112	-	112	-	-	-	-	CONNECTICUT
DELAWARE	(8/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	DELAWARE
FLORIDA	427	-	427	90	-	-	-	-	-	-	-	-	11	315	326	3	8	-	11	FLORIDA
GEORGIA	110	1	111	83	-	-	-	-	-	-	-	-	-	-	-	28	-	-	28	GEORGIA
IDAHO	73	-24	49	20	-	-	29	-	-	-	29	-	-	-	-	-	-	-	-	IDAHO
ILLINOIS	(8/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ILLINOIS
INDIANA	1,412	-9	1,403	114	672	-	34	-	-	-	706	442	101	-	543	40	-	-	40	INDIANA
IOWA	415	-8	407	72	62	-	-	-	63	63	125	*210	-	-	210	-	-	-	-	IOWA
KANSAS	1,629	-	1,629	448	800	-	15	25	74	99	914	267	-	-	267	-	-	-	-	KANSAS
KENTUCKY	441	1	442	63	335	-	6	-	-	-	341	38	-	-	38	-	-	-	-	KENTUCKY
LOUISIANA	149	-	149	30	-	-	-	-	-	-	-	-	-	-	-	119	-	-	119	LOUISIANA
MAINE	22	-	22	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	MAINE
MARYLAND	(9/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	MARYLAND
MASSACHUSETTS	138	-	138	45	-	-	-	-	-	-	-	-	-	-	-	93	-	-	93	MASSACHUSETTS
MICHIGAN	624	-13	611	247	364	-	-	-	-	-	364	-	-	-	-	-	-	-	-	MICHIGAN
MINNESOTA	47	-	47	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	MINNESOTA
MISSISSIPPI	239	-	239	50	-	-	-	-	-	-	-	*189	-	-	189	-	-	-	-	MISSISSIPPI
MISSOURI	942	615	1,557	90	733	-	26	362	6	368	1,127	340	-	-	340	-	-	-	-	MISSOURI
MONTANA	66	-25	41	41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	MONTANA
NEBRASKA	32	-	32	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NEBRASKA
NEVADA	317	-1	316	45	265	-	6	-	-	-	271	-	-	-	-	-	-	-	-	NEVADA
NEW HAMPSHIRE	4	-	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NEW HAMPSHIRE
NEW JERSEY	104	-	104	-	104	-	-	-	-	-	104	-	-	-	-	-	-	-	-	NEW JERSEY
NEW MEXICO	272	-95	177	73	104	-	-	-	-	-	104	-	-	-	-	-	-	-	-	NEW MEXICO
NEW YORK	26	-	26	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NEW YORK
NORTH CAROLINA	584	40	624	-	3/ 498	-	-	123	3	126	624	(3/)	-	-	-	-	-	-	-	NORTH CAROLINA
NORTH DAKOTA	46	-	46	42	4	-	-	-	-	-	4	-	-	-	-	-	-	-	-	NORTH DAKOTA
OHIO	685	-	685	107	421	-	-	-	-	-	421	118	39	-	157	-	-	-	-	OHIO
OKLAHOMA	29	19	48	14	27	-	-	-	-	-	27	7	-	-	7	-	-	-	-	OKLAHOMA
OREGON	1,664	-2	1,662	235	915	2	61	212	1	213	1,191	*223	1	-	224	-	-	12	12	OREGON
PENNSYLVANIA	7	-	7	-	7	-	-	-	-	-	7	-	-	-	-	-	-	-	-	PENNSYLVANIA
RHODE ISLAND	13	1	14	12	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	RHODE ISLAND
SOUTH CAROLINA	296	98	394	77	183	-	-	-	-	-	183	-	29	-	29	105	-	-	105	SOUTH CAROLINA
SOUTH DAKOTA	469	75	544	30	485	2	5	2	-	2	494	2	-	-	2	18	-	-	18	SOUTH DAKOTA
TENNESSEE	121	-	121	61	-	-	-	-	-	-	-	-	-	-	-	60	-	-	60	TENNESSEE
TEXAS	177	-	177	169	8	-	-	-	-	-	8	-	-	-	-	-	-	-	-	TEXAS
UTAH 10/	-	19	19	11	1	-	-	-	-	-	1	-	-	-	-	7	-	-	7	UTAH 10/
VERMONT	(8/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	VERMONT
VIRGINIA	491	-1	490	84	379	-	14	11	-	11	404	-	2	-	2	-	-	-	-	VIRGINIA
WASHINGTON	192	-	192	192	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	WASHINGTON
WEST VIRGINIA	140	-	140	-	68	-	-	72	-	72	140	-	-	-	-	-	-	-	-	WEST VIRGINIA
WISCONSIN	1,841	-	1,841	86	-	-	-	-	-	-	-	-	-	-	-	1,755	-	-	1,755	WISCONSIN
WYOMING	329	-1	328	30	290	-	8	-	-	-	298	-	-	-	-	-	-	-	-	WYOMING
DISTRICT OF COLUMBIA	268	-	268	-	-	-	-	-	-	-	-	-	-	-	-	268	-	-	268	DISTRICT OF COLUMBIA
TOTAL	20,576	563	21,139	3,596	7,751	6	227	908	164	1,072	9,056	2,206	295	315	2,816	5,651	8	12	5,671	TOTAL

