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U S 1 near Newark Airport, N. J., carries one of the heaviest traffic loads in the world

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E. A. STROMBERG, Editor

Traffic Trends on Rural Roads in 1946

BY THE DIVISION OF HIGHWAY TRANSPORT RESEARCH PUBLIC ROADS ADMINISTRATION

Reported by THOMAS B. DIMMICK, Highway Economist and MARY E. KIPP, Statistician

Total rural-road traffic in 1946 broke all previous records, exceeding the previous high in 1941 by a slight margin. The seasonal summer peak in 1946, however, was somewhat less than that in 1941.

On the main rural roads of the country, travel in 1946 was over 124 billion vehicle-miles, of which about 80 percent was by passenger cars. Commercial vehicles carried 21 percent more ton-mileage of freight in 1946 than in the previous year, but the proportion of trucks loaded dropped 6 percent. The average weight of carried load remained about the same.

The sharp rise in use of heavier commercial vehicles that occurred during the war was undiminished in 1946. Truck-combination travel was 27 percent higher than in 1941. Axle loads were 31 percent heavier than in the prewar period, and the frequency of heavy axle loads was five times greater. Gross loads have also increased greatly, and heavy loads are far more common than in the prewar period.

TRENDS in total rural traffic reported in this analysis are derived largely from the records received from approximately 670 automatic traffic-recorder stations operated continuously throughout the year on rural roads in 48 States. The automatic-counter records provide no classifications by vehicle type. Such information, and trends in volumes, weights, and characteristics of truck traffic reported here were obtained from the summer survey described in another part of this article. Supplemental counts made by many States yielded valuable information concerning total traffic and the classification of vehicles. Consideration has been given to all available data, but the most reliable of the information, or that derived from the traffic sample with the most complete coverage, is given preference here. In instances where the States have prepared and submitted vehicle-mile estimates for State systems, these have been employed rather than estimates made by applying trend factors to data of previous years.

In figure 1 is demonstrated the variation in rural traffic by months in the year 1941, the peak prewar year; the year 1943, the war year during which traffic was lowest; the year 1945, when traffic increased sharply after VJ-day as gasoline rationing was terminated; and in the year 1946, the first full postwar year. It is interesting to note the differences in the traffic patterns during these years when such varying circumstances existed. While 1946 traffic exceeded that of 1941 by a small percentage, the peak of 1946 traffic was appreciably below that of 1941, when traffic during the summer months was considerably higher than in any other year.

The monthly relations of traffic in the years 1942 through 1946 on all rural roads to that in corresponding months in 1941 are shown in figure 2. Apparent from this chart is the great postwar increase in traffic in the Western States—probably due to the migration of population to the west coast, which was pronounced during the war years. For the same reason, traffic decreased less during the war in the western regions than in other parts of the country. In contrast, traffic in 1946 in the eastern portions of the country generally failed to meet the levels attained in 1941.

Traffic information is analyzed in this report for the United States as a whole, for each census region, and generally for three groups of regions that roughly represent the eastern seaboard, the Central States, and the Western States. The States comprising each of the census regions are indicated in the first column of table 4, page 44. The data available are not deemed sufficient to justify presentation of separate statistics for each State.

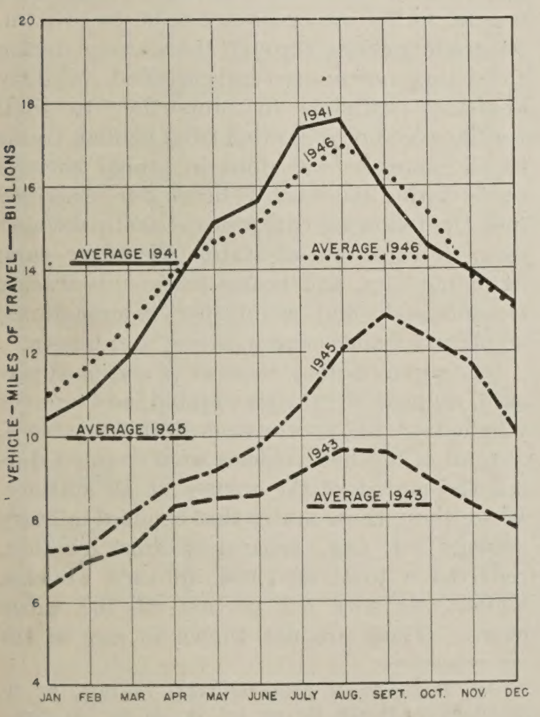

Figure 1.—Vehicle-miles of travel on all rural roads in 1941, 1943, 1945, and 1946, by months.

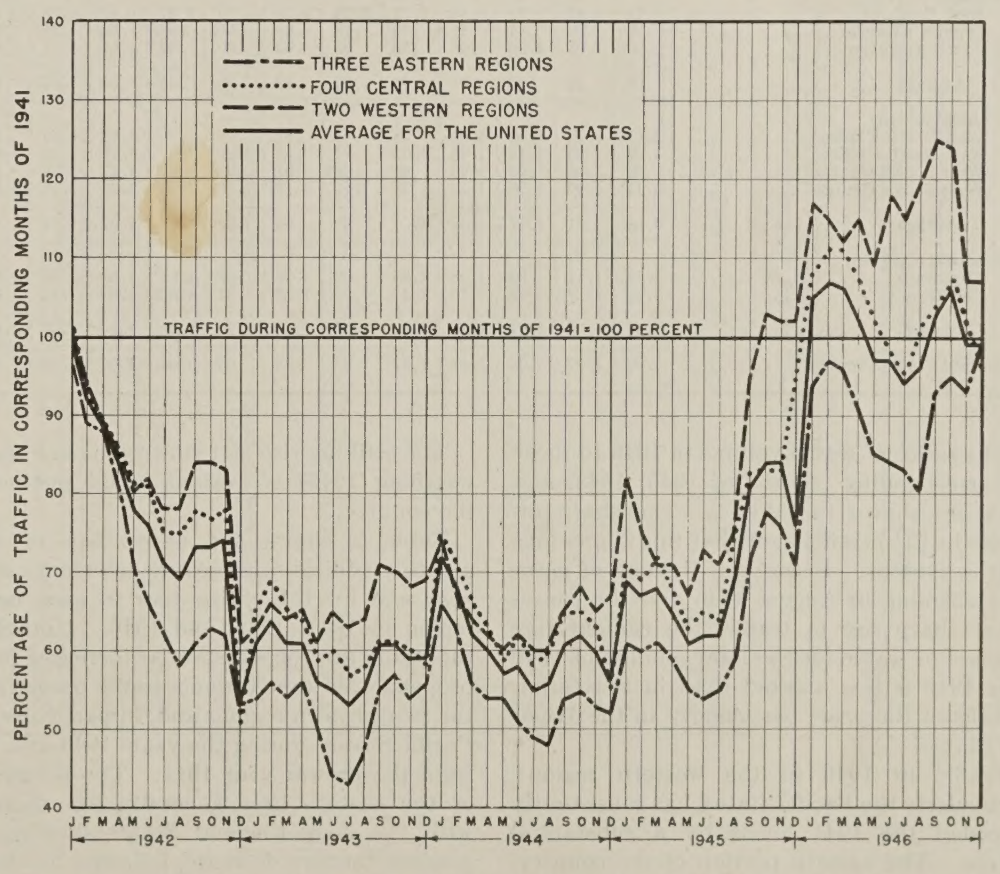

Figure 2.—Relation of rural traffic in the years 1942–46 to that in corresponding months of 1941, expressed as percentages.

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Table 1.—*Ratio of traffic volume in 1946 to that in corresponding months of 1945, 1943, and 1941, as determined from automatic traffic-recorder data*

RATIO OF 1946 TRAFFIC TO 1945 TRAFFIC

Region	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Eastern regions:												
New England	1.49	1.48	1.55	1.54	1.62	1.65	1.63	1.42	1.26	1.26	1.22	1.29
Middle Atlantic	1.62	1.62	1.56	1.55	1.54	1.56	1.47	1.26	1.32	1.22	1.23	1.57
South Atlantic	1.55	1.63	1.59	1.56	1.55	1.56	1.51	1.42	1.28	1.21	1.22	1.30
Average	1.56	1.61	1.58	1.55	1.56	1.57	1.51	1.35	1.29	1.22	1.23	1.40
Central Regions:												
East North Central	1.64	1.69	1.58	1.70	1.77	1.57	1.52	1.35	1.22	1.31	1.15	1.26
East South Central	1.47	1.61	1.49	1.47	1.51	1.40	1.39	1.31	1.29	1.26	1.23	1.49
West North Central	1.29	1.45	1.42	1.50	1.50	1.49	1.54	1.42	1.23	1.23	1.27	1.40
West South Central	1.58	1.70	1.59	1.52	1.60	1.50	1.49	1.41	1.32	1.33	1.23	1.31
Average	1.51	1.62	1.53	1.57	1.63	1.51	1.50	1.37	1.25	1.28	1.21	1.34
Western regions:												
Mountain	1.38	1.50	1.44	1.52	1.50	1.60	1.57	1.48	1.27	1.14	1.13	1.22
Pacific	1.47	1.54	1.64	1.67	1.70	1.63	1.63	1.66	1.34	1.25	1.02	0.99
Average	1.44	1.53	1.57	1.62	1.63	1.62	1.61	1.60	1.32	1.21	1.05	1.05
United States average	1.52	1.60	1.55	1.58	1.61	1.55	1.52	1.40	1.28	1.25	1.19	1.30
RATIO OF 1946 TRAFFIC TO 1943 TRAFFIC												
Eastern regions:												
New England	1.65	1.60	1.66	1.55	1.67	2.05	2.09	1.77	1.79	1.80	1.84	1.74
Middle Atlantic	1.69	1.70	1.75	1.59	1.73	1.97	1.97	1.64	1.74	1.69	1.74	1.92
South Atlantic	1.82	1:78	1.80	1.69	1.70	1.86	1.86	1.71	1.61	1.64	1.68	1.68
Average	1.74	1.73	1.76	1.63	1.71	1.93	1.94	1.69	1.70	1.69	1.72	1.78
Central regions:												
East North Central	1.61	1.56	1.67	1.67	1.70	1.57	1.60	1.63	1.52	1.68	1.52	1.51
East South Central	1.52	1.55	1.61	1.53	1.52	1.46	1.51	1.73	1.68	1.67	1.66	1.69
West North Central	1.41	1.39	1.50	1.49	1.51	1.57	1.63	1.66	1.62	1.63	1.64	1.55
West South Central	1.72	1.68	1.74	1.67	1.76	1.66	1.69	1.74	1.72	1.77	1.72	1.71
Average	1.58	1.55	1.64	1.61	1.64	1.58	1.61	1.67	1:61	1.69	1.62	1.60
Western regions:												
Mountain	1.61	1.62	1.61	1.58	1.66	1.71	1.80	1.86	1.65	1.64	1.53	1.64
Pacific	2.03	1.87	1.91	1.93	1.92	1.92	1.90	1.94	1.85	1.91	1.66	1.58
Average	1.88	1.78	1.80	1.80	1.83	1.84	1.86	1.92	1.78	1.82	1.61	1.60
United States average	1.67	1.64	1.70	1.64	1.69	1.72	1.75	1.72	1.67	1.71	1.65	1.65
RATIO OF 1946 TRAFFIC TO 1941 TRAFFIC												
Eastern regions:												
New England	0.91	0.83	0.98	0.84	0.77	0.76	0.74	0.70	0.87	0.87	0.78	0.80
Middle Atlantic	.92	.96	.84	.87	.79	.78	.81	.75	.93	.93	.91	1.06
South Atlantic	.97	1.01	1.05	.96	.96	.95	.90	.90	.96	1.02	1.01	1.01
Average	.94	.97	.96	.91	.85	.84	.83	.80	.93	.95	.93	.99
Central regions:												
East North Central	1.07	1.13	1.12	1.05	.98	.92	.87	.96	.99	1.02	.90	.87
East South Central	1.07	1.13	1.13	1.06	1.02	.97	.94	1.09	1.07	1.09	1.12	1.05
West North Central	.99	.98	.99	.98	.91	.95	.94	.94	1.01	1.03	.98	.94
West South Central	1.17	1.22	1.20	1.20	1.21	1.15	1.17	1.16	1.15	1.20	1.16	1.08
Average	1.08	1.11	1.11	1.07	1.02	.98	.95	1.01	1.04	1.07	1.01	.96
Western regions:												
Mountain	1.11	1.12	.99	1.08	1.00	1.06	1.01	1.08	1.11	1.08	.99	1.09
Pacific	1.21	1.17	1.19	1.19	1.14	1.25	1.23	1.27	1.32	1.33	1.11	1.07
Average	1.17	1.15	1.12	1.15	1.09	1.18	1.15	1.20	1.25	1.24	1.07	1.07
United States average	1.05	1.07	1.06	1.02	.97	.97	.94	.96	1.03	1.06	.99	.99

The ratios of traffic volume in 1946 to those in corresponding months of 1945, 1943, and 1941 are shown in table 1. The sharp increase in 1946 traffic over that in the previous year is evident. Because of the end of gasoline rationing in August 1945 and the consequent sharp rise in traffic, the comparative increase in traffic for the later months of 1946 over 1945 is less marked than in the earlier months of the year, particularly in the Western States.

Traffic in 1946 in the western regions, particularly the Pacific States, has consistently exceeded the 1941 levels by a substantial degree. The eastern portion of the country, especially the New England States, has remained generally below the 1941 figure.

The striking rise of 1946 traffic over that of wartime (1943) is evident in all sections of the country.

Table 2 shows the percentage of total monthly vehicle-mileage for each month of the year and for the entire year in each census region in 1941, 1943, and 1946. Notable in this table are the substantial increases in the proportion of the Nation's traffic occurring in the two western regions and, in particular, the Pacific States, during the years 1943 and 1946 from the prewar year 1941. The percentage of the eastern area generally has declined, with the New England States showing the greatest relative decrease, followed by that of the Middle Atlantic States. The central section of the country, on the whole, has remained comparatively stable in this respect; however, the percentages in the south-central portion have increased, while those of the north-central region have decreased.

Table 3 indicates the differences among the annual traffic patterns for the years 1941, 1943, and 1946, showing the percentage of traffic in each month of these years by regions. Normally, for the United States as a whole, the summer months of July and August have higher percentages of traffic than any other month of the year. This is generally true for the years shown; however, summer travel in both 1943 and 1946 was lower in proportion to total yearly traffic than it was in 1941, indicating that prewar summer travel peaks were not yet recovered in 1946.

SUMMER SURVEY ON MAIN RURAL ROADS

During the summer of 1946 the highway departments of 47 States, in cooperation with the Public Roads Administration, conducted a survey to obtain data concerning the volume and composition of traffic and the weights of trucks and truck combinations on rural roads for the determination of trends in traffic. This survey was similar in character to surveys conducted by the several States in 1942, 1943, 1944, and 1945.[1]

The majority of weighing stations were operated during July, August, or September, with Mississippi extending operations through October. This survey was accomplished in every State except South Carolina.

Data were obtained from 541 weighing stations, all of which had been used in the 1945 survey or in the most recent survey made by the State. The work was so scheduled as to insure maximum comparability with information obtained in previous years.

These stations, which were selected initially to effect a representative cross section of traffic on main rural roads, were generally operated for 8 hours on a weekday, either from 6 a. m. to 2 p. m. or from 2 p. m. to 10 p. m. All traffic passing through the stations during the period was counted and classified. Military vehicles, negligible in proportion to total traffic, were not separated from civilian traffic in all States as was done in similar surveys made during the war. Vehicles were classified into the following categories: Local passenger cars; foreign (out-of-State) passenger cars; light, medium, and heavy single-unit trucks; tractor-truck and semitrailer combinations; truck and trailer combinations; and busses.

The survey period, number of stations operated, number of vehicles counted, and number weighed are shown for each State in table 4. A total of 868,095 vehicles were counted during the period of the survey at all stations. In addition, those States that counted military vehicles, if any, separately from civilian, reported a total of 1,606 military vehicles, which was only 0.2 percent of the entire count. These are not shown in any of the

[1] See *Traffic trends on rural roads in 1945*, by T. B. Dimmick; PUBLIC ROADS, vol. 24, No. 10; Oct.-Nov.-Dec. 1946; and *Amount and characteristics of trucking on rural roads*, by J. T. Lynch and T. B. Dimmick; PUBLIC ROADS, vol. 23, No. 9; July-Aug.-Sept. 1943.

Table 2.—*Percentage of total monthly traffic on rural roads in each United States census region in 1941, 1943, and 1946*

Period		Eastern regions				Central regions					Western regions			United States total
		New England	Middle Atlantic	South Atlantic	Total	East North Central	East South Central	West North Central	West South Central	Total	Mountain	Pacific	Total	
January:	1941	4.60	13.10	16.45	34.15	18.32	6.71	11.58	13.48	50.09	5.19	10.57	15.76	100.00
	1943	4.10	11.71	14.41	30.22	18.47	7.40	13.03	14.56	53.46	5.87	10.45	16.32	100.00
	1946	3.99	11.51	15.30	30.80	18.72	6.86	10.91	15.07	51.56	5.49	12.15	17.64	100.00
February:	1941	5.06	12.54	15.88	33.48	18.36	6.59	12.49	12.87	50.31	5.30	10.91	16.21	100.00
	1943	4.07	11.04	14.20	29.31	19.21	7.20	13.48	14.16	54.05	5.77	10.87	16.64	100.00
	1946	3.94	11.23	15.09	30.26	19.32	6.97	11.36	14.67	52.32	5.53	11.89	17.42	100.00
March:	1941	5.02	13.05	15.17	33.24	19.11	6.41	12.31	12.60	50.43	5.78	10.55	16.33	100.00
	1943	4.77	10.28	14.48	29.53	19.64	6.97	13.19	13.17	53.50	5.93	11.04	16.97	100.00
	1946	4.62	10.35	15.07	30.04	20.22	6.78	11.51	14.21	52.72	5.41	11.83	17.24	100.00
April:	1941	5.61	14.59	14.86	35.06	19.87	6.19	12.19	11.26	49.51	5.25	10.18	15.43	100.00
	1943	4.93	13.10	13.91	31.94	19.03	6.69	13.05	12.86	51.63	5.97	10.46	16.43	100.00
	1946	4.61	12.43	14.00	31.04	20.38	6.39	11.70	13.18	51.65	5.53	11.78	17.31	100.00
May:	1941	5.95	15.38	13.42	34.75	20.58	6.06	12.48	10.34	49.46	5.39	10.40	15.79	100.00
	1943	4.86	12.47	13.43	30.76	19.64	6.93	13.27	12.24	52.08	5.91	11.25	17.16	100.00
	1946	4.75	12.50	13.24	30.49	20.80	6.38	11.71	12.86	51.75	5.56	12.20	17.76	100.00
June:	1941	6.00	15.21	13.70	34.91	20.28	6.08	12.51	10.74	49.61	5.61	9.87	15.48	100.00
	1943	4.01	10.92	12.80	27.73	20.14	7.02	13.67	13.10	53.93	6.41	11.93	18.34	100.00
	1946	4.74	12.26	13.55	30.55	19.41	6.10	12.31	12.76	50.58	6.13	12.74	18.87	100.00
July:	1941	6.49	15.22	13.77	35.48	20.81	6.09	12.18	9.84	48.92	5.70	9.90	15.60	100.00
	1943	4.32	11.84	12.66	28.82	20.04	6.83	13.17	12.53	52.57	6.20	12.41	18.61	100.00
	1946	5.10	13.07	13.22	31.39	19.21	6.06	12.10	12.20	49.57	6.14	12.90	19.04	100.00
August:	1941	6.63	15.87	13.47	35.97	20.60	5.86	12.49	9.78	48.73	5.50	9.80	15.30	100.00
	1943	4.74	13.21	12.96	30.91	20.34	6.49	12.79	11.56	51.18	5.94	11.97	17.91	100.00
	1946	4.83	12.35	12.62	29.80	20.45	6.65	12.17	11.82	51.09	6.17	12.94	19.11	100.00
September:	1941	6.12	15.27	13.37	34.76	20.36	6.29	12.37	10.76	49.78	5.32	10.14	15.46	100.00
	1943	4.87	13.44	13.26	31.57	19.86	6.35	12.53	11.46	50.20	6.03	12.20	18.23	100.00
	1946	5.18	13.75	12.53	31.46	19.46	6.49	12.02	11.92	49.89	5.70	12.95	18.65	100.00
October:	1941	6.08	14.53	13.64	34.25	19.85	6.43	12.78	11.26	50.32	5.42	10.01	15.43	100.00
	1943	4.78	13.11	13.95	31.84	18.48	6.60	13.16	12.16	50.40	5.99	11.77	17.76	100.00
	1946	5.00	12.74	13.17	30.91	19.14	6.61	12.42	12.78	50.95	5.52	12.62	18.14	100.00
November:	1941	5.86	14.14	14.30	34.30	19.76	6.20	12.60	11.82	50.38	5.39	9.93	15.32	100.00
	1943	4.16	12.51	14.66	31.33	18.53	6.83	12.68	13.06	51.10	6.04	11.53	17.57	100.00
	1946	4.61	12.93	14.62	32.16	18.00	7.02	12.50	13.80	51.32	5.39	11.13	16.52	100.00
December:	1941	5.39	12.94	14.89	33.22	19.79	6.72	12.43	13.11	52.05	4.84	9.89	14.73	100.00
	1943	4.19	12.13	15.26	31.58	18.01	6.85	12.66	13.71	51.23	5.56	11.63	17.19	100.00
	1946	4.36	13.81	15.24	33.41	17.33	7.14	11.82	14.34	50.63	5.29	10.67	15.96	100.00
Total:	1941	5.82	14.48	14.27	34.57	19.93	6.27	12.38	11.31	49.89	5.40	10.14	15.54	100.00
	1943	4.50	12.22	13.77	30.49	19.33	6.82	13.04	12.82	52.01	5.98	11.52	17.50	100.00
	1946	4.69	12.48	13.85	31.02	19.41	6.59	11.92	13.17	51.09	5.68	12.21	17.89	100.00