1/ AMOUNTS DISTRIBUTED DURING THE CALENDAR YEAR OFTEN DIFFER FROM ACTUAL COLLECTIONS BECAUSE OF UNDISTRIBUTED FUNDS AND LAG BETWEEN ACCOUNTS OF COLLECTING AND EXPENDING AGENCIES.

2/ IN MANY STATES THE PROCEEDS OF HIGHWAY-USER TAXES ARE PLACED IN A COMMON FUND FROM WHICH A DISTRIBUTION IS MADE. THE AMOUNTS SO DISTRIBUTED HAVE BEEN PRORATED IN PROPORTION TO THE RECEIPTS NOT OVERWISE DEDICATED. SEE TABLES G-3 AND MV-3.

3/ APPROXIMATELY $168,000 FOR USE ON COUNTY ROADS UNDER STATE CONTROL IN NORTH CAROLINA INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES.

4/ AMOUNTS DISTRIBUTED FOR STATE PARK AND FOREST ROADS, ETC. WERE REPORTED SEPARATELY, RATHER THAN UNDER "STATE HIGHWAY PURPOSES", ON TABLE MC-2 FOR YEARS PRIOR TO 1940.

5/ REIMBURSEMENT TO COUNTIES AND LOCAL UNITS OF GOVERNMENT FOR AMOUNTS SPENT ON ROADS NOW ON STATE SYSTEM.

6/ IN STATES INDICATED BY STAR (*) LAW PROVIDES THAT THESE FUNDS MAY ALSO BE USED FOR SERVICE OF LOCAL HIGHWAY OBLIGATIONS. AMOUNTS SO USED NOT REPORTED SEPARATELY. IN COLORADO FUNDS MAY BE USED ON BOTH STATE AND LOCAL ROADS.

7/ THIS COLUMN SHOWS SPECIFIC ALLOTMENTS FOR CITY STREETS. WHERE REPORTED SEPARATELY, FUNDS ALLOTTED FOR URBAN EXTENSIONS OF STATE HIGHWAY SYSTEM ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES.

8/ NO SPECIAL TAXES ON MOTOR-CARRIERS REPORTED.

9/ WEIGHT AND PASSENGER-MILE TAXES PAID BY MOTOR CARRIERS IN LIEU OF REGISTRATION FEES ARE INCLUDED IN MOTOR-VEHICLE RECEIPTS, TABLE MV-3.

10/ MOTOR-CARRIER TAXES NO LONGER IMPOSED. AMOUNTS SHOWN REPRESENT DISTRIBUTION OF REVENUES COLLECTED IN PRIOR YEARS.

DISPOSITION OF RECEIPTS FROM STATE IMPOSTS ON HIGHWAY USERS - 1941

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES

STATE	NET TOTAL RECEIPTS OF CALENDAR YEAR 1/	ADJUSTMENTS DUE TO UNDISTRIBUTED FUNDS, ETC. 2/	NET TOTAL FUNDS DISTRIBUTED	EXPENSES OF COLLECTION AND ADMINISTRATION 3/	FOR STATE HIGHWAY PURPOSES: CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION: ON STATE HIGHWAYS 4/	FOR STATE HIGHWAY PURPOSES: CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION: ON STATE PARK AND FOREST ROADS, ETC. 5/	FOR STATE HIGHWAY PURPOSES: STATE HIGHWAY POLICE	FOR STATE HIGHWAY PURPOSES: SERVICE OF STATE HIGHWAY OBLIGATIONS: STATE HIGHWAY BONDS AND NOTES	FOR STATE HIGHWAY PURPOSES: SERVICE OF STATE HIGHWAY OBLIGATIONS: REIMBURSEMENT OBLIGATIONS 6/	FOR STATE HIGHWAY PURPOSES: SERVICE OF STATE HIGHWAY OBLIGATIONS: TOTAL	FOR STATE HIGHWAY PURPOSES: TOTAL FOR STATE HIGHWAY PURPOSES 5/	FOR LOCAL ROADS AND STREETS: FOR WORK ON COUNTY AND LOCAL ROADS 4/ 7/	FOR LOCAL ROADS AND STREETS: FOR WORK ON CITY STREETS 8/	FOR LOCAL ROADS AND STREETS: SERVICE OF LOCAL HIGHWAY OBLIGATIONS	FOR LOCAL ROADS AND STREETS: TOTAL	FOR NONHIGHWAY PURPOSES: TO GENERAL FUNDS 9/: MOTOR-FUEL INSPECTION FEES, DEALERS LICENSES, ETC.	FOR NONHIGHWAY PURPOSES: TO GENERAL FUNDS 9/: ALL OTHER HIGHWAY-USER IMPOSTS	FOR NONHIGHWAY PURPOSES: FOR RELIEF OF UNEMPLOYMENT OR DESTITUTION	FOR NONHIGHWAY PURPOSES: FOR EDUCATION	FOR NONHIGHWAY PURPOSES: FOR OTHER PURPOSES 10/	FOR NONHIGHWAY PURPOSES: TOTAL	STATE
	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	
ALABAMA	25,254	-99	25,155	688	9,092	54	669	3,546	-	3,546	13,361	9,713	391	-	10,104	-	1,002	-	-	-	1,002	ALABAMA
ARIZONA	6,939	-50	6,889	402	4,688	-	178	-	-	-	4,866	*1,621	-	-	1,621	-	-	-	-	-	-	ARIZONA
ARKANSAS	17,158	282	17,440	439	5,931	-	235	8,574	-	8,574	14,740	1,416	150	601	2,167	94	-	-	-	-	94	ARKANSAS
CALIFORNIA	93,909	-3,329	90,580	3,710	37,582	-	3,172	3,604	-	3,604	44,358	*20,358	4,430	-	24,788	-	14,981	2,743	-	-	17,724	CALIFORNIA
COLORADO	12,645	-428	12,217	677	5,467	-	337	1,968	-	1,968	7,772	3,768	-	-	3,768	-	-	-	-	-	-	COLORADO
CONNECTICUT	20,390	-305	20,085	1,109	13,884	-	725	-	1,909	1,909	16,518	2,346	112	-	2,458	-	-	-	-	-	-	CONNECTICUT
DELAWARE	3,960	-	3,960	207	4/ 1,305	-	302	137	450	587	2,194	(4/)	-	-	-	-	1,559	-	-	-	1,559	DELAWARE