Table 3.—*Percentage of annual traffic in each month in 1941, 1943, and 1946*

Period		Eastern regions				Central regions					Western regions			United States total
		New England	Middle Atlantic	South Atlantic	Total	East North Central	East South Central	West North Central	West South Central	Total	Mountain	Pacific	Total	
January:	1941	4.84	5.54	7.06	6.05	5.63	6.56	5.72	7.30	6.15	5.89	6.39	6.21	6.12
	1943	5.86	6.16	6.73	6.37	6.14	6.98	6.42	7.30	6.61	6.31	5.83	5.99	6.43
	1946	5.44	5.90	7.06	6.35	6.16	6.65	5.85	7.32	6.45	6.18	6.36	6.30	6.39
February:	1941	5.59	5.57	7.16	6.23	5.93	6.76	6.49	7.33	6.49	6.31	6.93	6.71	6.43
	1943	6.36	6.36	7.27	6.77	6.91	7.43	7.28	7.78	7.32	6.80	6.65	6.70	7.05
	1946	5.76	6.16	7.46	6.68	6.82	7.24	6.53	7.63	7.01	6.66	6.67	6.67	6.85
March:	1941	6.06	6.33	7.46	6.75	6.73	7.17	6.98	7.82	7.10	7.51	7.30	7.37	7.02
	1943	7.80	6.20	7.75	7.14	7.48	7.53	7.44	7.87	7.58	7.30	7.06	7.14	7.37
	1946	7.31	6.15	8.08	7.19	7.73	7.63	7.16	8.01	7.66	7.06	7.19	7.15	7.42
April:	1941	7.69	8.05	8.32	8.10	7.96	7.89	7.86	7.95	7.93	7.76	8.03	7.93	7.99
	1943	9.15	8.96	8.44	8.76	8.23	8.20	8.36	8.38	8.30	8.34	7.59	7.85	8.36
	1946	8.01	8.11	8.24	8.15	8.55	7.90	7.99	8.15	8.23	7.93	7.86	7.88	8.15
May:	1941	9.06	9.43	8.34	8.92	9.16	8.58	8.94	8.11	8.80	8.85	9.10	9.01	8.87
	1943	9.23	8.72	8.34	8.62	8.69	8.69	8.70	8.16	8.56	8.45	8.35	8.38	8.55
	1946	8.68	8.60	8.21	8.44	9.20	8.31	8.43	8.38	8.69	8.40	8.58	8.53	8.58
June:	1941	9.46	9.65	8.82	9.27	9.35	8.91	9.28	8.72	9.14	9.53	8.94	9.15	9.18
	1943	7.70	7.73	8.04	7.87	9.02	8.91	9.07	8.85	8.97	9.28	8.96	9.07	8.65
	1946	8.92	8.67	8.63	8.69	8.82	8.15	9.11	8.55	8.73	9.52	9.21	9.31	8.82
July:	1941	11.37	10.71	9.84	10.46	10.65	9.90	10.02	8.87	9.99	10.74	9.95	10.23	10.19
	1943	8.83	8.91	8.45	8.69	9.53	9.21	9.28	8.99	9.29	9.53	9.91	9.78	9.19
	1946	10.39	9.99	9.10	9.65	9.45	8.76	9.69	8.84	9.26	10.31	10.08	10.15	9.54
August:	1941	11.76	11.33	9.76	10.75	10.68	9.67	10.42	8.93	10.09	10.51	9.98	10.17	10.33
	1943	10.21	10.49	9.13	9.83	10.21	9.23	9.51	8.75	9.54	9.63	10.09	9.93	9.70
	1946	10.21	9.80	9.03	9.52	10.44	9.99	10.11	8.89	9.91	10.74	10.50	10.58	9.90
September:	1941	9.80	9.84	8.74	9.38	9.53	9.36	9.31	8.87	9.30	9.19	9.32	9.28	9.33
	1943	10.47	10.65	9.33	10.02	9.95	9.02	9.30	8.66	9.35	9.77	10.26	10.09	9.68
	1946	10.58	10.57	8.67	9.72	9.61	9.44	9.67	8.68	9.36	9.63	10.17	10.00	9.59
October:	1941	8.94	8.60	8.19	8.49	8.54	8.78	8.84	8.53	8.64	8.59	8.46	8.51	8.57
	1943	9.46	9.58	9.04	9.32	8.53	8.64	9.00	8.46	8.64	8.94	9.12	9.06	8.92
	1946	9.62	9.21	8.57	8.99	8.89	9.04	9.40	8.75	8.99	8.77	9.32	9.14	9.02
November:	1941	8.25	8.01	8.22	8.14	8.13	8.11	8.35	8.58	8.28	8.17	8.03	8.08	8.21
	1943	7.66	8.48	8.82	8.52	7.95	8.31	8.06	8.44	8.14	8.38	8.30	8.33	8.29
	1946	7.96	8.38	8.54	8.39	7.50	8.61	8.48	8.48	8.13	7.67	7.38	7.47	8.09
December:	1941	7.18	6.94	8.09	7.46	7.71	8.31	7.79	8.99	8.09	6.95	7.57	7.35	7.76
	1943	7.27	7.76	8.66	8.09	7.28	7.85	7.58	8.36	7.70	7.27	7.88	7.68	7.81
	1946	7.12	8.46	8.41	8.23	6.83	8.28	7.58	8.32	7.58	7.13	6.68	6.82	7.65
Total:	1941	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	1943	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	1946	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.—*Survey period, number of stations operated, number of vehicles counted, and number weighed in each State in the special weight survey during the summer of 1946*

Region and State	Survey period	Number of stations	Vehicles counted: All vehicles	Vehicles counted: Trucks and combinations	Trucks and combinations weighed
New England:					
Connecticut	Aug. 5-28	10	27,424	3,886	1,671
Maine	July 29-Aug. 9	8	15,675	2,644	1,167
Massachusetts	do	10	26,631	4,747	2,001
New Hampshire	July 29-Aug. 2	5	12,073	1,437	531
Rhode Island	do	5	9,422	1,979	811
Vermont	Aug. 5-9	5	8,053	602	602
Subtotal		43	99,278	15,295	6,783
Middle Atlantic:					
New Jersey	Aug. 5-21	10	54,419	9,855	2,201
New York	Sept. 23-27	20	33,349	7,933	3,167
Pennsylvania	Aug. 5-13	11	31,666	5,511	1,488
Subtotal		41	119,434	23,299	6,856
South Atlantic:					
Delaware	Sept. 9-12	4	11,434	3,022	464
Florida	June 12-July 5	10	10,725	2,071	1,802
Georgia	Aug. 5-23	10	11,066	2,459	1,777
Maryland	July 29-Aug. 16	10	31,221	6,020	1,040
North Carolina	Aug. 6-23	10	17,115	3,603	2,240
South Carolina	No survey				
Virginia	July 31-Aug. 14	10	15,517	3,838	2,149
West Virginia	Aug. 13-Sept. 5	9	9,585	2,385	1,083
Subtotal		63	106,663	23,398	10,555
Eastern regions, subtotal		147	325,375	61,992	24,194
East North Central:					
Illinois	Aug. 13-Sept. 5	44	69,916	8,173	4,176
Indiana	July 31-Aug. 30	20	33,313	7,330	3,059
Michigan	July 25-Aug. 8	10	24,191	3,616	1,616
Ohio	July 23-Aug. 9	10	19,110	3,257	1,015
Wisconsin	July 25-Aug. 9	12	20,890	3,024	2,379
Subtotal		96	167,420	25,400	12,245
East South Central:					
Alabama	Aug. 14-29	10	9,024	2,025	1,413
Kentucky	July 8-19	10	10,366	2,370	865
Mississippi	July 10-Oct. 30	15	16,272	3,094	737
Tennessee	July 23-Aug. 30	10	8,940	2,215	1,709
Subtotal		45	44,602	9,704	4,724
West North Central:					
Iowa	July 22-31	10	10,037	1,780	1,687
Kansas	Aug. 7-20	10	7,958	1,581	867
Minnesota	Aug. 5-16	8	10,605	2,045	1,164
Missouri	July 29-Aug. 16	14	35,137	6,854	5,469
Nebraska	July 18-Aug. 8	11	9,148	2,000	1,927
North Dakota	Aug. 1-28	10	12,265	2,601	1,901
South Dakota	July 29-Aug. 15	12	5,848	1,018	1,002
Subtotal		75	90,998	17,879	14,017
West South Central:					
Arkansas	Aug. 5-16	10	12,809	3,485	1,553
Louisiana	July 29-Aug. 9	10	7,014	1,859	1,377
Oklahoma	July 25-Aug. 7	10	11,601	2,585	2,498
Texas	July 22-Aug. 19	18	23,780	5,180	3,037
Subtotal		48	55,204	13,109	8,465
Central regions, subtotal		264	358,224	66,092	39,451
Mountain:					
Arizona	May 7-June 7	10	7,439	1,336	594
Colorado	July 9-23	10	20,564	3,501	686
Idaho	Aug. 5-21	12	11,198	1,996	1,280
Montana	July 31-Aug. 28	19	13,573	2,606	2,418
Nevada	July 30-Aug. 13	10	5,527	851	772
New Mexico	July 29-Aug. 14	10	8,979	1,888	1,304
Utah	July 29-Aug. 9	10	11,934	2,318	660
Wyoming	Aug. 6-19	10	7,270	789	745
Subtotal		91	86,484	15,285	8,459
Pacific:					
California	May 29-July 3	20	64,487	10,465	3,738
Oregon	Aug. 12-30	9	16,790	2,755	1,102
Washington	Sept. 4-7	10	16,735	2,182	1,679
Subtotal		39	98,012	15,402	6,519
Western regions, subtotal		130	184,496	30,687	14,978
United States total		541	868,095	158,771	78,623

tables. Trucks and truck combinations numbered 158,771, or 18.3 percent of the total counted. Of these 78,623, or 49.5 percent, were stopped and weighed.

Wherever traffic volume permitted, all civilian trucks and combinations were stopped and weighed, but where this procedure was impracticable, a sample was obtained by weighing at random as many as possible of those which passed the station. Passenger cars and busses were counted but not stopped for weighing purposes. The heavier vehicles, or the single-unit trucks weighing 13 tons or more and combinations weighing 17 tons or more, when stopped, were measured as well as weighed. The type of vehicle, whether it was loaded or empty, and the number and spacing of axles were recorded, as well as the load on each wheel on one side of the vehicle.

COMPARISON OF 1946 AND 1945 SUMMER SURVEYS

The ratios of 1946 summer traffic to corresponding counts in 1945 are given by type of vehicle in table 5. As previously stated, military traffic during 1946 was negligible and is excluded in the present comparison. Particularly outstanding in this table is the striking rise in numbers of passenger cars counted in 1946, especially foreign (out-of-State) passenger cars, which is due in part to the resumption of peacetime vacation travel habits, despite the fact that production of new automobiles has not satiated the demand. Considering the 1946–45 ratio of trucks, generally, travel by single-unit trucks increased more than that by combinations except throughout the Western States where the trend is toward the greater use of the heavier type commercial vehicle.

Table 6 shows the percentage distribution of total traffic by vehicle type in 1946 and 1945. The increases in percentage of passenger cars to total vehicles in 1946 compared with 1945 were largely due to the rise in foreign or out-of-State traffic during 1946.

The average weights of loaded and of empty trucks and combinations in the summer of 1946 and in a corresponding period of 1945 and 1943 are shown in table 7. Contrasting 1946 to 1943, this table indicates that the average weight of loaded single-unit trucks increased 4 percent, that the average weight of loaded combinations increased 10 percent, while the average weight of all loaded trucks and combinations increased 8 percent. Similarly, comparing 1946 with 1945, the average weight of loaded single-unit trucks decreased 3 percent while the average weight of loaded combinations increased 3 percent, and a slight drop was evident in the average weight of all loaded trucks and combinations.

Table 7 indicates that empty weight of the average truck in 1946 declined 4 percent below that of the previous year. Comparing 1946 figures with those of 1943, an increase of 2 percent is evident for the average of all empty trucks. These variations correspond roughly to those shown for loaded vehicles.

VEHICLE-MILES AND TON-MILEAGE OF FREIGHT HAULED

A comparison by census regions of the estimated vehicle-miles of travel on all main rural roads in 1941, 1943, 1945, and 1946 is shown in table 8. Vehicle-miles of all vehicles on main rural roads in 1946 rose sharply in all sections of the country with travel throughout the United States 45 percent over 1945. Truck travel showed an over-all rise of 29 percent and increased in all regions except the Pacific States where single-unit truck travel declined to 88 percent of the previous year's figure. With the rise in passenger-car travel in the first full postwar year, the proportion of truck travel to that of all vehicles generally decreased, in contrast to 1945. In relation to

Table 5.—*Ratio of 1946 summer counts to corresponding counts in 1945*

Vehicle type	Eastern regions				Central regions					Western regions			United States average
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average	
All civilian vehicles	1.46	1.45	1.45	1.45	1.48	1.31	1.47	1.48	1.45	1.46	1.42	1.44	1.45
Passenger cars:													
All	1.52	1.51	1.49	1.50	1.53	1.29	1.50	1.53	1.49	1.47	1.58	1.55	1.51
Local	1.38	1.43	1.36	1.39	1.40	1.20	1.29	1.57	1.39	1.05	1.56	1.42	1.39
Foreign	1.96	2.06	1.95	1.98	2.18	1.60	2.56	1.34	1.96	2.37	1.72	2.07	1.98
Trucks and combinations:													
All	1.24	1.27	1.38	1.32	1.25	1.41	1.36	1.39	1.34	1.47	.97	1.11	1.29
Single units	1.25	1.29	1.43	1.35	1.32	1.42	1.36	1.42	1.38	1.44	.88	1.08	1.31
Combinations	1.17	1.22	1.27	1.24	1.12	1.38	1.37	1.29	1.24	1.58	1.11	1.18	1.23
Busses	1.11	.97	.98	.99	1.09	1.11	1.14	.85	1.03	.98	1.11	1.07	1.02

Table 6.—*Percentage distribution by vehicle types in the summer of 1946 and in a corresponding period of 1945*

Region	Passenger cars						Trucks and truck combinations						Busses	
	All		Local		Foreign		All		Single units		Combinations			
	1946	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946	1945
Eastern regions:														
New England	81.73	78.30	56.26	59.35	25.47	18.95	16.71	19.65	13.72	15.92	2.99	3.73	1.56	2.05
Middle Atlantic	79.81	76.56	65.61	66.55	14.20	10.01	19.14	21.88	14.41	16.24	4.73	5.64	1.05	1.56
South Atlantic	76.00	74.03	53.69	57.38	22.31	16.65	22.43	23.63	16.35	16.67	6.08	6.96	1.57	2.34
Average	78.31	75.63	58.71	61.25	19.60	14.38	20.32	22.38	15.21	16.40	5.11	5.98	1.37	1.99
Central regions:														
East North Central	83.65	80.50	62.74	66.36	20.91	14.14	15.57	18.44	10.38	11.59	5.19	6.85	.78	1.06
East South Central	76.51	77.67	53.93	59.16	22.58	18.51	21.54	20.02	17.90	16.56	3.64	3.46	1.95	2.31
West North Central	77.49	75.53	55.20	62.78	22.29	12.75	21.65	23.36	16.92	18.29	4.73	5.07	.86	1.11
West South Central	76.10	73.84	63.31	59.65	12.79	14.19	22.91	24.44	17.38	18.10	5.53	6.34	.99	1.72
Average	79.38	77.27	60.00	62.87	19.38	14.40	19.63	21.33	14.65	15.49	4.98	5.84	.99	1.40
Western regions:														
Mountain	76.91	76.48	37.78	52.36	39.13	24.12	22.01	21.90	18.04	18.24	3.97	3.66	1.08	1.62
Pacific	82.03	73.73	69.99	63.76	12.04	9.97	16.91	24.92	9.49	15.39	7.42	9.53	1.06	1.35
Average	80.34	74.62	59.36	60.05	20.98	14.57	18.59	23.94	12.31	16.31	6.28	7.63	1.07	1.44
United States average	79.21	76.26	59.47	61.83	19.74	14.43	19.66	22.14	14.40	15.93	5.26	6.21	1.13	1.60

Table 7.—*Average weights of loaded and of empty trucks and truck combinations in the summers of 1946, 1945, and 1943*

AVERAGE WEIGHTS OF LOADED TRUCKS

Region	All trucks and combinations					Single-unit trucks					Combinations				
	1946	1945	1943	1946: 1945	1946: 1943	1946	1945	1943	1946: 1945	1946: 1943	1946	1945	1943	1946: 1945	1946: 1943
Eastern regions:	*Pounds*	*Pounds*	*Pounds*			*Pounds*	*Pounds*	*Pounds*			*Pounds*	*Pounds*	*Pounds*		
New England	17,702	18,165	17,499	0.97	1.01	12,317	12,486	12,678	0.99	0.97	35,891	36,864	33,542	0.97	1.07
Middle Atlantic	19,912	21,028	19,786	.95	1.01	13,318	14,140	13,370	.94	1.00	38,215	36,954	35,597	1.03	1.07
South Atlantic	17,809	17,843	17,425	1.00	1.02	10,991	11,368	11,122	.97	.99	33,512	33,079	31,402	1.01	1.07
Average	18,609	19,040	18,255	.98	1.02	12,092	12,583	12,121	.96	1.00	35,361	34,781	33,000	1.02	1.07
Central regions:															
East North Central	22,625	24,283	21,588	.93	1.05	13,043	13,511	12,611	.97	1.03	35,776	34,449	33,313	1.04	1.07
East South Central	15,405	15,684	14,383	.98	1.07	10,784	11,556	10,576	.93	1.02	30,729	29,410	25,825	1.04	1.19
West North Central	16,968	16,779	15,734	1.01	1.08	10,282	10,386	10,383	.99	.99	34,023	33,252	29,524	1.02	1.15
West South Central	15,691	14,126	14,467	1.11	1.08	9,558	8,794	8,297	1.09	1.15	29,745	28,250	27,608	1.05	1.08
Average	18,521	18,768	17,301	.99	1.07	11,061	11,104	10,591	1.00	1.04	33,500	32,389	30,497	1.03	1.10
Western regions:															
Mountain	18,453	17,762	16,073	1.04	1.15	10,759	10,460	9,974	1.03	1.08	40,186	39,082	39,647	1.03	1.01
Pacific	24,486	23,161	21,551	1.06	1.14	12,714	13,292	11,388	.96	1.12	49,186	46,821	45,061	1.05	1.09
Average	22,621	21,928	19,293	1.03	1.17	11,930	12,483	10,770	.96	1.11	47,440	45,693	43,345	1.04	1.09
United States average	19,300	19,539	17,918	.99	1.08	11,580	11,890	11,137	.97	1.04	37,373	36,409	33,879	1.03	1.10

AVERAGE WEIGHTS OF EMPTY TRUCKS

Region	All trucks and combinations					Single-unit trucks					Combinations				
	1946	1945	1943	1946: 1945	1946: 1943	1946	1945	1943	1946: 1945	1946: 1943	1946	1945	1943	1946: 1945	1946: 1943
Eastern regions:															
New England	8,413	9,324	8,494	0.90	0.99	6,811	7,872	7,016	0.87	0.97	20,320	18,898	17,669	1.08	1.15
Middle Atlantic	9,939	10,197	8,659	.97	1.15	7,786	7,890	6,795	.99	1.15	18,362	18,767	16,675	.98	1.10
South Atlantic	7,236	7,383	8,384	.98	.86	5,498	5,603	5,903	.98	.93	15,753	15,585	15,004	1.01	1.05
Average	8,316	8,746	8,493	.95	.98	6,444	6,823	6,365	.94	1.01	17,093	17,154	15,788	1.00	1.08
Central regions:															
East North Central	9,426	10,042	9,104	.94	1.04	6,623	7,599	6,794	.87	.97	17,927	17,266	16,812	1.04	1.07
East South Central	5,499	7,022	6,501	.78	.85	5,456	5,832	5,493	.94	.99	14,393	15,573	12,384	.92	1.16
West North Central	8,079	7,789	7,404	1.04	1.09	5,837	5,789	5,587	1.01	1.04	17,255	16,907	14,802	1.02	1.17
West South Central	7,195	7,062	6,286	1.02	1.14	5,341	5,201	4,752	1.03	1.12	15,196	14,489	12,956	1.05	1.17
Average	7,173	8,069	7,594	.96	1.02	5,780	6,078	5,740	.95	1.01	16,459	16,054	15,108	1.03	1.09
Western regions:															
Mountain	7,012	6,653	6,544	1.05	1.07	5,322	5,162	4,923	1.03	1.08	19,150	19,949	19,855	.96	.96
Pacific	12,022	11,549	9,725	1.04	1.24	8,044	8,128	6,155	.99	1.31	23,843	22,861	19,326	1.04	1.23
Average	9,574	9,599	8,414	1.00	1.14	6,537	6,804	5,616	.96	1.16	22,693	22,314	19,494	1.02	1.16
United States average	8,201	8,558	8,017	.96	1.02	6,104	6,441	5,932	.95	1.03	17,793	17,517	15,864	1.02	1.12

Table 8.—*Comparison of estimated 1946 vehicle-miles of travel on main rural roads with corresponding figures for 1941, 1943, and 1945*