FLORIDA	40,287	-7	40,280	1,313	17,414	-	560	-	8,132	8,132	26,106	-	11	315	326	385	2,150	-	9,977	23	12,535	FLORIDA
GEORGIA	29,147	-2,352	26,795	1,108	13,263	-	799	130	-	130	14,192	5,085	-	-	5,085	33	2,057	-	4,320	-	6,410	GEORGIA
IDAHO	6,833	-87	6,746	121	3,820	-	167	112	-	112	4,099	*2,525	1	-	2,526	-	-	-	-	-	-	IDAHO
ILLINOIS	71,828	-43	71,785	2,227	26,766	-	1,337	9,667	-	9,667	37,770	12,490	13,474	905	26,869	194	194	4,531	-	-	4,919	ILLINOIS
INDIANA	42,284	131	42,415	1,474	21,035	-	1,077	-	-	-	22,112	13,828	3,161	-	16,989	590	1,250	-	-	-	1,840	INDIANA
IOWA	30,046	-9	30,037	1,480	8,114	-	448	-	8,290	8,290	16,852	*11,690	15	-	11,705	-	-	-	-	-	-	IOWA
KANSAS	17,761	-206	17,555	1,639	10,768	-	213	335	1,000	1,335	12,316	3,600	-	-	3,600	-	-	-	-	-	-	KANSAS
KENTUCKY	22,697	509	23,206	718	17,435	-	300	-	-	-	17,735	2,661	-	-	2,661	-	2,092	-	-	-	2,092	KENTUCKY
LOUISIANA	25,197	100	25,297	380	8,949	-	630	7,907	-	7,907	17,486	-	-	-	-	-	3,226	1,169	1,518	1,518	7,431	LOUISIANA
MAINE	11,110	-14	11,096	253	6,791	-	324	2,864	-	2,864	9,979	864	-	-	864	-	-	-	-	-	-	MAINE
MARYLAND	20,900	-	20,900	448	10,281	-	546	717	-	717	11,544	1,691	5,111	418	7,220	-	1,688	-	-	-	1,688	MARYLAND
MASSACHUSETTS	30,579	438	31,017	1,771	6,703	11/ 1,323	587	12/ 3,300	-	3,300	11,913	14,610	-	12/ 1,789	16,399	24	93	12/ 810	-	7	934	MASSACHUSETTS
MICHIGAN	63,291	1,431	64,722	2,643	26,366	-	744	3,000	-	3,000	30,110	*31,969	-	-	31,969	-	-	-	-	-	-	MICHIGAN
MINNESOTA	38,632	-7,798	30,834	1,032	18,921	-	483	2,120	1,762	3,882	23,286	*6,307	-	-	6,307	43	166	-	-	-	209	MINNESOTA
MISSISSIPPI	17,425	-38	17,387	391	5,724	13/ 483	298	1,765	-	1,765	8,270	*8,725	1	-	8,726	-	-	-	-	-	-	MISSISSIPPI
MISSOURI	27,106	588	27,694	850	17,160	-	621	8,480	127	8,607	26,388	340	-	-	340	116	-	-	-	-	116	MISSOURI
MONTANA	7,334	-84	7,250	138	5,413	-	253	55	-	55	5,721	1,342	49	-	1,391	-	-	-	-	-	-	MONTANA
NEBRASKA	15,584	50	15,634	491	7,142	5	228	-	-	-	7,375	*4,961	352	-	5,313	36	-	2,419	-	-	2,455	NEBRASKA
NEVADA	2,430	-1	2,429	163	2,174	3	11	78	-	78	2,266	-	-	-	-	-	-	-	-	-	-	NEVADA
NEW HAMPSHIRE	7,011	1	7,012	217	4,938	-	206	816	-	816	5,960	483	-	14/ 352	835	-	-	-	-	-	-	NEW HAMPSHIRE
NEW JERSEY	50,759	17	50,776	2,334	19,537	496	770	5,415	-	5,415	26,218	8,594	-	1,921	10,515	-	-	8,782	1,048	1,879	11,709	NEW JERSEY
NEW MEXICO	7,587	-42	7,545	543	3,852	-	239	1,942	-	1,942	6,033	254	37	-	291	-	678	-	-	-	678	NEW MEXICO
NEW YORK 15/	128,524	-4,970	123,554	2,963	17,707	1,262	1,705	9,653	-	9,653	30,327	*18,976	6,903	-	25,879	-	64,385	-	-	-	64,385	NEW YORK 15/
NORTH CAROLINA	42,292	550	42,842	650	4/ 31,920	-	835	7,858	168	8,026	40,781	(4/)	-	-	-	1,248	-	-	-	163	1,411	NORTH CAROLINA
NORTH DAKOTA	5,696	-30	5,666	282	3,538	-	148	-	-	-	3,686	1,692	-	-	1,692	-	6	-	-	-	6	NORTH DAKOTA
OHIO	92,219	-1,913	90,306	3,449	32,854	-	873	-	-	-	33,727	*24,900	12,792	-	37,692	-	15,139	-	-	299	15,438	OHIO
OKLAHOMA	26,091	-36	26,055	1,581	12,123	-	847	-	-	-	12,970	*7,176	1,549	-	8,725	231	2,333	-	215	-	2,779	OKLAHOMA
OREGON	19,091	-330	18,761	796	11,779	23	376	2,739	11	2,750	14,928	*2,876	6	-	2,882	-	-	-	-	155	155	OREGON
PENNSYLVANIA	106,205	865	107,070	2,347	65,608	174	4,513	5,732	-	5,732	76,027	*12,369	-	-	12,369	-	16,216	-	-	111	16,327	PENNSYLVANIA
RHODE ISLAND 16/	7,713	1	7,714	281	2,315	-	219	246	-	246	2,780	49	-	-	49	-	4,604	-	-	-	4,604	RHODE ISLAND 16/
SOUTH CAROLINA	19,105	98	19,203	386	12,064	-	686	2,366	551	2,917	15,667	*2,646	138	-	2,784	261	105	-	-	-	366	SOUTH CAROLINA
SOUTH DAKOTA	6,965	94	7,059	152	4,674	15	52	20	-	20	4,761	1,974	-	-	1,974	79	93	-	-	-	172	SOUTH DAKOTA
TENNESSEE	32,597	874	33,471	1,400	12,173	39	402	4,764	542	5,306	17,920	6,772	-	-	6,772	1,369	941	-	-	5,069	7,379	TENNESSEE
TEXAS	79,616	-168	79,448	2,801	34,565	-	737	-	9,146	9,146	44,448	*17,755	-	-	17,755	-	1,135	-	13,309	-	14,444	TEXAS
UTAH	5,705	-421	5,284	177	4,018	-	265	14	-	14	4,297	463	337	-	800	-	10	-	-	-	10	UTAH
VERMONT	5,680	1	5,681	87	2,981	12	115	40	-	40	3,148	1,895	-	524	2,419	-	-	-	-	27	27	VERMONT
VIRGINIA	31,750	-7	31,743	714	4/ 29,235	-	763	577	-	577	30,575	4/ 352	102	-	454	-	-	-	-	-	-	VIRGINIA
WASHINGTON	24,987	183	25,170	753	10,923	2	1,671	12/ 142	53	195	12,791	*7,376	2,663	12/ 194	10,233	-	-	12/ 1,207	-	186	1,393	WASHINGTON
WEST VIRGINIA	18,879	1	18,880	171	4/ 10,818	-	16	7,875	-	7,875	18,709	(4/)	-	-	-	-	-	-	-	-	-	WEST VIRGINIA
WISCONSIN 17/	39,629	-	39,629	1,367	11,109	266	-	-	3,643	3,643	15,018	9,278	1,486	-	10,764	-	12,480	-	-	-	12,480	WISCONSIN 17/
WYOMING	3,995	9	4,004	57	2,750	-	78	361	-	361	3,189	758	-	-	758	-	-	-	-	-	-	WYOMING
DISTRICT OF COLUMBIA	5,732	1	5,733	199	-	-	-	-	-	-	-	-	5,266	-	5,266	-	268	-	-	-	268	DISTRICT OF COLUMBIA
TOTAL	1,468,554	-16,543	1,452,011	49,579	653,669	4,157	30,760	108,919	35,784	144,703	833,289	288,548	58,537	7,019	354,104	4,703	148,851	21,661	30,387	9,437	215,039	TOTAL