Region and year	All vehicles, vehicle-miles	All trucks and combinations		Single-unit trucks		Truck combinations	
		Percentage of all vehicles	Vehicle-miles	Percentage of all trucks and combinations	Vehicle-miles	Percentage of all trucks and combinations	Vehicle-miles
Eastern regions:							
New England:	*Thousands*		*Thousands*		*Thousands*		*Thousands*
1941	6, 663, 830	14. 7	980, 695	90. 5	887, 783	9. 5	92, 912
1943	2, 961, 043	21. 8	645, 154	82. 3	531, 100	17. 7	114, 054
1945	3, 928, 601	19. 6	769, 497	81. 0	623, 565	19. 0	145, 932
1946	5, 713, 086	16. 7	953, 902	82. 1	783, 031	17. 9	170, 871
1946: 1945	1. 45	. 85	1. 24	1. 01	1. 26	. 94	1. 17
Middle Atlantic:							
1941	17, 108, 107	20. 2	3, 447, 631	81. 0	2, 793, 416	19. 0	654, 215
1943	8, 355, 926	24. 9	2, 078, 950	73. 9	1, 536, 083	26. 1	542, 867
1945	10, 725, 475	21. 8	2, 337, 486	74. 2	1, 735, 098	25. 8	602, 388
1946	15, 532, 600	19. 1	2, 968, 335	75. 3	2, 234, 986	24. 7	733, 349
1946: 1945	1. 45	. 88	1. 27	1. 01	1. 29	. 96	1. 22
South Atlantic:							
1941	18, 612, 782	23. 2	4, 315, 146	77. 8	3, 357, 800	22. 2	957, 346
1943	10, 365, 819	28. 4	2, 946, 837	69. 2	2, 038, 327	30. 8	908, 510
1945	12, 835, 292	23. 4	3, 007, 162	70. 6	2, 121, 565	29. 4	885, 597
1946	18, 439, 919	22. 5	4, 149, 173	72. 9	3, 025, 426	27. 1	1, 123, 747
1946: 1945	1. 44	. 96	1. 38	1. 03	1. 43	. 92	1. 27
Subtotal:							
1941	42, 384, 719	20. 6	8, 743, 472	80. 5	7, 038, 999	19. 5	1, 704, 473
1943	21, 682, 788	26. 2	5, 670, 941	72. 4	4, 105, 510	27. 6	1, 565, 431
1945	27, 489, 368	22. 2	6, 114, 145	73. 3	4, 480, 228	26. 7	1, 633, 917
1946	39, 685, 605	20. 3	8, 071, 410	74. 9	6, 043, 443	25. 1	2, 027, 967
1946: 1945	1. 44	. 91	1. 32	1. 02	1. 35	. 94	1. 24
Central regions:							
East North Central:							
1941	24, 192, 260	17. 8	4, 305, 309	68. 0	2, 926, 163	32. 0	1, 379, 146
1943	13, 681, 965	20. 8	2, 839, 057	64. 0	1, 817, 123	36. 0	1, 021, 934
1945	16, 018, 709	18. 4	2, 940, 681	62. 9	1, 848, 320	37. 1	1, 092, 361
1946	23, 563, 034	15. 6	3, 664, 837	66. 7	2, 444, 116	33. 3	1, 220, 721
1946: 1945	1. 47	. 85	1. 25	1. 06	1. 32	. 90	1. 12
East South Central:							
1941	7, 533, 991	21. 7	1, 632, 240	90. 0	1, 469, 033	10. 0	163, 207
1943	4, 771, 709	21. 4	1, 023, 092	82. 0	835, 937	18. 0	187, 155
1945	5, 423, 111	20. 9	1, 134, 490	82. 7	938, 635	17. 3	195, 855
1946	7, 470, 206	21. 5	1, 602, 875	83. 1	1, 332, 105	16. 9	270, 770
1946: 1945	1. 38	1. 03	1. 41	1. 00	1. 42	. 98	1. 38
West North Central:							
1941	15, 260, 119	20. 8	3, 172, 121	80. 8	2, 563, 019	19. 2	609, 102
1943	9, 201, 549	26. 0	2, 392, 452	78. 4	1, 876, 302	21. 6	516, 150
1945	10, 180, 874	23. 3	2, 367, 392	78. 3	1, 853, 832	21. 7	513, 560
1946	14, 971, 991	21. 5	3, 216, 942	78. 2	2, 514, 597	21. 8	702, 345
1946: 1945	1. 47	. 92	1. 36	1. 00	1. 36	1. 00	1. 37
West South Central:							
1941	13, 745, 126	21. 8	2, 994, 305	78. 9	2, 362, 360	21. 1	631, 945
1943	8, 997, 058	29. 2	2, 625, 956	74. 1	1, 946, 830	25. 9	679, 126
1945	10, 724, 349	24. 1	2, 583, 820	74. 1	1, 914, 077	25. 9	669, 743
1946	15, 721, 893	22. 8	3, 591, 054	75. 9	2, 724, 193	24. 1	866, 861
1946: 1945	1. 47	. 95	1. 39	1. 02	1. 42	. 93	1. 29
Subtotal:							
1941	60, 731, 496	19. 9	12, 103, 975	77. 0	9, 320, 575	23. 0	2, 783, 400
1943	36, 652, 281	24. 2	8, 880, 557	72. 9	6, 476, 192	27. 1	2, 404, 365
1945	42, 347, 043	21. 3	9, 026, 383	72. 6	6, 554, 864	27. 4	2, 471, 519
1946	61, 727, 124	19. 6	12, 075, 708	74. 7	9, 015, 011	25. 3	3, 060, 697
1946: 1945	1. 46	. 92	1. 34	1. 03	1. 38	. 92	1. 24
Western regions:							
Mountain:							
1941	6, 741, 489	19. 5	1, 316, 246	88. 0	1, 158, 270	12. 0	157, 976
1943	4, 315, 357	24. 8	1, 069, 674	85. 3	912, 433	14. 7	157, 241
1945	5, 194, 915	21. 5	1, 118, 716	83. 3	931, 905	16. 7	186, 811
1946	7, 476, 867	21. 9	1, 639, 583	82. 0	1, 343, 755	18. 0	295, 828
1946: 1945	1. 44	1. 02	1. 47	. 98	1. 44	1. 08	1. 58
Pacific:							
1941	12, 647, 141	16. 0	2, 021, 200	76. 1	1, 538, 563	23. 9	482, 637
1943	8, 373, 365	20. 8	1, 738, 241	67. 8	1, 178, 086	32. 2	560, 165
1945	10, 761, 149	24. 6	2, 647, 932	61. 7	1, 634, 744	38. 3	1, 013, 188
1946	15, 259, 494	16. 8	2, 559, 106	56. 1	1, 435, 685	43. 9	1, 123, 421
1946: 1945	1. 42	. 68	. 97	. 91	. 88	1. 15	1. 11
Subtotal:							
1941	19, 388, 630	17. 2	3, 337, 446	80. 8	2, 696, 833	19. 2	640, 613
1943	12, 688, 722	22. 1	2, 807, 925	74. 5	2, 090, 519	25. 5	717, 406
1945	15, 956, 064	23. 6	3, 766, 648	68. 1	2, 566, 649	31. 9	1, 199, 999
1946	22, 736, 361	18. 5	4, 198, 689	66. 2	2, 779, 440	33. 9	1, 419, 249
1946: 1945	1. 42	. 78	1. 11	. 97	1. 08	1. 06	1. 18
United States total:							
1941	122, 504, 845	19. 7	24, 184, 893	78. 8	19, 056, 407	21. 2	5, 128, 486
1943	71, 023, 791	24. 4	17, 359, 423	73. 0	12, 672, 221	27. 0	4, 687, 202
1945	85, 792, 475	22. 0	18, 907, 176	71. 9	13, 601, 741	28. 1	5, 305, 435
1946	124, 149, 090	19. 6	24, 345, 807	73. 3	17, 837, 894	26. 7	6, 507, 913
1946: 1945	1. 45	. 89	1. 29	1. 02	1. 31	. 95	1. 23

1941, the last prewar year, all-vehicle travel on main rural roads showed a gain of 1 percent in 1946, and although single-unit-truck travel in 1946 was only 94 percent of that in 1941, travel of truck combinations was 27 percent above the 1941 figure, evidencing a sharp rise in the use of heavier commercial vehicles. This trend was apparent during the war years when the proportion of truck travel performed by truck combinations remained consistently higher than in prewar years.

Table 9 shows the estimated percentage of trucks and truck combinations loaded the, average carried load, and the ton-miles carried on main rural roads in 1941, 1943, 1945, and 1946. For the country as a whole in 1946, the ton-mileage of all trucks and combinations increased 21 percent above the previous year, the average weight of the carried load remained the same, while the percentage of trucks loaded dropped from 55.1 percent to 51.7 percent. Ton-mileage of both single-unit trucks and truck combinations increased in all census regions in 1946 except the Pacific States, where single-unit ton-mileage was 77 percent of that of 1945. The mountain region showed the greatest rise in ton-mileage in comparison to 1945, it being 40 percent for single-unit trucks and 50 percent for combinations. While the use of heavier vehicles has increased since 1941, as mentioned above, the average carried load has increased 18 percent, and the ton-mileage hauled, 38 percent.

MAXIMUM AXLE AND GROSS LOADS

Table 10 shows the average of the maximum axle loads of the loaded vehicles weighed during the summer survey in 1946 and during those of previous years. Axle loads have remained approximately the same during the current year as in the prior war years; however, in comparison to prewar years, average maximum axle loads in 1946 for both truck classifications shown are substantially heavier. Since the prewar period, the average maximum axle load for the entire United States has increased 31 percent.

Paralleling the increase in the average maximum axle load, the frequency of heavier axle loads is on the whole five times greater than in the prewar period when the original survey was made (1936–40). This is demonstrated in the left half of table 11 which shows the number of axle loads of 18,000, 20,000, and 22,000 pounds or more per 1,000 trucks and combinations counted in summer surveys of 1946, 1945, 1943, and the original prewar survey. In each category shown, the highest frequency of heavy axle loads was found in the Middle Atlantic States. Heavy axle loads of 20,000 pounds and more are generally more frequent in that area and the New England States, where higher maximum axle loads are permitted by law, than in other sections of the country.

The frequency of heavy vehicles is shown in the right half of table 11. Here it is apparent again that heavier vehicles have come into increasingly wider use throughout the war period and are now far more common than in the prewar period. Although in 1946 an over-all slight drop from 1945 is found in gross weights exceeding 30,000 pounds, frequencies in the categories 40,000 pounds and over and 50,000 pounds and over have risen slightly in this same period. In the two heaviest of the three weight classes shown, the Pacific States, having liberal maximum gross weight restrictions, lead all other regions.

FREQUENCY OF HEAVY LOAD CONCENTRATIONS

In order that the effect of heavy axle loads and heavy total loads may be considered in relation to longitudinal distribution, loads and axle spacings have often been combined by the use of a so-called gross load formula, $W=C(L+40)$, in which W is the total weight of the vehicle in pounds, or the weight of an interior group of axles, and L is the distance in feet between the first and last axle of the vehicle, or of any interior group of

Table 9.—*Comparison of the estimated percentage of trucks and truck combinations loaded, average carried load, and ton-miles carried on main rural roads, with corresponding figures for 1941, 1943, and 1945*

Region and year	All trucks and combinations			Single-unit trucks			Truck combinations		
	Percentage loaded	Carried load		Percentage loaded	Carried load		Percentage loaded	Carried load	
		Average weight	Ton-miles		Average weight	Ton-miles		Average weight	Ton-miles
Eastern regions:									
New England:		*Tons*	*Thousands*		*Tons*	*Thousands*		*Tons*	*Thousands*
1941	72.9	2.79	1,993,120	72.7	2.22	1,435,923	74.3	8.06	557,197
1943	56.3	3.89	1,378,333	52.8	2.34	655,257	72.5	8.75	723,076
1945	53.8	3.92	1,623,664	50.9	2.27	721,397	66.4	9.31	902,267
1946	52.4	3.99	1,995,842	48.2	2.24	844,357	57.2	9.40	1,151,485
1946 : 1945	.97	1.02	1.23	.95	.99	1.17	.86	1.01	1.28
Middle Atlantic:									
1941	70.3	3.41	8,267,429	69.9	2.14	4,175,576	72.1	8.67	4,091,853
1943	57.4	4.16	4,963,933	54.5	2.24	1,879,681	65.4	8.69	3,084,252
1945	54.6	4.30	5,487,126	51.9	2.36	2,129,030	62.3	8.95	3,358,096
1946	57.7	4.10	7,023,600	55.8	2.18	2,719,736	63.4	9.25	4,303,864
1946 : 1945	1.06	.95	1.28	1.08	.92	1.28	1.02	1.03	1.28
South Atlantic:									
1941	65.6	3.88	10,982,765	64.6	2.61	5,663,491	69.0	8.05	5,319,274
1943	56.8	4.76	7,970,164	53.5	2.63	2,874,032	64.1	8.75	5,096,132
1945	57.4	4.84	8,350,393	53.2	2.48	2,803,119	67.5	9.28	5,547,274
1946	53.5	4.79	10,637,066	48.4	2.38	3,494,145	67.0	9.48	7,142,921
1946 : 1945	.93	.99	1.27	.91	.96	1.25	.99	1.02	1.29
Subtotal:									
1941	68.2	3.56	21,243,314	67.7	2.37	11,274,990	70.5	8.30	9,968,324
1943	56.9	4.43	14,312,430	53.8	2.45	5,408,970	65.1	8.73	8,903,460
1945	55.9	4.53	15,461,183	52.4	2.41	5,653,546	65.4	9.17	9,807,637
1946	54.9	4.44	19,656,508	51.1	2.29	7,058,238	66.1	9.39	12,598,270
1946 : 1945	.98	.98	1.27	.98	.95	1.25	1.01	1.02	1.28
Central regions:									
East North Central:									
1941	68.7	4.05	11,961,648	66.0	2.10	4,064,158	74.3	7.71	7,897,490
1943	62.3	4.74	8,381,988	54.3	2.18	2,148,969	76.5	7.98	6,233,019
1945	58.7	5.15	8,897,279	49.4	2.38	2,176,246	74.4	8.27	6,721,033
1946	57.2	4.81	10,081,218	50.5	2.17	2,685,088	70.6	8.59	7,396,130
1946 : 1945	.97	.93	1.13	1.02	.91	1.23	.95	1.04	1.10
East South Central:									
1941	64.8	3.13	3,303,537	64.1	2.70	2,546,285	70.5	6.58	757,252
1943	52.1	3.95	2,107,176	48.2	2.75	1,108,101	69.9	7.64	999,075
1945	47.0	4.01	2,136,854	43.4	2.72	1,108,602	63.8	8.23	1,028,252
1946	42.7	4.04	2,761,538	38.6	2.54	1,304,071	62.6	8.60	1,457,467
1946 : 1945	.91	1.01	1.29	.89	.93	1.18	.98	1.04	1.42
West North Central:									
1941	67.0	3.23	6,872,720	66.3	2.09	3,549,465	70.1	7.79	3,323,255
1943	63.3	3.30	4,994,660	63.2	2.06	2,448,202	63.6	7.76	2,546,458
1945	58.8	3.67	5,111,866	55.8	1.98	2,053,160	69.5	8.57	3,058,706
1946	55.1	3.72	6,585,211	52.2	1.97	2,582,219	65.2	8.74	4,002,992
1946 : 1945	.94	1.01	1.29	.94	.99	1.26	.94	1.02	1.31
West South Central:									
1941	60.6	2.99	5,427,182	59.6	2.23	3,144,368	64.5	5.60	2,282,814
1943	48.7	3.64	4,645,246	42.6	2.17	1,800,724	66.2	6.33	2,844,522
1945	42.6	3.79	4,165,546	37.1	2.54	1,808,167	58.2	6.05	2,357,379
1946	36.6	4.16	5,461,533	31.3	2.65	2,264,895	53.2	6.93	3,196,638
1946 : 1945	.86	1.10	1.31	.84	1.04	1.25	.91	1.15	1.36
Subtotal:									
1941	65.7	3.47	27,565,087	64.2	2.22	13,304,276	70.9	7.23	14,260,811
1943	57.4	3.95	20,129,070	52.6	2.21	7,505,996	70.3	7.47	12,623,074
1945	52.6	4.48	20,311,545	46.8	2.33	7,146,175	68.1	7.82	13,165,370
1946	48.6	4.24	24,889,500	43.4	2.26	8,836,273	63.7	8.23	16,053,227
1946 : 1945	.92	.95	1.23	.93	.97	1.24	.94	1.05	1.22
Western regions:									
Mountain:									
1941	62.6	3.39	2,795,644	61.6	2.46	1,755,379	69.7	9.45	1,040,265
1943	49.3	3.95	2,083,902	46.3	2.39	1,010,816	66.7	10.23	1,073,886
1945	45.8	4.63	2,374,966	41.5	2.51	950,677	71.5	10.66	1,424,289
1946	43.3	4.88	3,463,639	38.1	2.59	1,327,577	66.8	10.81	2,136,062
1946 : 1945	.95	1.05	1.46	.92	1.03	1.40	.93	1.01	1.50
Pacific:									
1941	68.8	5.13	7,132,737	65.2	2.14	2,151,962	80.4	12.84	4,980,775
1943	66.7	6.34	7,350,878	62.3	2.24	1,644,753	75.8	13.44	5,706,125
1945	65.4	7.05	12,216,924	58.1	2.57	2,435,956	77.3	12.49	9,780,968
1946	62.0	8.12	12,882,143	53.3	2.45	1,878,801	73.1	13.40	11,003,342
1946 : 1945	.95	1.15	1.05	.92	.95	.77	.95	1.07	1.12
Subtotal:									
1941	66.4	4.48	9,928,381	63.7	2.27	3,907,341	77.7	12.09	6,021,040
1943	60.0	5.60	9,434,780	55.3	2.30	2,655,569	73.8	12.80	6,779,211
1945	59.6	6.50	14,591,890	51.8	2.55	3,386,633	76.4	12.22	11,205,257
1946	54.7	7.12	16,345,782	46.0	2.51	3,206,378	71.8	12.90	13,139,404
1946 : 1945	.92	1.10	1.12	.89	.98	.95	.94	1.06	1.17
United States total:									
1941	66.7	3.64	58,736,782	65.4	2.29	28,486,607	71.6	8.23	30,250,175
1943	57.7	4.38	43,876,280	53.4	2.30	15,570,535	69.1	8.74	28,305,745
1945	55.1	4.84	50,364,618	49.6	2.40	16,186,354	69.2	9.31	34,178,264
1946	51.7	4.84	60,891,790	46.4	2.31	19,100,889	66.2	9.70	41,790,901
1946 : 1945	.94	1.00	1.21	.94	.96	1.18	.96	1.04	1.22

axles. *C* is a measure of load concentration and it is generally thought that a value of *C* greater than 750 is excessive.

The frequency of trucks and combinations with various values of *C* in 1946, 1945, and 1943 are shown in table 12 by census regions. Heavy load concentrations occur most often in the Pacific States, with the Middle Atlantic and East North Central States also having a high frequency. There has been a steady upward trend in this frequency throughout the country during the war years, although in comparing 1946 to the previous year, a slight over-all decline in heavy load concentrations is evident.

The American Association of State Highway Officials now recommends,[2] in lieu of a formula for the limitation of motor-vehicle weights, the use of a table of permissible weights based on the distance between the extremes of any group of axles. Table 13 shows data in relation to this and indicates, as does table 12, that overloading is most prevalent in the Pacific and Middle Atlantic regions, although in using this method of computing overloads there appears to be little variation among the years shown for the United States as a whole.

[2] *Policy concerning maximum dimensions, weights and speeds of motor vehicles to be operated over the highways of the United States*, adopted April 1, 1946, by the American Association of State Highway Officials; published by the association, 1946.

Table 10.—*Average maximum axle load of loaded trucks in the summer of 1946 and in corresponding periods of 1945 and 1943 and in the prewar period between 1936 and 1941*

Region	All trucks and combinations				Single-unit trucks				Truck combinations			
	1946	1945	1943	Prewar	1946	1945	1943	Prewar	1946	1945	1943	Prewar
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
New England	9, 611	10, 005	9, 643	7, 647	7, 688	7, 990	8, 068	6, 985	16, 031	16, 621	14, 966	13, 951
Middle Atlantic	11, 054	11, 584	10, 440	7, 858	8, 924	9, 346	8, 725	6, 779	16, 979	16, 768	16, 135	13, 551
South Atlantic	9, 698	9, 950	9, 482	8, 488	7, 161	7, 632	7, 229	7, 589	15, 095	15, 403	14, 612	11, 831
East North Central	11, 047	11, 678	10, 915	8, 290	8, 273	8, 595	8, 335	6, 806	14, 949	14, 797	14, 466	12, 090
East South Central	8, 982	9, 024	8, 431	7, 215	7, 384	8, 003	7, 366	6, 962	14, 306	14, 157	12, 036	8, 899
West North Central	9, 228	9, 300	9, 060	7, 593	7, 117	7, 212	7, 391	6, 565	14, 585	14, 633	13, 488	11, 594
West South Central	8, 452	7, 673	7, 583	5, 868	6, 455	5, 834	5, 344	5, 134	12, 959	12, 993	12, 247	8, 391
Mountain	9, 035	8, 858	8, 313	6, 051	7, 109	7, 110	6, 990	5, 444	14, 669	14, 118	14, 176	11, 284
Pacific	10, 093	9, 995	9, 346	7, 094	8, 213	8, 497	7, 653	5, 967	14, 097	13, 504	13, 444	11, 176
United States average	9, 881	10, 017	9, 411	7, 552	7, 645	7, 869	7, 432	6, 566	14, 722	14, 615	14, 072	11, 449

Table 11.—*Number of heavy axle loads and heavy gross weights per 1,000 loaded and empty trucks and combinations in the summers of 1946, 1945, 1943, and in the prewar period between 1936 and 1941*

Region	Number of heavy axle loads per 1,000 loaded and empty trucks and combinations of—												Number of gross weights per 1,000 loaded and empty trucks and combinations of—											
	18,000 pounds or more				20,000 pounds or more				22,000 pounds or more				30,000 pounds or more				40,000 pounds or more				50,000 pounds or more			
	1946	1945	1943	Prewar	1946	1945	1943	Prewar	1946	1945	1943	Prewar	1946	1945	1943	Prewar	1946	1945	1943	Prewar	1946	1945	1943	Prewar
New England	88	109	73	48	50	62	45	21	21	29	14	8	118	113	107	58	53	50	40	15	9	10	4	1
Middle Atlantic	151	149	128	40	85	75	75	18	42	33	28	7	149	163	159	62	80	77	59	17	25	18	17	3
South Atlantic	80	78	50	7	27	26	8	1	10	7	2	(1)	125	133	120	32	44	43	24	3	6	2	(1)	(1)
East North Central	93	74	62	14	27	10	15	4	6	5	4	2	194	233	199	65	80	72	48	13	36	28	16	5
East South Central	39	30	7	1	16	15	1	(1)	5	6	(1)	(1)	121	57	50	7	41	12	3	1	4	1	(1)	(1)
West North Central	49	41	32	5	13	8	4	(1)	3	1	1	(1)	112	114	105	34	45	33	35	2	14	11	3	(1)
West South Central	13	25	23	4	4	8	7	2	1	2	5	(1)	65	73	63	8	18	20	11	1	6	3	2	(1)
Mountain	46	44	33	5	16	12	8	3	5	3	5	2	92	98	83	20	53	54	46	7	31	28	28	3
Pacific	42	47	18	3	6	13	3	1	2	3	(1)	(1)	193	186	165	97	133	116	119	47	104	86	89	24
United States average	68	67	49	13	26	23	17	5	10	9	6	2	132	144	125	43	60	58	41	11	26	23	15	3

[1] Less than 5 per 10,000.

Table 12.—*Number of trucks with values of C in the gross weight formula in excess of various values, per 1,000 loaded and empty trucks and combinations in the summers of 1946, 1945, and 1943*

Region	Number of trucks and combinations with values of *C*—																	
	Over 650			Over 700			Over 750			Over 800			Over 850			Over 900		
	1946	1945	1943	1946	1945	1943	1946	1945	1943	1946	1945	1943	1946	1945	1943	1946	1945	1943
New England	39	33	33	22	18	14	11	9	7	6	4	3	1	2	1	1	1	(1)
Middle Atlantic	69	56	36	46	33	30	33	18	14	19	9	10	11	5	6	6	2	3
South Atlantic	16	20	10	7	9	3	5	5	2	3	3	(1)	1	1	0	1	1	0
East North Central	52	48	36	40	37	21	31	28	15	24	22	8	17	14	6	9	8	5
East South Central	6	5	3	2	1	1	2	(1)	(1)	1	(1)	0	(1)	(1)	0	0	(1)	0
West North Central	32	21	7	18	13	3	11	8	1	5	3	(1)	3	2	(1)	2	1	(1)
West South Central	8	9	8	5	3	4	5	1	2	4	1	1	2	(1)	1	1	(1)	1
Mountain	48	45	54	33	34	33	24	22	26	15	16	21	9	11	17	5	6	15
Pacific	126	135	131	107	112	111	81	89	88	46	59	60	15	22	31	3	8	17
United States average	43	45	31	31	33	18	22	24	15	14	17	9	7	8	6	4	4	4

[1] Less than 5 per 10,000.