1/ INCLUDES RECEIPTS FROM MOTOR-FUEL TAXES, MOTOR-VEHICLE FEES AND FINES, AND SPECIAL IMPOSTS ON MOTOR VEHICLES OPERATED FOR HIRE (MOTOR-CARRIER TAXES). SEE TABLES G-3, MV-3, AND MC-2, WHICH GIVE DISTRIBUTION OF RECEIPTS SEPARATELY.

2/ AMOUNTS DISTRIBUTED DURING THE CALENDAR YEAR OFTEN DIFFER FROM ACTUAL COLLECTIONS BECAUSE OF UNDISTRIBUTED FUNDS AND LAG BETWEEN ACCOUNTS OF COLLECTING AND EXPENDING AGENCIES.

3/ INCLUDES EXPENSES OF COLLECTION AND ADMINISTRATION OF MOTOR-FUEL TAX, MOTOR-VEHICLE FEES, AND MOTOR-CARRIER TAXES, AND MISCELLANEOUS EXPENSES OF MOTOR-VEHICLE REGULATION.

4/ THE FOLLOWING AMOUNTS FOR CONSTRUCTION AND MAINTENANCE OF COUNTY ROADS UNDER STATE CONTROL ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES: DELAWARE, $484,000; NORTH CAROLINA, $10,796,000; VIRGINIA, $8,579,000; WEST VIRGINIA, $3,343,000.

5/ AMOUNTS DISTRIBUTED FOR STATE PARK AND FOREST ROADS, ETC. WERE REPORTED SEPARATELY, RATHER THAN UNDER "STATE HIGHWAY PURPOSES", ON TABLE OF FOR YEARS PRIOR TO 1940.

6/ REIMBURSEMENT TO COUNTIES AND LOCAL UNITS OF GOVERNMENT FOR AMOUNTS SPENT ON ROADS NOW ON STATE SYSTEM.

7/ IN STATES INDICATED BY STAR (*) LAW PROVIDES THAT THESE FUNDS MAY ALSO BE USED FOR SERVICE OF LOCAL HIGHWAY OBLIGATIONS. AMOUNTS SO USED NOT REPORTED SEPARATELY. IN COLORADO FUNDS MAY BE USED ON BOTH STATE AND LOCAL ROADS.

8/ THIS COLUMN SHOWS SPECIFIC ALLOTMENTS FOR CITY STREETS. WHERE REPORTED SEPARATELY, FUNDS ALLOTTED FOR URBAN EXTENSIONS OF STATE HIGHWAY SYSTEM ARE INCLUDED IN ALLOTMENTS FOR STATE HIGHWAY PURPOSES.

9/ TO STATE GENERAL FUNDS EXCEPT AS FOLLOWS: ALABAMA, COUNTY AND MUNICIPAL GENERAL FUNDS; CALIFORNIA, $9,461,000 TO COUNTY AND MUNICIPAL GENERAL FUNDS; LOUISIANA, PARISH GENERAL FUNDS; NEW MEXICO, $424,000 TO COUNTY GENERAL FUNDS; WISCONSIN, $1,436,000 TO TOWNS, CITIES, AND VILLAGES IN LIEU OF PERSONAL PROPERTY TAX FORMERLY IMPOSED ON MOTOR VEHICLES. ALLOCATIONS TO COUNTY OR LOCAL GENERAL FUNDS MAY HAVE BEEN USED IN PART FOR HIGHWAYS, BUT SUCH AMOUNTS WERE NOT REPORTED.

10/ FOR THE FOLLOWING PURPOSES: FLORIDA, AVIATION; LOUISIANA, HARBOR IMPROVEMENT; MASSACHUSETTS, RIVER AND HARBOR IMPROVEMENT; NEW JERSEY, DEBT SERVICE ON INSTITUTIONAL CONSTRUCTION BONDS, $524,000; BOARD OF COMMERCE AND NAVIGATION, $812,000, DEFENSE COUNCIL, $500,000, VARIOUS COMMISSIONS, $43,000; NORTH CAROLINA, STATE PROBATION AND PAROLE COMMISSIONS; OHIO, CARE OF INDIGENT PERSONS INJURED IN MOTOR-VEHICLE ACCIDENTS; OREGON, STATE PARKS; PENNSYLVANIA, AVIATION, $101,000, COOPERATIVE WORK OTHER DEPARTMENTS, $10,000; TENNESSEE, DEBT SERVICE ON NONHIGHWAY BONDS; VERMONT, DEBT SERVICE ON NONHIGHWAY PORTION OF FLOOD RELIEF BONDS.