Table 13.—*Number of trucks and combinations per 1,000 loaded and empty vehicles that exceeded the permissible motor-vehicle loads recommended by the A. A. S. H. O., and various percentages of overload, in the summers of 1946, 1945, and 1943*

Region	Number of trucks and combinations with overload																	
	Total overloaded			Over 5 percent			Over 10 percent			Over 20 percent			Over 30 percent			Over 50 percent		
	1946	1945	1943	1946	1945	1943	1946	1945	1943	1946	1945	1943	1946	1945	1943	1946	1945	1943
New England	17	13	8	10	6	5	5	4	3	1	1	1	(1)	(1)	0	0	0	0
Middle Atlantic	35	27	23	26	19	15	18	13	10	7	6	4	3	2	1	1	1	0
South Atlantic	5	7	2	3	4	1	3	3	(1)	1	2	(1)	(1)	0	0	(1)	0	0
East North Central	29	24	16	23	20	13	18	17	9	9	8	4	4	3	3	1	1	1
East South Central	2	(1)	(1)	1	(1)	(1)	1	(1)	0	(1)	(1)	0	0	(1)	0	0	0	0
West North Central	11	7	2	7	4	1	4	3	(1)	1	1	(1)	1	(1)	(1)	0	0	0
West South Central	5	2	2	4	1	2	3	1	1	1	1	1	1	(1)	0	(1)	0	0
Mountain	26	20	16	18	16	11	11	11	8	4	5	2	2	2	1	1	1	(1)
Pacific	79	67	100	47	49	71	20	24	51	3	4	19	(1)	0	3	0	0	0
United States average	22	22	21	15	16	15	10	10	10	3	4	4	1	(1)	1	(1)	(1)	(1)

[1] Less than 5 per 10,000.

Trends in Motor-Vehicle Travel, 1946

BY THE DIVISION OF FINANCIAL AND ADMINISTRATIVE RESEARCH, PUBLIC ROADS ADMINISTRATION

Total motor-vehicle travel in the United States in 1946 amounted to more than 340 billion vehicle-miles, about evenly divided between urban and rural travel. This total was 2 percent greater than the previous record, established in 1941, and 37 percent above travel in 1945. The average vehicle traveled 9,958 miles in 1946, consuming 747 gallons of motor fuel at a rate of 13.32 miles per gallon.

CLASSIFIED estimates of motor-vehicle travel in the United States, previously published for the years 1936–45,[1] are here presented for the year 1946. Table 1 reports, for the various classes of motor vehicles, the estimates for 1946 of rural, urban, and total vehicle-miles traveled, average miles traveled and motor fuel consumed per vehicle, and average travel per gallon of motor fuel consumed.

The analysis on which these estimates are based was similar to that described in the previous report.[1] Because the volumes of motor-vehicle travel and motor-fuel consumption in 1946 were more nearly comparable to those in 1941 than any of the intervening years, 1941 was used as a base year in making the calculations.

Rural-road travel in 1946, reported in another article in this issue, was approximately one-half percent greater than in 1941. Highway use of motor fuel, however, was about 6 percent greater. Part of this apparent excess consumption of motor fuel is accounted for by the relative increase in the number of trucks and combinations, from 14.6 percent of the total motor-vehicle registration in 1941 to 17.1 percent in 1946. Part is due to the heavier loads carried by trucks and combinations during recent years, and an allowance for reduced average miles per gallon has been made in the calculations. Since these factors did not account for all of the apparent excess motor-fuel consumption, the indicated increase of 1946 urban travel over that in 1941 was greater than the increase of rural travel.

Total travel in 1946 was estimated as 340,655 million vehicle-miles—2 percent above the previous record set in 1941. Of the total, 170,606 million vehicle-miles were accounted for by rural travel and 170,049 million vehicle-miles by urban travel. While rural travel had increased only one-half percent over 1941, urban travel had risen almost 4 percent above that level.

Comparisons of 1946 travel with that of 1941 and 1945 are shown in table 2. The relative increase of 1946 rural travel over 1945 was much greater than that of urban travel. Rural travel suffered much greater set-backs during the war years and, in recovering, it naturally showed a greater percentage rise from 1945, during 8 months of which motor vehicles operated under wartime restrictions.

The relative increase of 1946 values over those of 1941, however, was greater for urban than for rural travel. A comparison of monthly rural traffic volumes in 1941 and 1946 shows that 1946 travel exceeded that of 1941 in January, February, March, April, September, and October, but was less in the usual peak-traffic months of June, July, and August, as well as in May, November, and December. Thus, while the level of rural traffic in 1946 was above that of 1941 during most of the winter, spring, and fall, summer traffic had not yet returned to normal. Probably the advanced age of millions of passenger cars somewhat deterred vacation and week-end touring; high costs of vacation accommodations may also have played a part. These factors would have had a minor effect on city travel, so it is not unnatural that the latter should display a more favorable comparison with 1941 levels than does rural travel.

The average miles traveled per vehicle in 1941 and 1946, for the two most important vehicle classes, were estimated as follows:

	1941	*1946*
Passenger cars	9, 285	9, 942
Trucks and combinations	10, 739	9, 615

Apparently inconsistent are the indications that the average mileage of trucks and combinations was less in 1946 than in 1941, while that of passenger cars was greater; and that passenger cars, which in past years traveled a lower annual mileage per vehicle than trucks and combinations, have exceeded the latter in mileage during 1946. A probable explanation lies in the 17.8 percent increase of truck and combination registrations in 1946 over those in 1945 while passenger car registrations increased only 9.4 percent. Factory sales figures indicate a large proportion of new truck sales in 1946 were made during the latter part of the year. This large influx of new

(*Continued on page 52*)

Table 1.—*Classified estimate of travel in the United States in calendar year 1946*

Vehicle type	Motor-vehicle travel: Rural travel	Motor-vehicle travel: Urban travel	Motor-vehicle travel: Total travel	Number of registered vehicles [1]	Average travel per vehicle	Motor-fuel consumption: Total [2]	Motor-fuel consumption: Average per vehicle	Average travel per gallon of fuel consumed
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Thousands*	*Miles*	*Million gallons*	*Gallons*	*Miles per gallon*
Passenger vehicles:								
Passenger cars [3]	134, 013	146, 444	280, 457	28, 209	9, 942	18, 759	665	14. 95
Busses:								
Commercial	1, 413	1, 987	3, 400	80	42, 500	680	8, 500	5. 00
School and nonrevenue	586	66	652	82	7, 981	63	768	10. 39
All busses	1, 999	2, 053	4, 052	162	25, 061	743	4, 594	5. 46
All passenger vehicles	136, 012	148, 497	284, 509	28, 371	10, 028	19, 502	687	14. 59
Trucks and combinations	34, 594	21, 552	56, 146	5, 839	9, 615	6, 068	1, 039	9. 25
All motor vehicles	170, 606	170, 049	340, 655	34, 210	9, 958	25, 570	747	13. 32

[1] These registrations differ from those given in Public Roads Administration table MV–1 for 1946 because of the following adjustments: (1) Approximate correction for defective classification in 6 States, as described in footnotes 7, 9, 11, 12, and 13 of that table; (2) inclusion of publicly owned vehicles, listed separately in table MV–1; (3) reduction of private and commercial truck registrations by 2.5 percent to allow for registration in more than 1 State; and (4) substitution of bus totals as estimated by the bus industry, to afford a complete segregation of commercial busses from school and nonrevenue busses and to allow for duplication because of registration in more than 1 State.

[2] Total highway use of motor fuel in 1946 is given as 25,649 million gallons in Public Roads Administration table G–21. For this analysis there was deducted from that total 79 million gallons estimated use by motorcycles (250 gallons per motorcycle).

[3] Including taxicabs.

Table 2.—*Increase in motor-vehicle travel, 1946 compared with 1941 and 1945*

Vehicle type	Percentage increase of travel—1946 over 1941: Rural	1946 over 1941: Urban	1946 over 1941: Total	1946 over 1945: Rural	1946 over 1945: Urban	1946 over 1945: Total
Passenger vehicles	0. 45	3. 77	2. 16	47. 78	33. 80	40. 14
Trucks and combinations	. 56	5. 18	2. 29	27. 42	14. 88	22. 30
All vehicles	. 47	3. 95	2. 18	43. 15	31. 07	36. 85

[1] *Trends in motor-vehicle travel, 1936 to 1945*, by G. P. St. Clair; PUBLIC ROADS, vol. 24, No. 10; Oct.-Nov.-Dec. 1946.

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Trends in the Distribution of State Road-User Taxes, 1940–1947

BY THE DIVISION OF RESEARCH REPORTS PUBLIC ROADS ADMINISTRATION

Reported by R. W. MEADOWS, Highway Economist and W. R. McCALLUM, Associate Highway Economist

This article summarizes the recent trends and the current status of State–local highway finance relationships, with particular emphasis upon the distribution of State road-user tax revenues.

The large postwar highway programs, coupled with greatly increased construction costs, have intensified demands by both State and local groups for additional highway funds. In order to fill the more urgent needs, several States have been compelled to increase highway-user tax rates or to revise distribution formulas. This has brought about some misconceptions concerning the present allocation of these revenues. Actually, there does not appear to have been any significant change in the basic State–local distribution ratios in recent years. Both State and local roads have benefited from greater tax yields, with the State generally retaining the larger share of total revenue, for expenditures on State highway systems. Where revisions of the distribution formulas have occurred, increases in State or local shares have usually been accomplished by decreasing the portion of tax revenues formerly allocated to nonhighway purposes.

MOST States have shared a considerable part of their road-user revenues with their political subdivisions almost from the inception of special road-user taxes. The distribution of these revenues has always been a matter of lively interest. With the growing attention centered on highway needs and highway financing methods, much discussion has revolved around the changes that have been made in road-user revenue allocations in recent years.

Local groups, both rural and urban, have insistently presented their claims for a greater share of the revenue. At the same time, the need for an adequate system of main roads has at all times been so universally recognized that legislatures have been reluctant to increase the allocations for local roads and streets at the expense of delaying the development of the State arterial systems.

In order to clarify the State–local relationship, a study has been made of the 1940–47 trend in the distribution of road-user revenues to State highways, to local roads and streets, and also to nonhighway purposes. The 1940–46 portion of the study is based upon an analysis of the annual reports of State highway authorities to the Public Roads Administration, and the changes for 1947 are based upon the probable effects of legislation passed during the year. The 1940 and 1946 allocations are shown in detail in table 1.

CONCLUSIONS

An analysis of the 1940–1947 trend in highway financing methods indicates that while many States have in recent years provided additional funds for local roads and streets, this has rarely been done at the expense of revenues for State highways. In several cases local roads have received funds formerly allocated for nonhighway purposes, or have received a portion of new tax revenues. In a few instances they have received appropriations from State general fund surpluses. The States, however, have usually preserved the basic distribution ratios that were in effect in 1940, and where the ratios have been changed in favor of local roads, steps have been taken to assure that certain minimum revenues will be available to finance the postwar programs for improvement of State highways and secondary roads of more than local importance.

Both State highways and local roads have shared in an increase in State highway-user revenues, which in 1946 were 21 percent greater than the collections in 1940. Both are also receiving a greater portion of the total highway-user revenues: the State share increased from 58 percent of the amount distributed in 1940 to 64 percent in 1946, and the local share from 27 percent in 1940 to 30 percent in 1946. It is not the intention here to discuss the relative value of the rise in highway revenues, or the adequacy of the present highway-user tax structure. It should be obvious that increased revenues in recent years have been more than nullified by increased highway construction costs.

The increase in the State and local shares of highway-user revenues was accompanied by a decrease in the portion used for nonhighway purposes. This decrease has been the result of two factors: (1) The effectiveness of the campaign against allocation of user revenues to nonhighway purposes; and (2) increased appropriation of funds for highways out of general State revenue, offsetting statutory nonhighway allocations of highway-user revenue. Such appropriations, however, do not necessarily indicate a continuing policy.

COMPARISON OF 1940 AND 1946 ALLOCATIONS

By limiting this study to an evaluation of changes in the allocation of State funds for highways, some important factors in State–local highway relationships have necessarily been excluded. One of the most important of these is the effect of transferring mileage from the local road systems to State systems without providing a larger portion of total revenues to the State highway departments.[1] The roads thus taken over by the States are usually the most heavily traveled in the local systems, and therefore the most costly to improve and maintain. Also it may not be readily apparent that large amounts of State highway funds, while nominally expended in rural areas, are actually spent on heavily traveled roads adjacent to cities. Thus, while they are not actually expended within corporate limits, they are largely for the benefit of urban areas.

Another factor not included in this study is the control exercised by the States over funds allotted for local roads and streets. The degree of State control may influence the class of road upon which the money is spent.

While both highway revenues and highway construction were declining during the years 1942–45 as a result of wartime restrictions, the State legislatures gave little attention to revision of existing formulas for the distribution of funds. With the end of the war, however, the Federal-aid Highway Act of 1944 gave considerable impetus to expansion of highway construction on main State highways, on the more important secondary roads, and on arterial streets forming the major traffic channels within urban areas. At the same time, local governments renewed their demands for a greater share of State highway revenues.

By 1946 a few States had anticipated the postwar needs and demands by increasing highway-user tax rates, by reallocating the revenue from existing taxes, or by making appropriations for highways out of State general funds.

[1] The total mileage of the State highway systems, excluding county roads under State control in Delaware, North Carolina, Virginia, and West Virginia, increased from 434,000 miles in 1940 to 458,000 in 1946. The State-administered county roads in the four States mentioned increased from 114,000 miles to 119,000 miles during the same period.

Table 1.—*Distribution of State highway-user revenues, 1940 and 1946*

State	Total funds distributed		For highway purposes												For nonhighway purposes			
			For State highways [1]				For local roads and streets [2]				Total for highway purposes				Amount		Percent of total funds	
			Amount		Percent of total funds		Amount		Percent of total funds		Amount		Percent of total funds					
	1940	1946	1940	1946	1940	1946	1940	1946	1940	1946	1940	1946	1940	1946	1940	1946	1940	1946
	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	20,096	29,537	11,070	12,640	55.1	42.8	8,192	15,723	40.8	53.2	19,262	28,363	95.9	96.0	834	1,174	4.1	4.0
Arizona	5,838	9,618	4,367	7,344	74.8	76.4	1,471	2,274	25.2	23.6	5,838	9,618	100.0	100.0				
Arkansas	14,756	21,263	13,329	18,434	90.3	86.7	1,427	2,774	9.7	13.0	14,756	21,208	100.0	99.7	------	55	------	.3
California	77,254	107,702	40,860	50,442	52.9	46.8	22,405	47,758	29.0	44.4	63,265	98,200	81.9	91.2	13,989	9,502	18.1	8.8
Colorado	10,948	14,169	7,387	9,600	67.5	67.8	3,561	4,569	32.5	32.2	10,948	14,169	100.0	100.0				
Connecticut	17,244	18,738	14,017	10,251	81.3	54.7	3,226	8,487	18.7	45.3	17,243	18,738	100.0	100.0	1	------	------	------
Delaware	3,420	3,735	3,392	3,515	99.2	94.1	2	------	------	------	3,394	3,515	99.2	94.1	26	220	.8	5.9
Florida	34,757	49,925	23,478	25,859	67.5	51.8	281	6,068	.9	12.1	23,759	31,927	68.4	63.9	10,998	17,998	31.6	36.1
Georgia	24,609	33,975	15,456	22,258	62.8	65.5	5,337	5,897	21.7	17.4	20,793	28,155	84.5	82.9	3,816	5,820	15.5	17.1
Idaho	6,232	9,254	3,843	6,867	61.7	74.2	2,389	2,387	38.3	25.8	6,232	9,254	100.0	100.0	------	------	------	------
Illinois	64,322	68,473	33,798	38,278	52.5	55.9	23,539	30,195	36.6	44.1	57,337	68,473	89.1	100.0	6,985	------	10.9	------
Indiana	36,282	37,317	20,623	21,505	56.8	57.6	13,944	15,225	38.4	40.8	34,567	36,730	95.2	98.4	1,715	587	4.8	1.6
Iowa	27,244	27,960	19,238	18,699	70.6	66.9	8,006	9,261	29.4	33.1	27,244	27,960	100.0	100.0	------	------	------	------
Kansas	15,400	21,024	11,765	17,056	76.4	81.1	3,635	3,968	23.6	18.9	15,400	21,024	100.0	100.0	------	------	------	------
Kentucky	19,396	25,808	14,953	19,964	77.1	77.4	2,606	5,844	13.4	22.6	17,559	25,808	90.5	100.0	1,837	------	9.5	------
Louisiana	22,257	28,966	16,009	21,146	71.9	73.0	------	575	------	2.0	16,009	21,721	71.9	75.0	6,248	7,245	28.1	25.0
Maine	10,045	11,338	8,745	10,511	87.1	92.7	1,158	827	11.5	7.3	9,903	11,338	98.6	100.0	142	------	1.4	------
Maryland	17,713	20,897	10,353	11,006	58.5	52.7	6,025	8,271	34.0	39.6	16,378	19,277	92.5	92.3	1,335	1,620	7.5	7.7
Massachusetts	26,846	27,119	11,180	17,444	41.6	64.3	14,403	9,675	53.7	35.7	25,583	27,119	95.3	100.0	1,263	------	4.7	------
Michigan	55,566	59,981	27,499	28,871	49.5	48.1	28,067	31,110	50.5	51.9	55,566	59,981	100.0	100.0	------	------	------	------
Minnesota	27,843	31,628	21,490	24,007	77.2	75.9	6,106	7,382	21.9	23.3	27,596	31,389	99.1	99.2	247	239	.9	.8
Mississippi	14,789	20,415	7,173	10,088	48.5	49.4	7,616	10,327	51.5	50.6	14,789	20,415	100.0	100.0	------	------	------	------
Missouri	23,527	25,148	23,439	25,148	99.6	100.0	------	------	------	------	23,439	25,148	99.6	100.0	88	------	.4	------
Montana	6,933	7,485	5,448	6,072	78.6	81.1	1,485	1,394	21.4	18.6	6,933	7,466	100.0	99.7	------	19	------	.3
Nebraska	14,227	18,217	6,412	8,604	45.1	47.2	5,493	6,535	38.6	35.9	11,905	15,139	83.7	83.1	2,322	3,078	16.3	16.9
Nevada	2,001	2,868	2,001	2,868	100.0	100.0	------	------	------	------	2,001	2,868	100.0	100.0	------	------	------	------
New Hampshire	6,514	6,860	5,735	6,230	88.0	90.8	779	630	12.0	9.2	6,514	6,860	100.0	100.0	------	------	------	------
New Jersey	44,872	45,703	23,086	30,040	51.5	65.7	10,296	15,046	22.9	32.9	33,382	45,086	74.4	98.6	11,490	617	25.6	1.4
New Mexico	6,510	9,476	5,627	8,399	86.4	88.6	267	338	4.1	3.6	5,894	8,737	90.5	92.2	616	739	9.5	7.8
New York	123,844	120,558	32,345	102,374	26.1	84.9	27,517	18,184	22.2	15.1	59,862	120,558	48.3	100.0	63,982	------	51.7	------
North Carolina	35,629	50,225	23,977	25,610	67.3	51.0	10,519	22,941	29.5	45.7	34,496	48,551	96.8	96.7	1,133	1,674	3.2	3.3
North Dakota	4,956	5,281	3,414	3,640	68.9	68.9	1,539	1,641	31.0	31.1	4,953	5,281	99.9	100.0	3	------	.1	------
Ohio	77,519	92,345	30,445	39,517	39.3	42.8	33,785	43,659	43.6	47.3	64,230	83,176	82.9	90.1	13,289	9,169	17.1	9.9
Oklahoma	20,251	39,592	12,605	29,380	62.2	74.2	7,414	10,212	36.6	25.8	20,019	39,592	98.8	100.0	232	------	1.2	------
Oregon	15,380	22,568	12,818	19,005	83.3	84.2	2,423	3,563	15.8	15.8	15,241	22,568	99.1	100.0	139	------	.9	------
Pennsylvania	99,184	99,595	71,341	83,184	71.9	83.5	12,019	16,383	12.1	16.4	83,360	99,567	84.0	99.9	15,824	28	16.0	.1
Rhode Island	6,893	7,070	2,895	3,640	42.0	51.5	56	59	.8	.8	2,951	3,699	42.8	52.3	3,942	3,371	57.2	47.7
South Carolina	15,902	21,278	13,368	17,634	84.0	82.9	2,317	2,967	14.6	13.9	15,685	20,601	98.6	96.8	217	677	1.4	3.2
South Dakota	6,486	7,200	4,512	5,513	69.6	76.6	1,867	1,626	28.8	22.6	6,379	7,139	98.4	99.2	107	61	1.6	.8
Tennessee	26,390	38,758	12,528	23,351	47.5	60.2	5,930	9,178	22.5	23.7	18,458	32,529	70.0	83.9	7,932	6,229	30.0	16.1
Texas	66,976	92,069	37,841	55,438	56.5	60.2	17,549	17,189	26.2	18.7	55,390	72,627	82.7	78.9	11,586	19,442	17.3	21.1
Utah	4,994	7,175	4,084	5,465	81.8	76.2	873	1,073	17.5	14.9	4,957	6,538	99.3	91.1	37	637	.7	8.9
Vermont	5,318	5,755	2,810	3,124	52.8	54.3	2,480	2,608	46.7	45.3	5,290	5,732	99.5	99.6	28	23	.5	.4
Virginia	26,175	36,861	17,969	17,762	68.7	48.2	8,197	19,022	31.3	51.6	26,166	36,784	100.0	99.8	9	77	------	.2
Washington	20,357	28,644	10,361	14,840	50.9	51.8	8,924	13,804	43.8	48.2	19,285	28,644	94.7	100.0	1,072	------	5.3	------
West Virginia	17,214	20,090	14,259	16,578	82.8	82.5	2,955	3,512	17.2	17.5	17,214	20,090	100.0	100.0	------	------	------	------
Wisconsin	34,893	42,849	11,037	28,029	31.6	65.4	11,016	10,993	31.6	25.7	22,053	39,022	63.2	91.1	12,840	3,827	36.8	8.9
Wyoming	3,553	5,794	2,864	4,694	80.6	81.0	689	1,100	19.4	19.0	3,553	5,794	100.0	100.0	------	------	------	------
Dist. of Columbia	5,034	5,992	------	------	------	------	4,779	5,542	94.9	92.5	4,779	5,542	94.9	92.5	255	450	5.1	7.5
Total	1,274,389	1,544,298	733,246	991,924	57.5	64.2	344,564	457,796	27.1	29.7	1,077,810	1,449,720	84.6	93.9	196,579	94,578	15.4	6.1

[1] Includes $629,000 allotted for county roads under State control in Delaware in 1940. Segregation is not available for 1946.

[2] Includes amounts allotted for county roads under State control in North Carolina, Virginia, and West Virginia. Similar allotments in Delaware are included with State highways. (See note 1.)

Increased highway-user tax rates.—Five States increased their motor-fuel tax rates during 1945 or 1946. In Idaho, Kansas, Oklahoma, and Virginia, the increase was made to assure adequate resources to match the Federal funds provided for the three Federal-aid programs. In none of these four States was the additional revenue intended to be used for roads of less importance than those in the Federal-aid systems. In Iowa, however, the motor-fuel tax was increased to provide funds for local roads and streets, without reference to the Federal program.