11/ TO METROPOLITAN DISTRICT COMMISSION FOR PARKWAYS AND BOULEVARDS.

12/ INCLUDES DEBT SERVICE CHARGES ON EMERGENCY RELIEF BOND ISSUES, PRORATED IN PROPORTION TO USE OF PROCEEDS FOR STATE HIGHWAYS, LOCAL ROADS AND STREETS, AND NONHIGHWAY PURPOSES.

13/ INCLUDES $287,000 TO GULF COAST COUNTIES FOR SEA-WALL PROTECTION OF STATE HIGHWAYS.

14/ INCLUDES $236,000 PAID ON HIGHWAY RELIEF BONDS ISSUED BY STATE FOR LOCAL ROADS, AND $116,000 ON PRO-RATA SHARE OF HIGHWAY FLOOD BONDS.

15/ APPROPRIATIONS FOR HIGHWAY PURPOSES OUT OF STATE GENERAL FUND HAVE BEEN CREDITED AGAINST PAYMENTS OF MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES TO THE GENERAL FUND AND PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS NOT OTHERWISE DEDICATED.

16/ EXPENDITURES FOR HIGHWAY PURPOSES HAVE BEEN CREDITED AGAINST PAYMENTS OF MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES TO THE STATE GENERAL FUND AND PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS NOT OTHERWISE DEDICATED.

17/ MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES ARE PAID INTO HIGHWAY ACCOUNT OF STATE GENERAL FUND, AND ARE USED FOR ANY PURPOSE, INCLUDING HIGHWAYS. EXPENDITURES FOR HIGHWAY PURPOSES HAVE BEEN CREDITED AGAINST RECEIPTS FROM MOTOR-FUEL TAX AND MOTOR-VEHICLE REVENUES, PRORATED IN PROPORTION TO NET RECEIPTS FROM THESE IMPOSTS.

U. S. GOVERNMENT PRINTING OFFICE: 1942

PUBLICATIONS of the PUBLIC ROADS ADMINISTRATION

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Agency and as the Agency does not sell publications, please send no remittance to the Federal Works Agency.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1932. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1938. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1939. 10 cents.

Work of the Public Roads Administration, 1940, 10 cents.

Work of the Public Roads Administration, 1941, 15 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

No. 191MP. . Roadside Improvement. 10 cents.

No. 272MP. . Construction of Private Driveways. 10 cents.

No. 279MP. . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

Transition Curves for Highways. 60 cents.

Highways of History. 25 cents.

Specifications for Construction of Roads and Bridges in National Forests and National Parks. 1 dollar.

DEPARTMENT BULLETINS

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T . . . Highway Bridge Surveys. 20 cents.

No. 265T. . . Electrical Equipment on Movable Bridges. 35 cents.

Single copies of the following publications may be obtained from the Public Roads Administration upon request. They cannot be purchased from the Superintendent of Documents.

MISCELLANEOUS PUBLICATIONS

No. 296MP. . Bibliography on Highway Safety.

House Document No. 272 . . . Toll Roads and Free Roads.

Indexes to PUBLIC ROADS, volumes 6–8 and 10–22, inclusive.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

REPORTS IN COOPERATION WITH UNIVERSITY OF ILLINOIS

No. 303. . . Solutions for Certain Rectangular Slabs Continuous Over Flexible Supports.

No. 304. . . A Distribution Procedure for the Analysis of Slabs Continuous Over Flexible Beams.

No. 313. . . Tests of Plaster-Model Slabs Subjected to Concentrated Loads.

No. 314. . . Tests of Reinforced Concrete Slabs Subjected to Concentrated Loads.

No. 315. . . Moments in Simple Span Bridge Slabs With Stiffened Edges.

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Public Roads Administration, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to Public Roads Administration, North Interior Bldg., Washington, D. C.