Reallocations of existing tax revenues.—In only one State, Alabama, was there a reallocation of existing taxes to provide a smaller share for State highways and a larger share for local roads. In 1943 the State decreased its motor-fuel tax allotment for State highways from 3 cents to 2 cents, and increased the amount for local roads and streets from 3 cents to 4 cents. The 1 cent taken away from State highways was to be used to match 1 cent of the county share to improve selected county roads, including those forming a part of the Federal-aid secondary system.

In Connecticut, Kentucky, North Carolina, Pennsylvania, and Virginia, where allocations are not based entirely on a percentage of revenues, appropriations for local roads and streets out of the State highway fund have increased at a greater rate than have the revenues collected. In Kentucky and Pennsylvania, the increases for local roads have been largely offset by a discontinuance of allocations for nonhighway purposes. In Connecticut, a 1947 increase in the motor-fuel tax rate may restore the prewar relation between appropriations for State highways and those for local roads. In North Carolina and Virginia, the large increase in appropriations for local roads under State control, made in 1945 and 1946, was partly to match Federal-aid secondary funds and partly to complete war-deferred improvements. In Massachusetts, the appropriations for local roads decreased during this period.

In Kentucky, Pennsylvania, and Wisconsin, basic changes in the distribution of highway-user revenues or in the handling of highway accounts resulted in the allocation for highway purposes of funds formerly used for nonhighway purposes. Nonhighway allocations in Kentucky decreased from 10 percent of total highway-user revenues in 1940 to none in 1946; in Pennsylvania the change was from 16 percent to less than 1 percent; and in Wisconsin from 37 percent to less than 9 percent. The immediate effect of the reallocation in Wisconsin was to provide additional funds for State highways, while in Kentucky and Pennsylvania it served to offset an increase in appropriations for local roads.

Appropriations from State general funds.—Many States accumulated large surpluses of general revenues during the war years. These surpluses have been used by some States to increase funds for the State and local highway programs. To some extent they have also been used to defer a demand for an increase in highway-user tax rates or a reallocation of existing taxes.

Between 1943 and 1946, considerable amounts were provided in this manner for local roads and streets by California, Illinois, and Washington, and for State highways by Louisiana, Ohio, and Oklahoma. Mississippi and West Virginia appropriated general revenues for both State and local roads. Only in West Virginia, where all county roads are under State control, were the appropriations the result of a continuing policy that was in effect in 1940.

Five other States—Delaware, Georgia, New Jersey, New York, and Rhode Island—regularly make appropriations for highways out of State general funds. These States, however, do not segregate highway revenues in a highway fund: they place all revenues in the State general fund and appropriate therefrom for all purposes, including highways. There has been no significant change in the ratio of amounts appropriated for State highways and for local roads and streets during recent years in these "one-fund" States. In New York, where highway appropriations in prior years were considerably less than the total highway revenues, the appropriations for 1945 and 1946 greatly exceeded such revenues.

In those States where appropriations for highways are made out of State general funds, while at the same time highway-user revenues are allocated by law to nonhighway purposes, the general fund appropriations, in effect, compensate highway funds partly or fully for the loss of highway-user revenues. This factor has been taken into consideration in determining the highway and nonhighway allocations in table 1.

EFFECTS OF 1947 LEGISLATION

The first general postwar legislative sessions in 1947 were confronted with insistent demands for additional funds for both State highways and local roads and streets. Rapidly increasing highway costs, together with the expanding highway programs, made it necessary for several States to seek additional revenues by increasing highway-user tax rates. In a few others the revenue from existing taxes was reallocated to provide additional funds for local roads and streets. Other States continued to appropriate funds for highways out of general revenues, but the full effect of these appropriations cannot yet be determined.

Increased highway-user tax rates.—Seven States—California, Colorado, Connecticut, Maine, Maryland, Rhode Island, and Vermont—increased their motor-fuel taxes during 1947. Several States also increased their motor-vehicle fees. From available information, it appears that in only one of these States, Colorado, has there been any basic change in the proportions of total highway-user revenues to be allotted to State highways and to local roads and streets. Under the previous 4-cent motor-fuel tax, Colorado allotted 27 percent to the counties. With an increase of 2 cents in the tax and some changes in its distribution, the counties and cities together will now receive approximately 37 percent of total motor-fuel revenues.

California and Maryland revised their distribution formulas when they increased highway-user tax rates, but the net result appears to be that State–local sharing was not materially changed. Nonhighway allocations were eliminated in Maryland and decreased in California.

Reallocations of existing tax revenues.—Eight States reallocated their highway-user revenues to give a greater share to local governments for roads and streets. In four of these the revisions affect the funds available for State highways: Oregon increased the cities' share of highway-user revenues from 5 percent to 10 percent and the counties' share from 15.7 percent to 19 percent, while Arkansas, Indiana, and Wisconsin allotted additional funds for local roads and streets provided the State receives certain guaranteed minimum amounts. The remaining four States in this group—Nebraska, New Mexico, Oklahoma, and Utah—increased their allotments to local roads and streets by decreasing or eliminating former nonhighway allocations.

(*Continued from page 49*)

vehicles, which were driven relatively low mileages during 1946, decreased the average travel per vehicle even though the average for trucks and combinations operated for the full 12-month period may have been as great as in 1941, or greater. The similar effect for passenger cars was of much less magnitude because the relative increase in numbers was much lower. Probably, since the number of trucks registered in 1946 was 14 percent greater than in 1941, the demand for new trucks came much nearer to being satisfied than that for passenger cars. The unslaked demand for the latter is reflected in an average mileage per car that is probably greater than would have been found if a normal number had been available for use.

The annual consumption of motor fuel per vehicle has risen well above prewar levels, from 694 gallons in 1941 to 747 in 1946. However, the 13.32 miles per gallon averaged by all vehicles in 1946 is somewhat below the 13.75 average of 1941. This is due chiefly to the following causes: (1) Trucks and combinations formed a larger percentage of the total motor-vehicle registration in 1946; (2) the average operating gross loads of trucks and combinations have increased substantially; and (3) because the average age of passenger cars was much greater than formerly, and their relative use of rural roads as compared with their urban travel had not quite returned to normal, it is probable that the average miles per gallon of passenger cars was somewhat below the prewar level.

The Effect of Petroleum-Like Constituents on Road Tars

and

A Test for Determining the Homogeneity of Road Tars

BY THE DIVISION OF PHYSICAL RESEARCH
PUBLIC ROADS ADMINISTRATION

Reported by R. H. LEWIS, Senior Chemist and W. J. HALSTEAD, Associate Chemist

Differences in behavior, during construction, of road tars meeting the same specifications have been traced to the presence in the tars of petroleum-like constituents consisting of unsulfonatable hydrocarbons. In this investigation it was found that the unsulfonatable hydrocarbons have a flocculating effect on the tar which increases as the percentage of unsulfonatable hydrocarbons increases until a separation of the blend into two phases results. The progressive flocculation up to the point of separation can be detected only by microscopic examination.

In the course of the investigation, a new test was devised to measure the relative compatability of unsulfonatable hydrocarbons and tars. It involves adding increments of a petroleum distillate to the tar and noting the "separation point"—the percentage of diluent at which the blended materials separate into two phases. The test indicates the relative amount of unsulfonatable hydrocarbons in tars from the same source, but cannot be used as an exact determination of these constituents in lieu of the sulfonation-index test. The new separation-point test will be useful as a rapid laboratory check on the uniformity of tar shipments from the same source.

DIFFERENCES in behavior of road tars meeting the same specification have frequently been noted by engineers using these materials in road construction. Recent studies to determine the cause for such variations in behavior point to the presence of petroleum-like constituents in the tar. It is well known that petroleum products and tars do not blend completely in all proportions, and thus there is a tendency toward incompatibility between these petroleum-like constituents and the normal constituents of the tar.

The presence of the petroleum-like constituents in tar is occasioned in two ways: First, by the use, as bases or fluxes, of water-gas tars that through improper processing contain a considerable amount of the original petroleum oil which has not been cracked or altered in the carburation process; and second, by the unintentional mixture in shipment, through failure to steam-clean a tank car or truck that had contained petroleum products before loading it with tar.

Since the usual tests made on road tars give no indication of the relative compatibility of petroleum-like constituents and tar, a new test has been developed to measure this condition. Briefly, this test is made by adding a petroleum distillate to measured portions of tars, thoroughly mixing the components, and noting the percentage of diluent at which the blended materials separate into two phases. The percentage of diluent required to bring about a separation is termed the "separation point."

Since the separation point represents an end point only and the visual observations give no indication of the intermediate effects of lesser additions of the petroleum distillate, further investigations were conducted in which the progressive changes in the tar structure produced by increasing increments of the petroleum-like materials were observed under a microscope. In addition, the effect of these changes on the kinematic viscosity of the tar blends was also studied.

The data obtained in each of the phases of this study are closely interrelated and the report has been arranged so as to give not only the development and significance of the separation-point test but also to present as complete a picture as possible of the changes produced in a tar by the presence of any percentage of petroleum-like material from zero up to the separation point.

The problems discussed in this paper are generally the same as those previously discussed in a report on the sulfonation-index test,[1] and a brief review of the basic chemical groups described in that paper and of the general conclusions drawn at that time are given here in order that the principles involved in this investigation may be fully understood.

The phenomenon of separation exhibited by blends of petroleum products and tars is not caused by any inherent difference in petroleum and tar, but rather because of the partial incompatibility of the major constituents usually found in these materials.

The major proportion of the constituents of most tars are hydrocarbons of the aromatic group, while uncracked petroleum products contain chiefly those of the paraffinic and naphthenic groups. Cracked petroleum products contain high percentages of the olefinic group, also. However, both tars and petroleum products may contain some percentage of all these groups; and the percentage of any group that may be present in either type of material will vary, depending on the source of the crude and the manufacturing process used. It is the paraffinic and naphthenic hydrocarbons that have been termed the petroleum-like constituents and whose presence in a tar is considered undesirable.

The maximum amounts of the paraffinic and naphthenic groups permitted in a road tar are controlled by the recently adopted specification requirements for the sulfonation index. This index represents the amount of material in the tar distillate that is unaffected when the distillate is treated with a very strong (98.6 percent) sulfuric acid. These are the paraffinic and naphthenic hydrocarbons, since the conditions of the test are so controlled that all other groups present will be oxidized or converted into sulfonic acids and dissolved in the excess sulfuric acid present in the reacting mixture.

In the report on the sulfonation index, it was shown that the presence of the unsulfonatable (paraffinic and naphthenic) hydrocarbons has an adverse effect on the binding and weathering properties of the tar. In that investigation, however, no attempt was made to evaluate the effect of these constituents on the structure of the tar. In this investigation the effect of the paraffinic and naphthenic constituents on the tar structure was of primary interest.

CONCLUSIONS

The data presented in this report are concerned chiefly with the effect on tar of the unsulfonatable hydrocarbons which have distillation characteristics similar to those of the distillate from RT–2 to RT–4 grade road tars.

[1] *The sulfonation index test for road tars,* by R. H. Lewis and W. J. Halstead; PUBLIC ROADS, vol. 23, No. 7; Jan–Feb.–Mar. 1943.

Some differences in behavior for the various types of base materials were obtained which are believed to be chiefly caused by differences in viscosity. It is probable that unsulfonatable materials which distill at a lower or higher range in temperature will show additional variations in behavior. It is believed, however, that the fundamental cause of the phenomena observed is the same in all cases. As a result of this study the following conclusions, based on the behavior of the RT–2 to RT–4 grades, may be drawn:

1. The unsulfonatable hydrocarbons present in a tar blend have a flocculating effect on the dispersed phase of the tar. This effect increases as the percentage of unsulfonatable hydrocarbons increases until a separation into two phases results.

2. Tests on filtered tars showed that, in addition to this flocculation of the dispersed phase, large amounts of unsulfonatable hydrocarbons caused the development of incompatibility of certain constituents originally soluble in the continuous phase.

3. No evidence of the flocculation of the dispersed phase can be seen with the unaided eye until the separation point is reached. The progressive development of this flocculation for increasing percentages of Diesel oil can be seen by microscopic examination.

4. The separation-point test is a means of measuring the relative compatibility of the constituents in a tar blend, and can be used as a rapid check in the laboratory to determine the uniformity of shipments from the same source.

5. The separation-point test gives an indication of the relative amount of unsulfonatable hydrocarbons in tars from the same source, but it cannot be used as an exact determination of these constituents in lieu of the sulfonation-index test.

6. No attempt has been made to correlate directly the results of the separation-point test with service behavior or laboratory tests designed to show bonding strength or other road building properties. Such correlations may be impossible to obtain because of the many complex factors that affect the quality of a road tar. However, it is believed that the compatibility of the various constituents in a road tar is an important one of these factors, and the separation-point test is a simple means of securing a relative measure of this property.

PETROLEUM DISTILLATE CHARACTERISTICS

There are a number of petroleum distillates available, all of which will give similar results when used as the diluent in determining the separation point. In this investigation, preliminary studies were conducted with four types of petroleum oil: A close-cut paraffinic distillate in the boiling range of kerosene, Bunker–B fuel oil, No. 2 grade fuel oil, and Diesel oil. It was found that separation occurred with lower percentages of the paraffinic distillate and Bunker–B fuel oil than with the No. 2 grade fuel oil or Diesel oil, the latter two giving comparable results.

For the purpose of the investigation it was desirable to use a material that had the same general distillation characteristics as the tar distillate from the more fluid grades of tar, and also one in which the unsulfonated hydrocarbons would be chemically similar to the unsulfonated materials in the tars.

Preliminary tests on several petroleum distillates showed Diesel oil to have these desirable characteristics. Table 1 compares the characteristics of the Diesel oil and its unsulfonated residue with a typieal distillate from a RT–2 grade tar, and with a composite sample of the unsulfonated residues from numerous samples of tars that had formerly been tested in the laboratory. The last-mentioned material was obtained by accumulating the unsulfonated residues from all the tars tested in the laboratory over a period of several years. The residues were combined, washed free of acid, separated from the water, and dried with anhydrous sodium sulfate.

Table 1 shows the specific gravity, the index of refraction, and distillation characteristics for each of the distillates. These distillation data are plotted in figure 1. It is shown by these results that the unsulfonated residue from the tar distillates and the unsulfonated residue from the Diesel oil have very nearly the same boiling range, specific gravity, and index of refraction, and therefore must be chemically similar. It is also shown that the distillation curve of the Diesel oil itself does not vary greatly from that of the tar distillate.

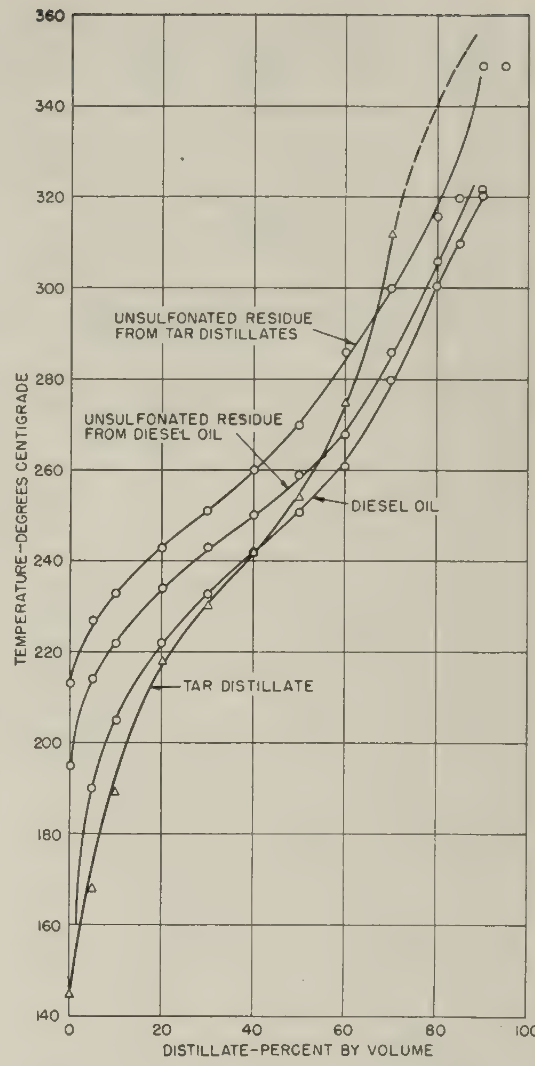


Figure 1.—Comparison of distillation properties of Diesel oil, a tar distillate, and their unsulfonated residues.

For further identification of the Diesel oil, the results of a number of standard tests are given below:

Specific gravity at 25°/25° C	0. 842
Density at 35° C____gms. per cm³	. 832
Volume distillation characteristics (A. S. T. M. test method D158–41):	
Initial boiling point__degrees C	120
Vapor temperature at which:	
10 percent boiled off_degrees C	194
20 percent boiled off____do	211
30 percent boiled off____do	229
40 percent boiled off____do	238
50 percent boiled off____do	248
60 percent boiled off____do	257
70 percent boiled off____do	268
80 percent boiled off____do	282
90 percent boiled off____do	302
End point____do	318
Volume distillate at end point____percent	94
Residue at end point____do	5
Weight distillation characteristics (A. S. T. M. test method D 20–30):	
Distillate to 300° C____percent	87. 2
Distillate 300–318° C____do	8. 5
Residue____do	3. 6
Sulfonation index:	
Distillate to 300° C	66. 3
Distillate 300–318° C	6. 1
Volume of Diesel oil unsulfonated____percent	64

Table 1.—***Comparison of test characteristics of various types of distillates***

	Diesel oil	Unsulfonated residue from Diesel oil	RT–2 tar distillate (to 355° C.)	Unsulfonated residue from tar distillate (to 355° C.)
Specific gravity at 25°/25° C	0. 842	0. 808	0. 995	0. 827
Index of refraction at 25° C	1. 469	1. 447	1. 587	1. 452
Distillation characteristics: [1]				
Initial boiling point____degrees C	125	195	145	213
Vapor temperature at which:				
5 percent boiled off____degrees C	190	214	168	227
10 percent boiled off____do	205	222	189	233
20 percent boiled off____do	222	234	218	243
30 percent boiled off____do	233	243	230	251
40 percent boiled off____do	242	250	242	260
50 percent boiled off____do	251	259	254	270
60 percent boiled off____do	261	268	275	286
70 percent boiled off____do	280	286	312	300
80 percent boiled off____do	301	306	(2)	316
85 percent boiled off____do	310	320	(2)	
90 percent boiled off____do	321	322	(2)	349
95 percent boiled off____do				349
End point____do	321	322	367	349
Volume distillate at end point____percent	92	90	93	95

[1] Distillation made using 20 milliliters in a 50-milliliter Engler distilling flask, with water-cooled condenser.
[2] Readings not obtained because of solids in the condenser.

PROCEDURE FOR DETERMINING THE SEPARATION POINT OF TARS

Weigh 10 milliliters of tar (weight calculated from density at 25° C.) into a flat 2-ounce ointment can and add Diesel oil from a burette in increments so that each increment will increase the percentage by volume of Diesel oil in the final blend by 2.5 percent.[1] The sample shall be stirred thoroughly after each addition of Diesel oil [2] [3] and examined for evidence of separation. When a definite precipitation or separation remains after several minutes of stirring, this sample shall be set aside and Diesel oil added to other 10-milliliter portions of the tar so that the percentages of Diesel oil in the blends are 2.5, 5.0, 7.5, etc. percent [4] lower than that at which separation was obtained with the initial sample. The blended samples shall be allowed to remain undisturbed overnight and then examined for separation. Their condition shall then be noted on the following basis:

- ***NS* (No Separation)—The appearance and flow properties of a normal tar remain.**
- ***VSS* (Very Slight Separation)—No definite separation can be detected, but the material does not flow as a normal tar.**
- ***SS* (Slight Separation)—Some evidence of separation, gelling, or precipitation can be detected initially, but after thorough stirring it is difficult to see.**
- ***DS* (Definite Separation)—Unmistakable separation, gelling, or precipitation can be detected even after thorough stirring.**

The lowest percentage, by volume, of Diesel oil that causes slight separation (*SS*) shall be reported as the separation point. Sometimes the point of slight separation cannot be determined with precision and in such cases the percentage of Diesel oil that causes definite separation (*DS*) shall be reported as the separation point.

NOTES

[1] The milliliters of Diesel oil added to a 10-milliliter sample of tar to give the required percentages of diluent in mixtures are as follows:

Percentage of diluent	*Volume added (ml.)*	*Percentage of diluent*	*Volume added (ml.)*
2.5	0.26	27.5	3.79
5.0	.53	30.0	4.29
7.5	.81	32.5	4.81
10.0	1.11	35.0	5.39
12.5	1.43	37.5	6.00
15.0	1.77	40.0	6.67
17.5	2.12	42.5	7.40
20.0	2.50	45.0	8.18
22.5	2.90	47.5	9.05
25.0	3.33	50.0	10.00

[2] Viscous samples, or those that are difficult to blend, may be warmed on a steam bath. The temperature should not be allowed to exceed 60° C. and the sample should be covered while on the steam bath. When it is known that the separation point will be relatively high, increments larger than 2.5 percent may be added until the end point is approached.

[3] All stirring should be done with a spatula, since a slight precipitation is more readily seen when the tar is allowed to flow over a flat surface.

[4] Usually the separation point is 2.5 or 5.0 percent lower than the point of definite separation determined on the first samples so that three portions of the tar are sufficient to determine the separation point after settling overnight. However, if tests on three samples fail to give the desired range, additional tests must be made until the lowest point of slight separation is determined.

After considerable experimentation with various size samples, various temperatures, and various methods of blending, the laboratory procedure for making the test for separation point was standardized as described in a separate statement on this page.

A check on the precision of the test was conducted by having three operators determine the separation point of a small group of specially prepared samples. The results of these tests are shown in table 2. In most cases the same observations were recorded, and in all cases except for sample *3–X*, the same separation point was reported by all operators. For sample *3–X*, operator 2 reported the separation point as 35.0 percent, while operators 1 and 3 reported 32.5 percent. Since operators 2 and 3 had no instructions other than those in the written procedure, it was concluded that personal variations in determining the points at which separation occurs will not be great and close agreement should be obtained by different operators or laboratories when the same diluent is used.

TARS AND FLUXES FROM KNOWN SOURCES USED

Through the courtesy of one of the tar manufacturers, five crude base tars from different sources and four different types of fluxing material were obtained for use in this investigation. The test characteristics of these materials are shown in table 3.

Sample *A*, the coke-oven tar, is of a type that normally gives very good service when used as a road tar.

Sample *B*, the horizontal-retort tar, is of a type that is produced only in small quantities in the United States and it is rarely used in road-tar manufacture.

Sample *C*, the vertical-retort tar, is usually blended with other types of material, such as a heavy water-gas tar, when used in a road tar. It is generally considered unsatisfactory if used alone.

Sample *D*, the heavy water-gas tar, is one of a very large class of tars that exhibit considerable variation in properties. These tars are widely used as base materials for road-tar manufacture.

Sample *E* is an extremely viscous water-gas tar that would probably be blended with less viscous bases if used in a road tar.

Sample *F* represents a low-boiling coal-tar distillate, and sample *G* a medium-boiling distillate. Both these materials are satisfactory fluxes when used in a balanced blend.

Sample *H*, the low sulfonation-index water-gas tar, is rated as very good fluxing material for any type base.

Sample *I* is reported to be the highest sulfonation-index tar available to the manufacturer who supplied the samples, yet it is a satisfactory flux when used in limited quantities.

The tar acids were removed from the crude coal tars, samples *A*, *B*, and *C*, by distilling to 270° C. and treating the distillate with sodium hydroxide. The residual tar oils were then separated from the caustic, washed, dried with anhydrous sodium sulfate, and recombined with the distillation residue. The tests resulting in the data shown in table 3, and all other tests, were conducted on these recombined samples. Samples *D* and *E* were not treated but were used as received.

SPECIAL PRESSURE FILTER USED

In order to trace the effect of the unsulfonatable hydrocarbons on the tar after removal of the free carbon, a portion of each base tar was filtered. Tests with these filtered tars

Table 2.—*Comparison of the separation points of selected samples, determined by different operators*

Identification No.	Volume of Diesel oil in blend	Condition of blend [1] reported by operator—			Separation point [2] reported by operator—		
		1	2	3	1	2	3
	Percent						
1–X	2.5	*NS*	*NS*	*NS*	5.0	5.0	5.0
	5.0	*SS*	*SS*	*SS*			
	7.5	*DS*	*DS*	*DS*			
	10.0	*DS*	*DS*	*DS*			
2–X	2.5	*DS*	*SS*	*SS*	2.5	2.5	2.5
	5.0	*DS*	*DS*	*DS*			
	7.5	*DS*	*DS*	*DS*			
3–X	30.0	*NS*	*NS*	*NS*	32.5	35.0	32.5
	32.5	*SS*	*VSS*	*SS*			
	35.0	*DS*	*DS*	*DS*			
4–X	22.5	*NS*	*NS*	*NS*	27.5	27.5	27.5
	25.0	*VSS*	*VSS*	*VSS*			
	27.5	*DS*	*DS*	*DS*			
5–X	10.0	*NS*	*NS*	*NS*	15.0	15.0	15.0
	12.5	*NS*	*NS*	*VSS*			
	15.0	*SS*	*SS*	*SS*			
6–X	2.5	*DS*	*DS*	*DS*	2.5	2.5	2.5
	5.0	*DS*	*DS*	*DS*			
	7.5	*DS*	*DS*	*DS*			

[1] *NS*=no separation; *VSS*=very slight separation; *SS*=slight separation; *DS*=definite separation.
[2] As represented by percentage volume of Diesel oil in blend.

were conducted in parallel with tests on the unfiltered tars, except that the viscosity determinations of the Diesel-oil blends with the filtered tars were not made. The filtration was accomplished in a special pressure filter without the use of any solvent or diluent. This filter was designed and constructed according to the principle of that sketched by Volkmann, Rhodes, and Work.[2]

The filter medium is an alundum extraction shell, 34 millimeters in diameter and 100 millimeters high. Experiments showed that the coarse or medium porosity shells gave equally satisfactory results. Air pressure was maintained manually at 50 to 60 pounds per square inch. The water bath was heated electrically and thermostatically controlled at the desired temperature. The flask receiving the filtrate was immersed in ice water to reduce evaporation losses. Samples *A* and *C* were filtered at 60° C. and samples *B*, *D*, and *E* were filtered at 90° C.

Table 4 shows a comparison of the characteristics of the filtered and unfiltered tars. In all cases the specific gravity was reduced by filtration. The kinematic viscosity of the filtered samples showed a slight decrease for samples *A* and *C*, and a considerable decrease for sample *B* which contained a high percentage of organic matter insoluble in carbon disulfide. For samples *D* and *E* the viscosity increased. This increase is believed to have been caused by evaporation losses. These samples (*D* and *E*) were more difficult to filter than the coal tars.

The tar-insoluble material shown in the last column of table 4 represents the carbonaceous material that is suspended in the tar and can be seen under the microscope. The percentage of this material was calculated from the difference between the solubilities in carbon disulfide of the unfiltered and filtered tars. It is not the difference between the values shown in table 4 since the percentage for the filtered tar is not on the basis of the total tar and this correction must be considered. The percentage of tar-insoluble material showed wide variations among the different types of tars. It is of interest to note that even though the organic material insoluble in carbon disulfide for the unfiltered coal tars *A* and *C* and the unfiltered water-gas tars *D* and *E* showed only minor differences, there is a large difference in the amount of suspended matter present. All of the filtered tars were essentially clear of any suspended particles when viewed under the microscope.

As a further check on the efficiency of the filtration, determination was made of the amount of material in a 10-gram sample of the filtered horizontal retort tar *B*, that was insoluble in 100 milliliters of nitrobenzene. The result of this test was 0.02 percent insoluble organic material.

SEPARATION POINT RELATED TO BREAK-DOWN OF TAR

In order to study the phenomena accompanying the separation of the tar blend and to determine the effect of aging on the separation point, series of blends with Diesel oil were made for filtered and unfiltered portions of each base tar. The percentage of Diesel oil was varied from zero up to the separation point and observations made during a period of 30 days. The percentage of Diesel oil in the blend showing a slight separation for the various periods of aging are shown in table 5.

[2] *Physical properties of coal tars*, by E. W. Volkmann, E. O. Rhodes, and L. T. Work; Industrial and Engineering Chemistry, vol. 28, No. 6; June 1936; p. 721.

Table 3.—*Characteristics of bases and fluxes from known sources*

	Base tars					Fluxes			
						Coal-tar fluxes		Water-gas tar fluxes	
	Coke-oven tar	Horizontal-retort tar	Vertical-retort tar	Heavy water-gas tar	Heavy water-gas tar	Low boiling	Medium boiling	Low sulfonation	High sulfonation
Sample identification	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Grade	RT-4	RT-9	RT-4	RT-8	RT-11	Flux	Flux	Flux	Flux
Specific gravity at 25°/25° C	1.176	1.245	1.106	1.171	1.176	1.008	1.101	1.085	1.012
Engler specific viscosity:									
At 40° C	23.4	--------	35.4	--------	--------	1.1	1.7	1.9	1.6
At 50° C	--------	--------	15.4	--------	--------	--------	--------	--------	--------
Float test:									
At 32° C, seconds	--------	165.2	--------	87.9	849.0	--------	--------	--------	--------
At 50° C	--------	69.0	--------	45.0	144.0	--------	--------	--------	--------
Kinematic viscosity at 35° C., centistokes	322	29,900	429	10,900	306,000	2.0	11.0	13.4	9.2
Carbon disulfide solubility:									
Bitumen, percent	94.20	76.63	94.41	92.51	93.28	99.95	99.54	99.91	99.90
Organic insoluble material, do	5.76	23.32	5.55	7.25	6.56	.05	.43	.08	.08
Inorganic insoluble material, do	.04	.05	.04	.24	.16	0	.03	.01	.02
Water content, do	0	0	Trace	.5	0	0	Trace	0	1.4
Distillation (by weight):									
Total distillate:									
To 170° C, percent	.29	0	.43	.47	.21	.52	.13	.45	1.11
To 200° C, do	2.02	0	1.23	1.18	.83	5.21	.63	2.78	2.14
To 235° C, do	6.79	1.74	5.52	4.23	4.28	66.94	2.23	13.59	11.49
To 270° C, do	15.83	7.62	17.62	10.87	11.17	94.90	17.20	26.60	41.20
To 300° C, do	23.39	12.42	27.12	19.10	19.45	97.57	37.11	37.22	57.55
To 355° C, do	38.05	25.45	45.27	30.99	32.58	98.17	78.55	58.18	76.18
Residue from distillate to 300° C., percent	75.98	86.84	72.00	79.82	80.16	1.80	62.30	62.40	41.49
Softening point of residue above 300° C, percent	38.0	52.2	39.6	62.8	60.9	[1]	[1]	29.6	29.4
Sulfonation index:									
On total distillate to 300° C	.3	.2	2.7	.3	.1	1.2	.3	.6	11.1
On distillate between 300–355° C	.1	.2	1.9	.1	.3	.1	.4	.1	1.9
On total distillate to 355° C	.4	.4	4.6	.4	.4	1.3	.7	.7	13.0
Separation point	27.5	22.5	20.0	32.5	25.0	[2]	50.0	55.0	27.5

[1] Too fluid for softening point determination.

[2] Miscible with Diesel oil in all proportions.

Table 4.—*Comparison of characteristics of filtered and unfiltered tars*

Sample identification	Specific gravity at 25° C.		Kinematic viscosity at 35° C.		Organic material insoluble in carbon disulfide		Tar-insoluble material [1]
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	
			Centistokes	*Centistokes*	*Percent*	*Percent*	*Percent*
A	1.176	1.172	373	342	5.76	4.81	1.00
B	1.245	1.197	31,200	10,000	23.32	9.01	15.73
C	1.106	1.103	854	683	5.55	4.20	1.41
D	1.171	1.152	12,900	13,500	7.25	.85	6.45
E	1.176	1.161	378,000	415,000	6.56	1.87	4.78

[1] Calculated from differences in organic material insoluble in carbon disulfide for filtered and unfiltered tar. This represents the carbonaceous material suspended in the tar.

Table 5.—*Variation of separation point and precipitation point with age of blends tested*

Sample identification	Test method	Percentage of Diesel oil in blend showing slight separation after aging test blends for—				
		0	1 day	2 days	7 days	30 days
Sample *A*:						
Unfiltered	Separation point	--------	27.5	--------	--------	22.5
Filtered	do	27.5	27.5	27.5	25.0	22.5
Do	Precipitation point [1]	22.5	20.0	20.0	20.0	20.0
Sample *B*:						
Unfiltered	Separation point	22.5	22.5	--------	--------	22.5
Filtered	do	27.5	22.5	22.5	22.5	22.5
Do	Precipitation point [1]	20.0	20.0	20.0	20.0	20.0
Sample *C*:						
Unfiltered	Separation point	20.0	20.0	--------	--------	20.0
Filtered	do	25.0	25.0	25.0	22.5	20.0
Do	Precipitation point [1]	22.5	20.0	20.0	--------	17.5
Sample *D*:						
Unfiltered	Separation point	37.5	32.5	--------	--------	32.5
Filtered	do	37.5	37.5	37.5	35.0	32.5
Do	Precipitation point [1]	37.5	35.0	35.0	35.0	30.0
Sample *E*:						
Unfiltered	Separation point	--------	25.0	--------	--------	25.0
Filtered	do	32.5	30.0	--------	--------	--------
Do	Precipitation point [1]	27.5	27.5	--------	--------	--------

[1] Determined by microscopic examination.

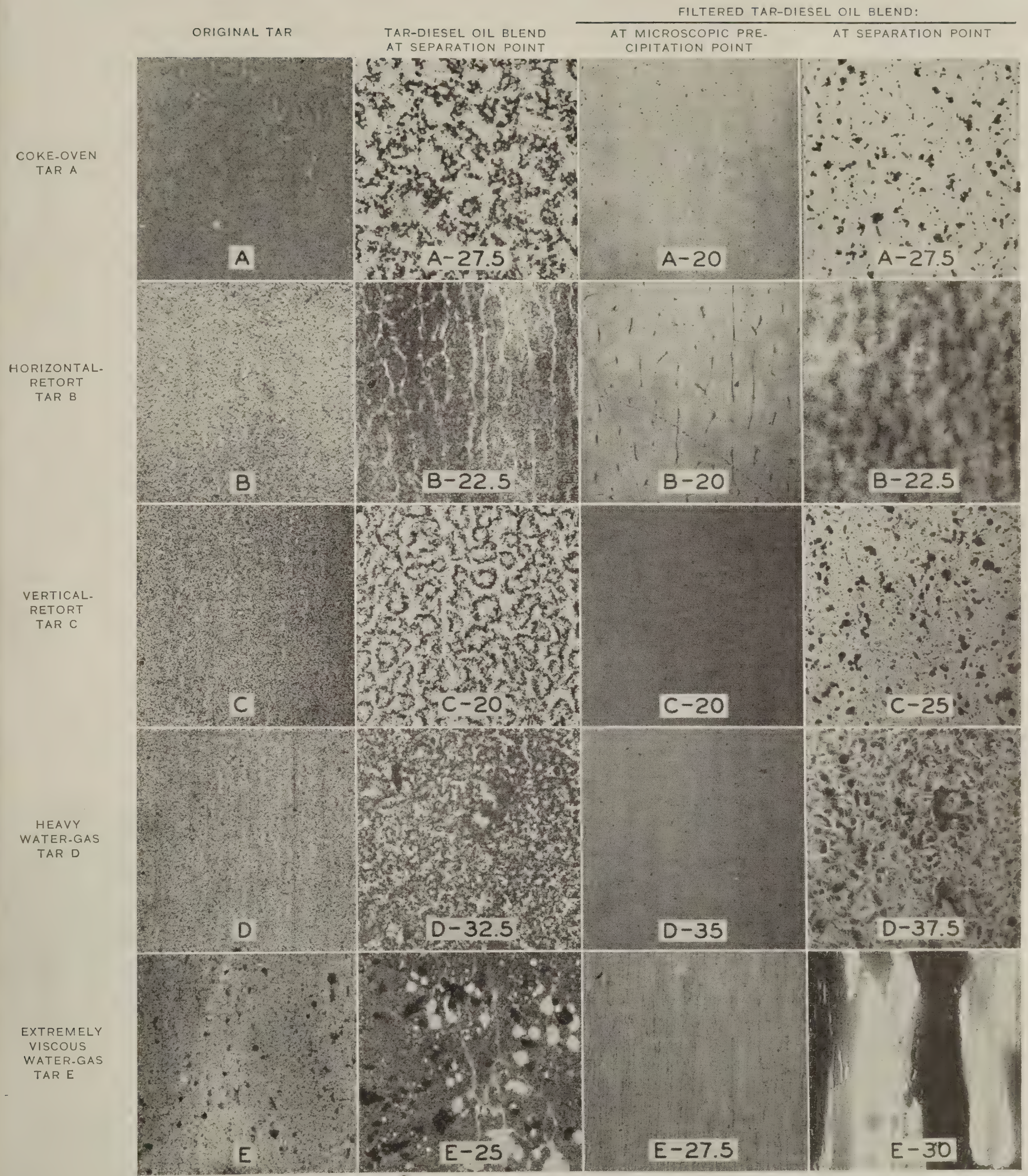


Figure 2.—Photomicrographs of blends of various tars with Diesel oil, showing (from left to right) the original tar, the tar–Diesel oil blend at separation point, the filtered tar–Diesel oil blend at microscopic separation point, and the filtered tar–Diesel oil blend at separation point. The type of tar and the percentage of Diesel oil in each blend are indicated at the bottom of each photograph by letter and number.

In addition to the usual observations for separation point, blends of the filtered tar were also examined under the microscope and the blend containing the lowest percentage of Diesel oil which showed the presence of precipitated particles or a separation into two phases, was recorded as the precipitation point. These data are also shown in table 5.

In all of the blends shown in table 5, the degree of the separation increased with the age of the blend. When separation first occurred the presence of two phases was often difficult to determine but upon standing there was a definite formation of a bottom phase, which became increasingly more viscous, and a top phase, which became less viscous and free of any flocculated particles. For all the unfiltered tars except sample *A*, there was no change in the separation point between 1 and 30 days. For sample *A*, the separation point decreased 5 percent in 30 days. For the filtered tars, the separation point decreased 5 percent from 1 to 30 days in all cases except for sample *B*. For sample *B*, the separation point was constant after 1 day, but there was a 5-percent decrease in the 1-day period. The observations with the microscope showed that there was only a slight change in the precipitation point after 1 day, and in the cases where a change occurred (sample *C*, 30 days, and sample *D*, 30 days) the amount of precipitation was extremely small. These results indicate that the changes in the appearance of the blends with age is caused chiefly by a mechanical settling of the flocculated particles and that the chemical equilibrium established after 1-day aging is only slightly affected by time.

The precipitation point determined with the microscope indicates a break-down in the structure of the tar and can be determined precisely. However, this determination requires the use of considerable special apparatus and is time consuming. The separation point is closely related to this precipitation point and the simplicity of the method makes it a more valuable laboratory test.

Microscopic study of all the blends involved in the determination of the separation points shown in table 5 showed that for the unfiltered tars there was a progressive flocculation of the dispersed phase with increasing percentages of Diesel oil. Photomicrographs were made to show this effect and also to show the appearance of the tars at the various critical points.

Photomicrographs of each base tar, the appearance of the blend at the separation point, the appearance of the filtered tar at the precipitation point, and the appearance of the filtered tar at the separation point are shown in figure 2. In each part of the figure, the type of tar and the percentage of Diesel oil in the blend are indicated by letter and number. The blends for all these photomicrographs were 1 day old and the pictures were taken of fresh slides that stood undisturbed for approximately 15 minutes, until all movement stopped. The slides were made with a sliding gage which gives a film thickness of 0.001 inch except those shown in figures 2*B* and the 2*E* series, which were 0.0005-inch films. No cover glass was used for any of these photomicrographs. The magnification in all cases is 58 diameters.

The coke-oven tar *A* has the most finely divided particles of any of the base materials studied. The separation point for this tar resulted from the flocculation of the dispersed phase and the precipitation of these conglomerates from the tar blend. When viewed immediately, the precipitated particles in the filtered tar had a fine lacy structure and were evenly distributed throughout the field. However, they quickly coalesced, forming closely clustered masses. The photomicrograph of the 1-day old blend shows these clusters after coalescence into larger groups (top right illustration, fig. 2).

The horizontal-retort tar *B* was very difficult to photograph because of its high concentration of free carbon. It was necessary to use a 0.0005-inch film thickness for the original material. The precipitated particles in the third illustration in the *B* series, figure 2, were evenly distributed when the slide was first made, but they quickly formed the pattern shown. The same is true for the fourth illustration in the *B* series. Small droplets of excess oil which had separated from the mass of the tar were visible under the microscope, but these are obscure in this photomicrograph.

The vertical-retort tar *C* (fig. 2*C*) showed essentially the same type of behavior as did the coke-oven tar *A*. One important difference between these two materials which cannot be shown by the photographs is the difference between the color and opacity of the continuous phase. The film for the coke-oven tar *A* is a brownish red and requires a considerably greater light intensity for photographing than does the yellow film for the vertical-retort tar *C*. The dispersed particles in the original tar are initially larger for sample *C* than for sample *A*.

The water-gas tar *D* (fig. 2*D*) shows evenly distributed small bodies throughout the tar with large, very black particles scattered unevenly. These particles will settle from the tar on long standing and are not an integral part of the tar system. For this material, the separation is chiefly a separation into two liquid phases. This is most clearly shown by the filtered tar blend in the last illustration in the *D* series, figure 2.

The extremely viscous water-gas tar *E* (fig. 2*E*) shows considerably more of the large carbon particles than does sample *D*. The separation in this case occurs when the tar cannot dissolve any more Diesel oil and the very light oils separate out, leaving the bulk of the tar with generally the same appearance as the original. Slides of this material are very difficult to make because of the lubri-

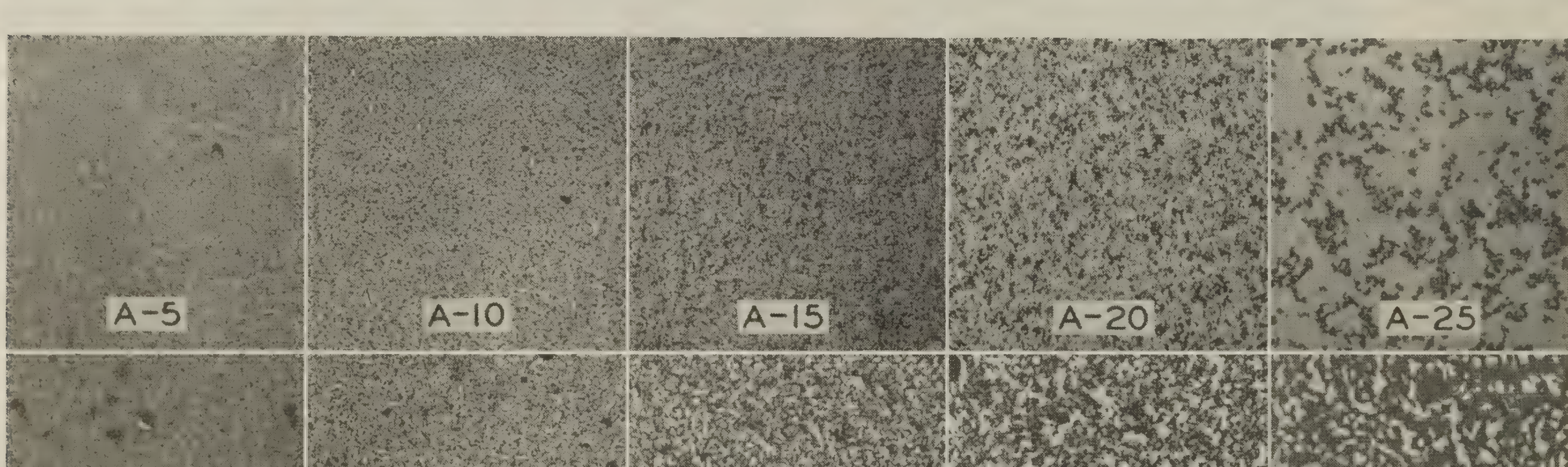


Figure 3.—Photomicrographs of blends of coke-oven tar A and water-gas tar D with Diesel oil, showing progressive flocculation of the dispersed phase. The type of tar and the percentage of Diesel oil in each blend are indicated at the bottom of each photograph by letter and number.

Table 6.—*Characteristics of special blends with heavy water-gas tar* D

Blend	Composition by volume			Specific gravity at 25° C.		Kinematic viscosity of unfiltered sample at 35° C.	Diesel oil added to reach separation point		Total Diesel oil in blend at separation point	
	Base tar *D*	Light water-gas tar *H*	Diesel oil	Unfiltered sample	Filtered sample		Unfiltered sample	Filtered sample	Unfiltered sample	Filtered sample
	Percent	*Percent*	*Percent*			*Centistokes*	*Percent*	*Percent*	*Percent*	*Percent*
a	65	35	0	1.144	1.136	452	37.5	37.5	37.5	37.5
b	65	28	7	1.129	1.126	353	32.5	32.5	37.2	37.2
c	65	21	14	1.111	1.104	250	27.5	27.5	37.6	37.6
d	65	14	21	1.095	1.086	191	17.5	17.5	34.8	34.8
e	65	7	28	1.075	1.071	196	10.0	10.0	35.2	35.2
f	65	0	35	1.061	1.054	252	0	0	35.0	35.0

cating effect of the separated oil which prevents an even distribution of the tar–Diesel oil film.

The photomicrographs (magnified 58 times) shown in figure 3 are typical examples of the progressive flocculation of the dispersed phase which occurs when increasing percentages of Diesel oil are added to the unfiltered tar. In these cases the 0.001-inch tar film was covered immediately with a cover glass which prevented the pattern formation previously discussed. The type of tar and the percentage of Diesel oil in the blends are indicated by letter and number, in each part of the figure. It is noted that the flocculation of the dispersed phase has progressed to an advanced stage before separation occurs. The blends shown in figures 3*A–25* and 3*D–30* are 2.5 percent below the separation point. The point at which visual separation occurs cannot be determined under the microscope by any sudden change in the appearance of the blends of the unfiltered tar.

VISCOSITY OF TAR HAS SLIGHT EFFECT ON SEPARATION POINT

In these series of blends there were wide differences in the viscosities of the original materials, and the various amounts of Diesel oil added gave blends that were widely different in viscosity at the separation point. A limited study of blends of approximately the same viscosity was made, using the heavy water-gas tar *D* as the base material. Six blends were made, with a constant volume of 65 percent of the base material and 35 percent of a flux made up of combinations of the light water-gas tar *H* and Diesel oil. The proportion of Diesel oil in the flux varied from 0 to 100 percent in 20 percent increments. The composition and characteristics of these blends are shown in table 6. The appearance of each of these materials 1 day after blending is shown in figure 4, and the same identifying letters are used as in table 6. These photomicrographs, of 0.001-inch films magnified 58 times, show progressive flocculation with increasing percentages of Diesel oil in essentially the same manner as did the base materials already shown.

The last two columns of table 6 show only a slight downward trend in the total amount of Diesel oil at the separation point as the amount of true flux, *H*, is decreased. If the viscosity of the combination of the base tar and flux *H* be considered, it is seen that this series is equivalent to a series of tars ranging from approximately RT–4 (viscosity range of blend *a*) to RT–8 (viscosity range of base tar) and thus it is indicated that the viscosity has only a minor influence on the separation point. The kinematic viscosity data shown in table 6 indicate a break in the viscosity–composition curve of the unfiltered tars caused by the increasing flocculation. The viscosities of blends *e* and *f* rise slightly instead of decreasing as would be expected by the trend of decreasing viscosity for additional Diesel oil established by the blends *a* through *d*.

UNSULFONATABLE HYDROCARBONS AT SEPARATION POINT VARY

In order to study the effect of unsulfonatable hydrocarbons on the properties of RT–2, RT–3, and other grades of road tar, a number of combinations of the base and flux materials shown in table 3 were made. Diesel oil was also added when materials of very high sulfonation indexes were desired. To obtain base materials of the same order of viscosity, it was necessary to distill samples *A* and *C* to 270° C. The residues from these distillations were then used as the base material in all the blends for samples *A* and *C*.

Table 7 shows the results of various tests made on a series of blends for each base tar. The blends with suffix number *1* represent a balanced road material made up in accordance with the suggestions of the producer who supplied the material. These blends are believed to be representative of the best practices for manufacturing road tars of the RT–2 and RT–3 grades using only a single type of base material. Photomicrographs of these blends show them to have the same general appearance and very nearly the same degree of dispersion as do the original base tars. The blends with suffix number *2* contain the same percentages by weight of base and light flux, but the medium fluxing material has been replaced with the same percentage of the high sulfonation-index light water-gas tar, *I*. In all cases, except for sample *A* in which no change was noted, the separation point was less when sample *I* was used. No appreciable flocculation could be detected in these blends.

The blends with suffix numbers *3* and *4* were made using only the light water-gas tars as fluxes. For the number *3* blends sample *I* (high sulfonation index) was used, and for the number *4* blends sample *H* (low sulfonation index) was used. In these cases the separation point was less for the number *3* blends, which contained the greater amount of unsulfonatable hydrocarbons, than for the number *4* blends. The blends with suffix number *5*, made with samples *A* and *D*, each contain the same percentage of unsulfonatable hydrocarbons as did the number *3* blends of the respective material, but the source of the flux and the sulfonation residue differs. The flux for the number *5* blends was a mixture of Diesel oil and sample *H*. In each case the separation point was 2.5 percent (one incre-

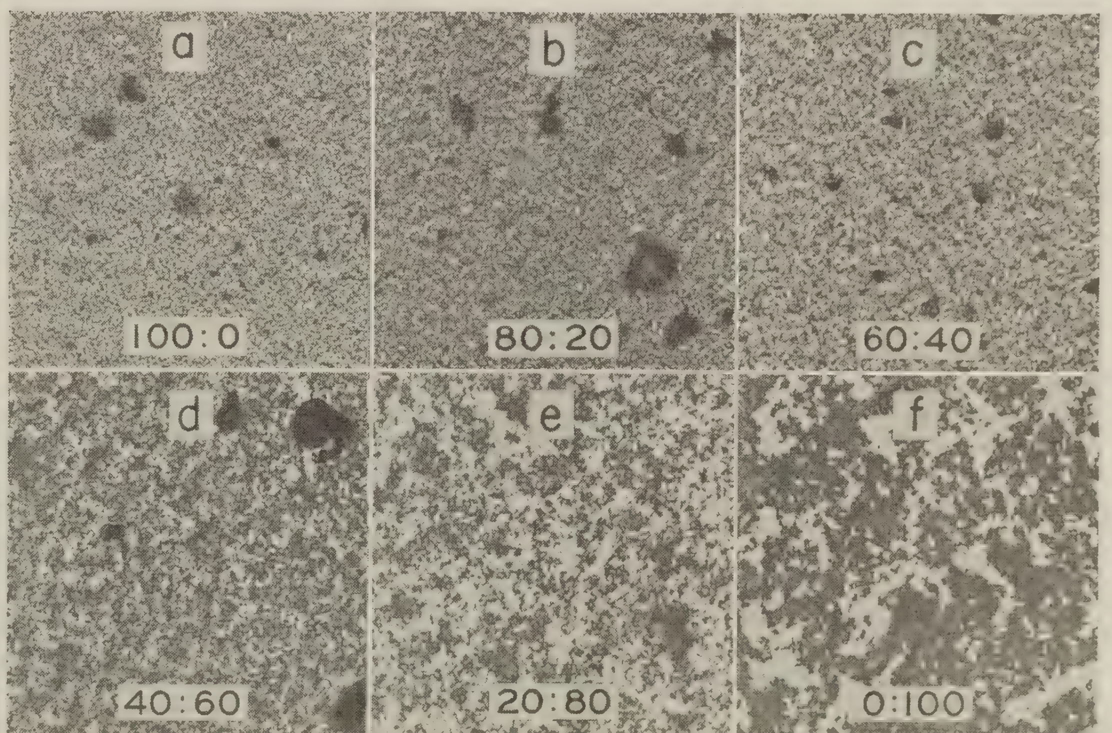


Figure 4.—Photomicrographs of blends of water-gas tar D *containing 65 percent by volume of the base tar and a flux of various proportions of light water-gas tar* H *and Diesel oil. The proportions of the flux in each blend are indicated at the bottom of each photograph, the first number being the percentage of tar* H*, and the second number the percentage of Diesel oil.*

Table 7.—*Characteristics of blends of base tars with various fluxes*

Blend identification	Composition: Base: Identification	Base: Weight	Base: Volume	Medium flux: Identification	Medium flux: Weight	Medium flux: Volume	Light flux: Identification	Light flux: Weight	Light flux: Volume	Specific gravity at 25°/25° C.	Kinematic viscosity at 35° C.	Sulfonation index to 355° C. (calculated)	Separation point	Total volume of unsulfonatable distillate at separation point
Blends with tar *A*:		*Percent*	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*		*Centistokes*			*Percent*
A-1	*A* [1]	70.0	67.7	*H*	15.0	16.0	*F*	15.0	17.3	1.164	298	0.4	27.5	17.9
A-2	*A* [1]	70.0	65.8	*I*	15.0	17.0	*F*	15.0	17.1	1.150		2.3	27.5	19.5
A-3	*A* [1]	70.0	66.0	*I*	30.0	34.0				1.149	847	5.0	20.0	17.4
A-4	*A* [1]	70.0	67.4	*H*	30.0	32.6				1.179		.3	27.5	17.9
A-5	*A* [1]	70.0	65.2	*H*	24.9	27.9	Diesel oil	5.1	6.9	1.135	835	5.0	22.5	19.0
A-6	*A* [1]	70.0	63.8	*I*	15.0	16.4	do	15.0	19.8	1.111	851	13.0	2.5	15.8
A-7	*A* [1]	70.0	62.7	*I*	7.5	8.1	do	22.5	29.2	1.093		17.6	(2)	
Blends with tar *B*:														
B-1	*B*	70.0	66.3	*G*	15.0	16.1	*F*	15.0	17.6	1.179	232	.4	12.5	8.4
B-3	*B*	70.0	65.5	*I*	30.0	34.5				1.160	1,158	4.2	5.0	7.9
B-6	*B*	70.0	63.3	*I*	15.0	16.7	Diesel oil	15.0	20.0	1.126		13.1	(2)	
Blends with tar *C*:														
C-1	*C* [1]	68.0	66.1	*G*	16.0	16.2	*F*	16.0	17.7	1.116	264	2.2	32.5	22.5
C-2	*C* [1]	68.0	65.1	*I*	20.0	21.8	*F*	12.0	13.1	1.100		4.7	27.5	21.4
C-3	*C* [1]	68.0	65.2	*I*	32.0	34.8				1.101	885	6.1	17.5	16.7
C-4	*C* [1]	68.0	66.7	*H*	32.0	33.3				1.127		2.1	30.0	20.8
C-6	*C* [1]	68.0	65.5	*I*	16.0	15.7	Diesel oil	16.0	18.8	.991	863	14.0	(2)	
C-7	*C* [1]	68.0	64.5	*I*	8.9	7.7	do	24.0	27.8	.976		18.7	(2)	
Blends with tar *D*:														
D-1	*D*	67.0	64.8	*G*	20.0	20.6	*F*	13.0	14.6	1.132	173	.5	40.0	25.9
D-2	*D*	67.0	63.6	*I*	20.0	22.0	*F*	13.0	14.4	1.112		3.0	37.5	26.1
D-3	*D*	67.0	63.7	*I*	33.0	36.3				1.109	452	4.5	27.5	21.2
D-4	*D*	67.0	65.3	*H*	33.0	34.7				1.141		.4	40.0	25.9
D-5	*D*	67.0	64.1	*H*	27.5	28.4	Diesel oil	5.6	7.5	1.121	452	4.5	30.0	22.8
D-6	*D*	67.0	61.4	*I*	16.5	17.5	do	16.5	21.1	1.074	298	14.4	10.0	20.1
D-7	*D*	67.0	60.8	*I*	8.3	8.7	do	24.7	30.9	1.056	347	19.2	2.5	20.4
D-8	*D*	67.0	60.0	*I*	5 0	5.1	do	28.0	34.9	1.048		21.2	(2)	
Blends with tar *E*:														
E-1	*E*	62.5	60.2	*G*	25.0	25.7	*F*	12.5	14.1	1.133	263	.6	35.0	22.8
E-2	*E*	62.5	58.9	*I*	25.0	27.4	*F*	12.5	13.7	1.108		3.7	32.5	23.6
E-3	*E*	62.5	59.9	*I*	37.5	41.1				1.105	1,010	5.1	22.5	18.7
E-4	*E*	62.5	60.6	*H*	37.5	39.4				1.140		.5	35.0	22.8
E-6	*E*	62.5	56.6	*I*	18.75	19.7	Diesel oil	18.75	23.7	1.066	804	16.3	2.5	18.5
E-7	*E*	62.5	55.4	*I*	9.4	9.7	do	28.1	34.9	1.044		21.8	(2)	

[1] Residue from distillation to 270° C.

[2] Blend separated.

ment) higher for blend *5* than for blend *3*. Photomicrographs showed no discernible difference in the degree of dispersion in these tars.

The blends with suffix numbers *6*, *7*, and *8*, together with number *3*, form a series in which, for each tar, a constant percentage by weight of base tar was blended with a flux in which the amount of unsulfonatable hydrocarbons varied greatly. The flux for the number *6* blends contained 50 percent by weight of Diesel oil and 50 percent by weight of sample *I*. The flux for the number *7* blends contained 75 percent (by weight) Diesel oil and 25 percent sample *I*. For the number *8* blend with sample *D*, the flux was 85 percent (by weight) Diesel oil and 15 percent sample *I*. The blends for each of the base materials showed the same behavior as the series reported in table 6 for the water-gas tar *D*; that is, those blends with smaller amounts of tar flux and greater amounts of Diesel oil showed increasing flocculation of the dispersed phase as the percentage of Diesel oil increased.

Unusual behavior was shown by the blends from sample *B*, the horizontal-retort tar. These samples formed a gel with Diesel oil at percentages considerably lower than the point at which two distinct phases could be detected. Microscopic examination showed that this gelling was caused primarily by the high concentration of the flocculated particles. These formed a lacy network which, upon standing, developed a structural strength from the coherence of the tar particles. After standing overnight, containers holding these samples could be inverted without causing flow. After stirring, however, the material flowed freely. Special blends were made using the filtered tar as base, with the same percentages of flux as was used in the *B-1* and *B-3* blends. This filtered *B-1* blend had a precipitation point (microscopic) of 12.5 percent, and the filtered *B-3* blend had a precipitation point of 2.5 percent. These points were in close agreement with the point of gelling, 12.5 percent for *B-1* and 5.0 percent for *B-3*, determined for the unfiltered blends. The separation point for the filtered blends was 20 percent for *B-1* and 10 percent for *B-3*.

The final column in table 7 shows the total percentage of unsulfonatable material present in the test blend at the separation point, as calculated from the amount in the Diesel oil added and from that contained in the tar as determined by the sulfonation index. The amount of unsulfonatable hydrocarbons that can be tolerated by each tar is approximately constant. Much of the variation in each group of blends is caused by the method of test for the separation point, since the Diesel oil was added in increments of 2.5 percent, each increment representing 1.6 percent of unsulfonatable material in the blend.

Another source of variation is the large difference in the amount of good tar flux present in the blends, since this material will tolerate more Diesel oil than will the base tar. The average value of the percentage of paraffinic and naphthenic hydrocarbons required to cause separation varied for each base material, with the lower values being obtained with the coal tars. These values were 17.9 percent for sample *A*, 8.1 percent for sample *B*, and 20.3 percent for sample *C*. The values for the water-gas tars were 23.2 percent for *D*, and 21.3 percent for *E*.

The blends reported in table 7 were made with a limited number of materials and in most cases essentially all of the unsulfonatable hydrocarbons present in the various blends were from the Diesel-oil flux. In order to obtain data that would be more representative of the materials which are encountered in practice, a number of trade tars were tested. These tars were selected so as to give as wide a range in the sulfonation index as was possible. The very high sulfonation-index tars selected include almost all such tars submitted to the laboratory over a period of several years and are not typical of the usual road tar submitted for routine analysis. Some of the test characteristics for these materials are shown in table 8. Comparison of the separation point with the sulfonation index shows that there is a definite trend toward a decreasing separation point for an increasing sulfonation index of the total distillate to 355° C. This is also shown by the close agreement of the total amount of unsulfonatable distillate required to cause separation (last column of table 8), since for an exact inverse relation between sulfonation index and separation point this value would be a constant.

There are some materials that show deviations in this value which are considerably larger than can be attributed to experimental error. This is probably caused by a low resistance to flocculation of the particular base tar or by an unbalanced blend of tar materials. In general, however, neither the grade of the material nor its source (as represented by the producer) made any definite difference in the amount of unsulfonatable hydrocarbons that could be tolerated by the tar. The average percentage of unsulfonatable hydrocarbons in the blend at the separation point is 21.9. The average deviation from this mean is ± 2.2 percent. Since, as previously noted, the procedure for the determination of the separation point requires the Diesel oil to be added in increments of 2.5 percent, which equals 1.6 percent unsulfonatable material, it is concluded that most tar being used for the manufacture of road materials will separate with essentially the same percentage of paraffinic and naphthenic hydrocarbons.

Microscopic examinations of the trade tars show that, as was the case with the laboratory blends, the degree of flocculation of the particles in the tar increases as the separation point decreases. This is shown by the photomicrographs in figure 5, in which *1* and *12* are samples so identified in table 8 (sample *X* illustrated in figure 5 is not included in table 8). It should also be noted that those materials that have lower separation points than would be indicated by the sulfonation indexes are flocculated to a greater degree than are those having separation points more consistent with the sulfonation indexes. This is indicated by the appearance of the tars shown in figures 5–*12* and 5–*X*. There is a wide difference in the separation points of the two tars—12.5 for the sample in figure 5–*12* and 2.5 for the sample in figure 5–*X*—while the sulfonation indexes of the total distillate to 355°C. are 7.5 and 8.8, respectively, which is equivalent to a difference of only 1.3 percent in unsulfonatable material.

KINEMATIC VISCOSITY—COMPOSITION CURVES

The effect of the unsulfonatable hydrocarbons on the kinematic viscosity of tars was studied by blending the base tars and selected trade tars with various percentages of either Diesel oil or a coal-tar distillate (sample *F*, table 3). The kinematic viscosities of these blends at 35° C. were determined by means of a capillary viscosimeter.[3]

In order to insure uniform blending, the blends of the base tars were prepared by adding the desired amount of flux and warming in a closed container on the steam bath to approximately 60° C. The sample was then stirred until a uniform blend was obtained. The blends with the RT–2 and RT–3 materials were made at room temperature.

[3] This viscosimeter and the procedure for making the test is the same as that described in the report *The determination of the kinematic viscosity of petroleum asphalts with a capillary viscosimeter*, by R. H. Lewis and W. J. Halstead; PUBLIC ROADS, vol. 21, No. 7; September 1940; p. 127.

Table 8.—*Test characteristics for various grades of road tars*

Identification	Producer	Consistency: Engler specific viscosity at 40° C.	Consistency: Float test at 32° C.	Specific gravity at 25°/25° C.	Softening point of residue above 300° C.	Sulfonation index: Distillate to 300° C.	Sulfonation index: Distillate from 300° C. to 355° C.	Sulfonation index: Total distillate to 355° C.	Separation point	Volume of unsulfonatable distillate at separation point
			Seconds		*° C.*					*Percent*
Grade RT–2 tar, sample:										
1	Z	12.2		1.152	50.7	0.3	0.1	0.4	32.5	21.3
2	Z	12.9		1.148		.9	.1	1.0	27.5	18.7
3	X	10.1		1.128	49.6	1.5	.7	2.2	32.5	23.3
4	Y	12.3		1.122		1.8	.7	2.5	32.5	23.6
5	X	11.8		1.108	29.2	2.2	2.0	4.2	25.0	20.7
6	Z	11.3		1.137	33.0	2.9	1.4	4.3	30.0	24.1
7	X	11.7		1.115	46.8	3.3	1.2	4.5	27.5	22.6
8	X	9.1		1.126	40.4	3.2	1.6	4.8	27.5	23.0
9	X	11.8		1.102	47.2	4.0	1.4	5.4	27.5	23.6
10	W	12.7		1.153	42.8	5.2	.5	5.7	12.5	14.6
11	X	11.2		1.111	59.2	6.4	1.0	7.4	27.5	25.8
12	X	12.1		1.098	35.7	5.4	2.1	7.5	12.5	16.2
13	Y	11.5		1.096		10.3	.7	11.0	17.5	23.3
14	X	12.9		1.084	33.5	6.9	4.5	11.4	15.0	22.0
Average for grade										21.6
Grade RT–3 tar, sample:										
15	U	17.3		1.151	50.8	.6	.2	.8	37.5	24.9
16	Z	16.2		1.138	37.0	.8	.3	1.1	37.5	25.3
17	U	21.2		1.127	57.1	2.2	.8	3.0	35.0	25.8
18	Y	20.5		1.122	50.4	2.2	1.0	3.2	27.5	21.2
19	Y	18.2		1.146	28.2	2.8	.8	3.6	27.5	21.7
20	Y	17.0		1.136	33.0	3.9	1.0	4.9	25.0	21.6
21	Y	15.9		1.130	36.5	4.9	1.5	6.4	25.0	23.2
22	W	15.0		1.155	42.9	6.0	.4	6.4	17.5	18.6
23	Z	13.3		1.128		7.6	.1	7.7	22.5	23.1
24	X	20.0		1.104	40.7	7.2	2.6	9.8	17.5	22.0
25	X	13.8		1.087	42.8	7.7	3.4	11.1	7.5	16.9
26	X	14.9		1.075	44.5	10.2	3.1	13.3	12.5	22.3
27	X	13.3		1.090	46.5	10.8	3.0	13.8	20.0	27.8
28	X	13.8		1.085	42.0	12.4	2.4	14.8	7.5	20.9
29	X	20.7		1.055	48.2	17.0	2.2	19.2	2.5	21.9
Average for grade										22.5
Grade RT–4 tar, sample:										
30	U	32.5		1.135	60.4	2.2	.5	2.7	37.5	27.1
31	X	23.1		1.115	47.5	3.4	1.4	4.8	27.5	23.0
32	X	25.6		1.108	32.6	7.1	4.1	11.2	10.0	18.8
33	X	28.4		1.086	56.5	16.0	2.4	18.4	5.0	23.2
Average for grade										23.0
Grade RT–5 tar, sample:										
34	Z	[1] 25.0		1.180	55.4	.2	.1	.3	25.0	16.3
35	T	[1] 22.2		1.159	39.6	.5	.2	.7	32.5	21.5
36	U	[1] 22.6		1.140	59.4	1.7	.6	2.3	32.5	23.3
Average for grade										20.4
Grade RT–6 tar, sample:										
37	U		45	1.232	58.5	.3	.2	.5	27.5	18.2
38	U	[1] 31.6		1.145	60.0	1.5	.8	2.3	32.5	23.3
Average for grade										20.7
Grade RT–8 tar, sample:										
39	U		117	1.196	73.3	.1	.1	.2	30.0	19.4
40	X		85	1.212	42.6	.4	.2	.6	27.5	18.3
41	S		102	1.166	41.6	.9	1.0	1.9	30.0	21.5
42	X		106	1.182	49.2	4.5	1.2	5.7	25.0	22.8
43	X		94	1.154	60.8	7.1	1.6	8.7	20.0	24.2
Average for grade										21.2
Average for all grades										21.9

[1] Specific viscosity at 50° C.

The viscosity tests of all the blends in which the coal-tar distillate was the diluent were not affected by the period of aging or the amount of stirring of the material before testing. It was concluded that in the proportions used for these tests the tar distillate was completely compatible with all the tars.

The blends with low percentages of Diesel oil in which the flocculation was not excessive generally had the same viscosity at the top and bottom of the sample and also after standing overnight without stirring. The blends with percentages of Diesel oil near or greater than the separation point gave erratic results. Such blends were allowed to stand overnight in the viscosimeter tube and brought to test temperature without stirring. The capillary tube was then immersed to a depth of 0.2 centimeters for the first test and to a depth of 2.0 centimeters for the second test. In cases where a definite separation into two phases had occurred, the depth of immersion of the capillary tube for the second test was adjusted so that the tip of the tube was in the lower phase. The viscosity of each phase was thus

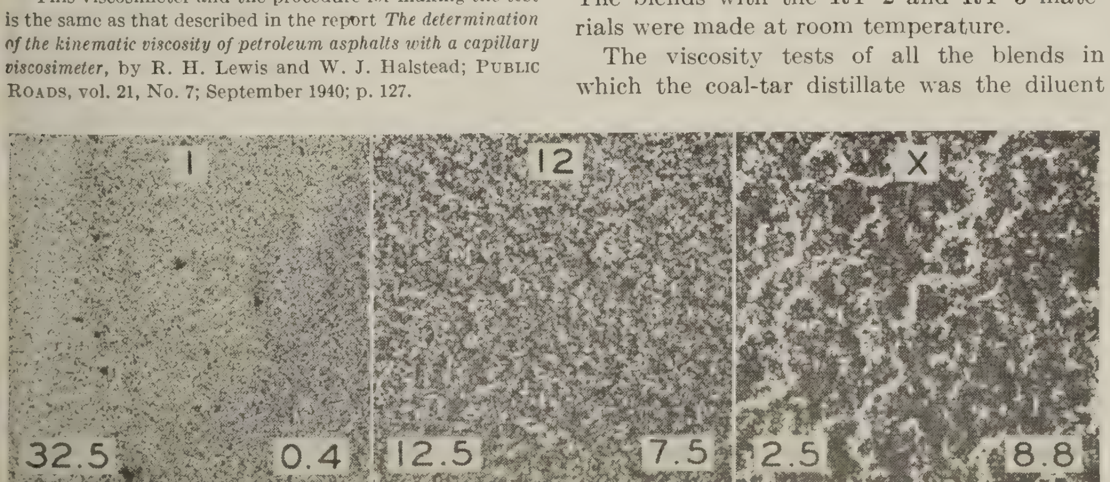


Figure 5.—Photomicrographs of trade tars showing variations in degree of flocculation with variations in the separation point. The percentage of Diesel oil added to the tar at the separation point is indicated by the left-hand number at the bottom of each photograph; the sulfonation index on the total distillate to 355° C. by the right-hand number.

Table 9.—*Kinematic viscosity of base tars blended with various percentages of Diesel oil and coal-tar distillate*

Identification of tar and volume of diluent in sample	Kinematic viscosity at 35° C.		
	Coal-tar distillate blends	Diesel-oil blends	
		Top	Bottom
Coke-oven tar *A* [1] with diluent percentage of:	*Centistokes*	*Centistokes*	*Centistokes*
0	120, 000	120, 000	120, 000
10.0	4, 800	8, 300	8, 300
20.0	609	1, 700	1, 700
22.5		1, 530	1, 530
25.0		1, 470	1, 470
27.5		1, 490	1, 830
30.0	127	840	3, 080
40.0	41	5	7, 130
Horizontal-retort tar *B* with diluent percentage of:			
0	29, 000	29, 000	29, 000
10.0		4, 930	4, 930
12.5		3, 720	3, 720
15.0		2, 980	2, 980
17.5		3, 120	3, 120
20.0	755	2, 580	2, 580
22.5		2, 820	2, 820
25.0	236	400	
30.0	140		2, 960
40.0	62		12, 450
Vertical-retort tar *C* [1] with diluent percentage of:			
0	68, 800	68, 800	68, 800
10.0	5, 100	10, 700	10, 700
20.0	289	3, 150	3, 150
22.5		2, 650	2, 650
25.0		1, 850	1, 850
27.5		66	2, 430
30.0	142	51	4, 100
40.0	50	16. 5	105, 000
Heavy water-gas tar *D* with diluent percentage of:			
0	10, 900	10, 900	10, 900
10.0		2, 450	2, 450
17.5	410		
20.0		960	960
22.5	219		
30.0	87		
32.5		270	270
35.0		200	390
40.0		13. 5	37, 000
45.0		5. 8	17, 000
Heavy water-gas tar *E* (extreme case) with diluent percentage of:			
0	306, 000	306, 000	306, 000
10.0	17, 800	43, 700	43, 700
20.0	1, 980	15, 000	15, 000
22.5		3, 270	3, 270
25.0		4, 050	15, 000
27.5		2, 560	
30.0	320	16. 6	28, 500
40.0	76		1, 050, 000

[1] Residue from distillation to 270° C.

determined. Because of the grainy or flocculated characteristics of the lower phase, check results varied greatly and only an approximate average value could be determined for this portion of the material.

Tables 9, 10, and 11 show the results of these viscosity tests. Table 9 shows the data for the base tars, table 10 gives the results for the RT–2 and RT–3 tars made by fluxing the base tars in the laboratory, and in table 11 are shown representative samples of RT–2 and RT–3 trade tars.

These data were plotted, using a viscosity scale the same as that for the modified viscosity temperature charts (A. S. T. M. method D 341–39) for the ordinates. A natural scale for the percentage of Diesel oil in the blend was used for the abscissae. All the curves, with the exception of that for the RT–3 tar made with horizontal-retort tar *B* as the base, were similar in appearance.

Typical examples of these curves are shown in figure 6 for the blends of sample *A* (table 9), the coke-oven base tar (270° C. distillation residue); for sample *D* (table 9), made with the heavy water-gas tar; for sample *1* (table 11), the RT–2 trade tar; for sample *A–1* (table 10), the RT–3 tar made from the coke-oven tar base; and for sample *25* (table 11), the RT–3 trade tar. The peculiar behavior of tar–Diesel oil blends of sample *B–1* (table 10), the RT–3 from the horizontal-retort tar, is also shown in figure 6. On the same grid is also shown a curve for coal-tar distillate blends. The data for this curve are as follows:

Volume of diluent in sample	*Kinematic viscosity at 35° C.*
Percent	*Centistokes*
0	232
10	89. 5
20	47. 3
30	31. 4

In figure 6, the coke-oven tar *A* shows the effect on the viscosity when the separation is that of excess "oil" separating from the tar. In this case there is a considerable range in which there is only a very small change in the viscosity, with increasing amounts of Diesel oil. After the separation point has been exceeded the viscosity of the top phase becomes very low while the bottom shows a more gradual increase. For sample *A–1*, an RT–3 from coke-oven tar, there is no wide range of equal viscosity. Upon separation both phases retain liquid characteristics and the difference between the value for the viscosity of each phase increases more slowly. The separation for base tar *D* may also be classed as a separation into two liquid phases and the curve has the same general shape as that for the RT–3 (sample *A–1*). For the RT–2 trade tar (sample *1*) and for the RT–3 trade tar (sample *25*), the separation is a settlement of flocculated particles with the formation of a grainy mass after standing. The RT–2 is a low sulfonation residue tar with a separation point of 32.5 percent. The RT–3 is a high sulfonation tar and has a separation point of 7.5 percent. Both curves show a very rapid increase in the viscosity of the bottom phase.

For all the blends made with coal-tar distillate, the curves are approximately straight lines, with greater slopes than for the initial portion of the curves for the Diesel-oil blends for the same tar.

The peculiar behavior of sample *B–1*, the RT–3 made from the horizontal-retort tar, results from the gelling action caused by the high concentration of the flocculated particles. As the amount of Diesel oil is increased, the size and concentration of the flocculated particles increases and thus the resistance to flow also increases and the apparent viscosity of the blend increases. When the amount of Diesel oil increases to such an extent that an excess of oil is present this separates out on top while the bottom retains much the same appearance as the gel except that it becomes increasingly more viscous.

In general, the erratic changes in curvature of these viscosity–composition curves with increasing amounts of Diesel oil reflect the developments of incompatability of the components of the blend. This was shown by the studies with the microscope to result in the flocculation of the dispersed phase followed by the precipitation of some of the constituents of the continuous phase. The percentage of Diesel oil in the blend at the point of separation for the viscosity curves for the top and bottom of the samples corresponds closely to the separation point determined in the usual manner. Comparisons of these values are shown in table 12. Exact agreement is shown in five cases and in eight cases the separation point determined by the usual procedure was 2.5 percent (one increment) higher than that determined from the viscosity curves. In one case (sample *C*) the separation point by the usual procedure was 5 percent lower than that from the curves.

UNIFORMITY CHECKED BY SEPARATION-POINT TEST

While the separation point is not an exact measurement of a distinct property of a tar, these results show it to be a valuable indication of the compatibility of the components in any tar blend. This compatibility is closely related to the amount of unsulfonatable hydrocarbons present in the tar, but the relation between the separation point and the sulfonation index is not sufficiently exact to enable the separation-point test to be used in lieu of the sulfonation-index test. Further study of road tars with this test or similar tests based on the same principle to develop correlations with service behavior is believed necessary before it can be used in specifications.

The simplicity of the test suggests several practical uses by those engaged in testing or conducting research on road tars. One such application is its use as a control test to check the uniformity of shipments from the same source and to indicate contamination with petroleum products if this should occur. This is illustrated by the results obtained on two samples of the same RT–2 grade road tar. This material was tested and the storage tank sealed. The sulfonation index was 4.5 (on the total distillate to 355° C.) and the separation point was 27.5 percent. The first distributor load from the storage tank was tested and the separation point was found to be 5 percent. The sulfonation index was 18.0 (on the total distillate to 355° C.). Investigation showed that the distributor had been filled with cut-back asphalt, RC–2, the previous day and apparently had not been cleaned before loading with tar. While overnight settling is necessary for a final result, definite indications of unusual conditions are obtained in the laboratory in only a few minutes by the use of the separation-point test.

Another application of this test is its use in research investigations as an indication of the compatibility of the constituents and as a measure of the changes in compatibility of the various tars being studied. In such applications, exact duplication of the procedure and flocculating agent (Diesel oil) used in this work would not be necessary as long as the same material and procedure is used throughout a series of tests.

THEORETICAL EXPLANATION OF DIESEL-OIL ACTION

A theoretical explanation of the phenomena shown in the test for separation point is suggested by the correlation of the results with the theory of the structure of tar and other bituminous materials. Most authors attribute changes in the dispersion characteristics or mutual solubility of the hydrocarbons to a change in surface and interfacial tension as a result of some outside influence. Oliensis discussed this theory in explaining the fundamental significance of the Oliensis spot test for asphalts.[4]

He described the action of the naphtha used in the test as weakening the surface tension of the lighter phases in the asphalt, thereby increasing the interfacial tension between them and the heavier phases, and impairing the mutual solubility. The degree of impairment is made a constant in the Oliensis test. The asphalts that develop negative spots have mutual solubilities (phase relations) which are so stable they are not destroyed by the standard amount of naphtha; hence no insoluble dispersion results. On the other hand, those materials giving positive spots do not have stabilities sufficient to prevent incompatibility of certain constituents when subjected to the action of the solvent, and a precipitation of these constituents results. The separation-point test for tars involves the same fundamental principles. In this case the "disturbing influence" or "flocculating force" is varied by adding different amounts of Diesel oil. The value of this flocculating force necessary to produce the same condition in all tars is measured, and is represented by the amount of Diesel oil required to cause separation into two phases. This has been previously shown to be very closely related to the point at which some constituents that were originally

[4] *Fundamental significance of Oliensis spot test—Quantitative tests for homogeneity*, by G. L. Oliensis; Proceedings of the 44th annual meeting of the American Society for Testing Materials, vol. 41; 1941; p. 1108.

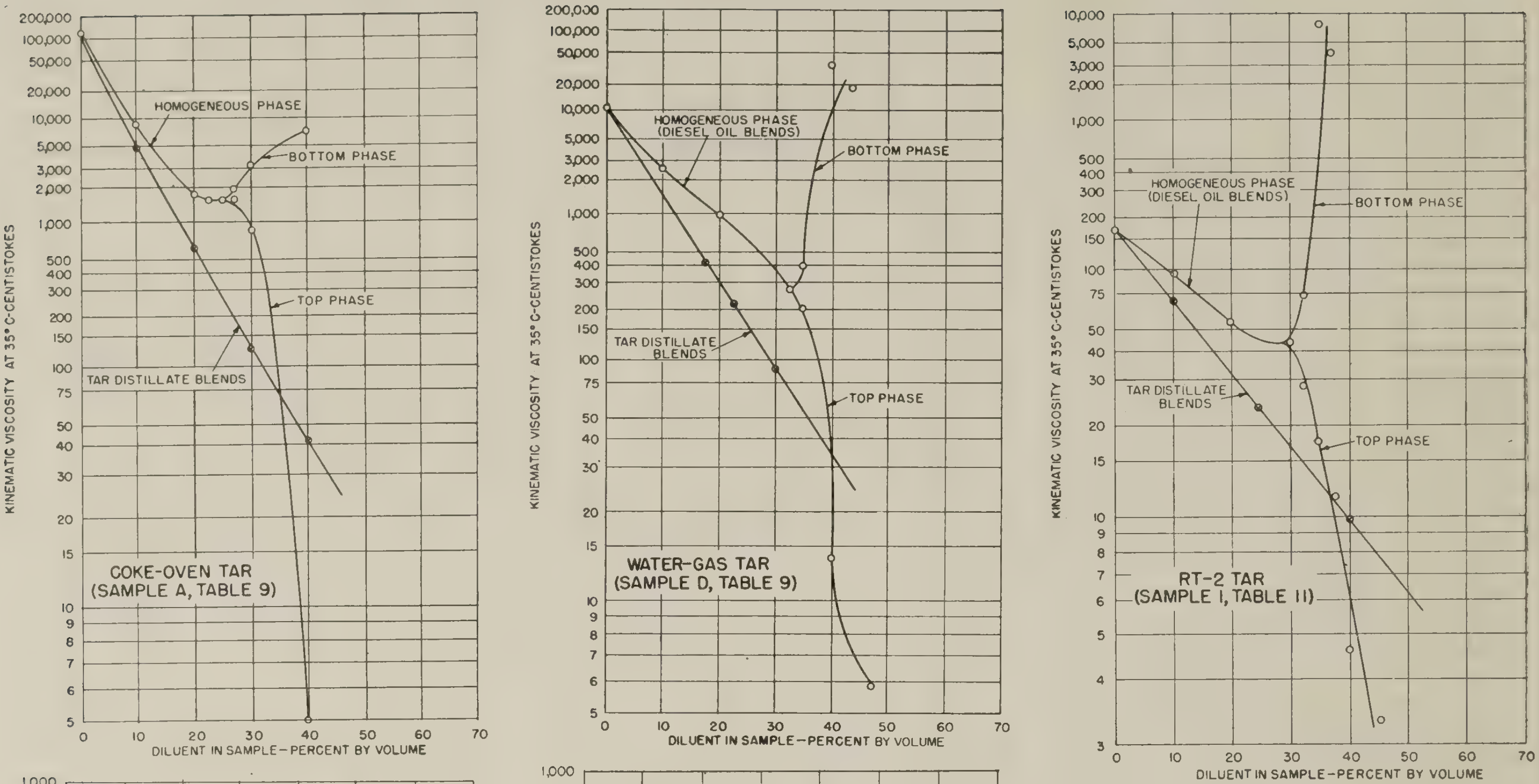
Table 10.—*Kinematic viscosity of fluxed tars blended with various percentages of Diesel oil*

Identification of tar and volume of Diesel oil in sample	Kinematic viscosity at 35° C.	
	Top	Bottom
Sample *A-1* (RT–3 tar) with diluent percentage of:	*Centistokes*	*Centistokes*
0	191	191
10.0	104	104
20.0	75	75
25.0	56	56
27.5	51	51
30.0		74
32.5	20	
37.5	10	125
Sample *B-1* (RT–3 tar) with diluent percentage of:		
0	232	232
5.0	168	168
10.0	153	153
15.0	304	304
17.5	422	422
20.0	501	501
22.5	600	600
25.0	300	
27.5		3,800
30.0	22.6	24,140
35.0	9.1	(1)
45.0	3.2	(1)
Sample *C-1* (RT–3 tar) with diluent percentage of:		
0	186	186
15.0	68	68
27.5	30	30
30.0	24	24
35.0	19	19
40.0	12	(1)
45.0	7	(1)
Sample *D-1* (RT–2 tar) with diluent percentage of:		
0	109	109
10.0	70	70
20.0	53	53
35.0	18	18
40.0	6.3	330
45.0	6.4	138
50.0	3.0	(1)
Sample *E-1* (RT–3 tar) with diluent percentage of:		
0	234	234
10.0	124	124
20.0	73	73
30.0	61	61
32.5	82	82
35.0	22	87
37.5	14	(1)
40.0	9.1	(1)

[1] Material semisolid, wide variations in results makes actual viscosity indeterminable.

Table 11.—*Kinematic viscosity of trade tars blended with various percentages of Diesel oil and coal-tar distillate*

Identification of tar and volume of diluent in sample	Kinematic viscosity at 35° C.		
	Coal-tar distillate blends	Diesel-oil blends	
		Top	Bottom
Sample *1* (RT–2 tar) with diluent percentage of:	*Centistokes*	*Centistokes*	*Centistokes*
0	170	170	170
10.0	69	95	95
20.0		54	54
25.0	23.2		
30.0		43	43
32.5		28	72
35.0		17.4	7,970
37.5		11.7	3,820
40.0	9.8	4.6	
45.0		3.3	
Sample *8* (RT–2 tar) with diluent percentage of:			
0	88	88	88
10.0	41.3	61	61
20.0		36	36
22.5		27	27
25.0	15.6	25	25
27.5		15.4	422
30.0		18.7	169
32.5		14.6	96
35.0		11.6	
40.0	8.6		
Sample *10* (RT–2 tar) with diluent percentage of:			
0		227	227
5.0		187	187
10.0		233	233
12.5		231	231
15.0		110	431
20.0		47	1,930
Sample *25* (RT–3 tar) with diluent percentage of:			
0		266	266
2.5		260	260
5.0		201	201
7.5		175	175
10.0		119	233
15.0		10.7	485



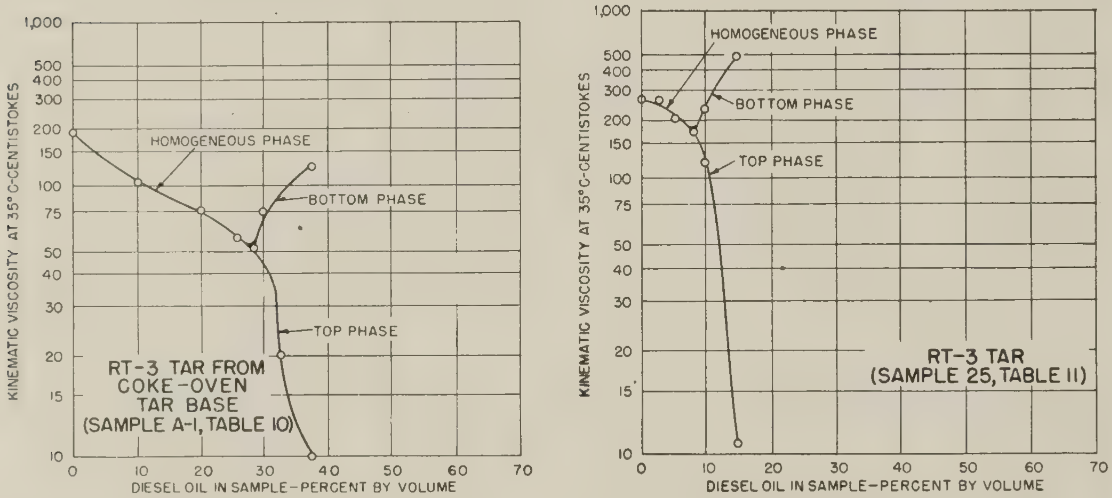
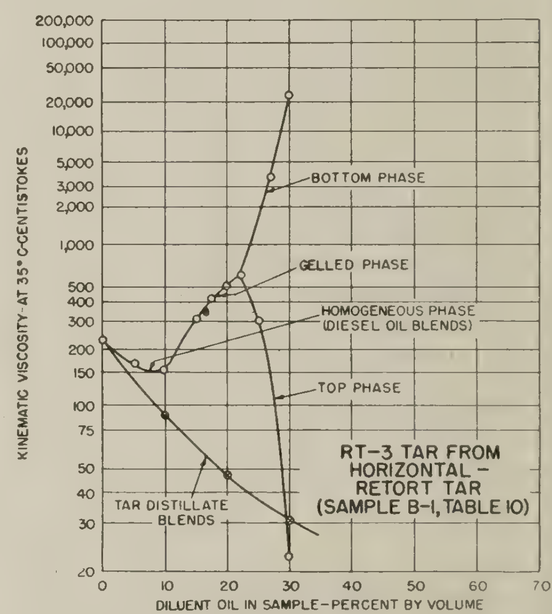


Figure 6.—Effect of various percentages of diluent on the kinematic viscosity at 35° C. of various tars.



soluble in the continuous phase become incompatible and precipitate (precipitation point as shown by microscope).

Essentially the same basic conception of the phenomena involved was discussed recently by E. J. Dickinson.[5] His studies involved a division of the tars into five fractions by a combination of distillation and solvent extraction, and molecular-weight determination on the various fractions. Studies were also made of the effect of these various fractions on the properties of dispersion in several media. His tests led to the following conclusions:

> On this evidence, and from its general viscosity characteristics, it is suggested that tar is an "associated colloid" in which the units are composed of a core of hydrocarbons of high molecular weight surrounded by a solvation layer of hydrocarbon molecules of lower molecular weight; these micelle units are dispersed in a continuous oily medium and there is no abrupt discontinuity of phase between this medium and the nuclei of the micelles.

Dickinson also showed that certain flocculating agents tended to dissolve the protecting media around the micelles resulting in the flocculation of the neuclei. This conception, although expressed differently, is fundamentally the same as that discussed by Oliensis. The progressive flocculation of the dispersed phase may also be explained on the same basis. In the normal tar there is an equilibrium established between the continuous phase and the dispersed phase which is believed to be dependent on the interfacial tension between the two phases. When Diesel oil is added, the surface tension of the continuous phase is changed, which also changes the interfacial tension. This changes the equilibrium conditions, resulting in a coalescence of some of the dispersed particles into larger groups.

[5] *The constitution of road tar*, by E. J. Dickinson; Journal of the Society of Chemical Industry; vol. 64; May 1945; pp. 121–130.

Table 12.—*Comparison of separation point as determined by usual test method and from viscosity curves*

Type or grade of tar	Sample identification	Separation point	
		Usual test method	From viscosity curve
Coke-oven	*A* [1]	27.5	25.0
Horizontal-retort	*B*	22.5	20.0
Vertical-retort	*C* [1]	20.0	25.0
Heavy water-gas	*D*	32.5	32.5
Heavy water-gas (extreme case)	*E*	25.0	22.5
RT-3	*A-1*	27.5	27.5
RT-3	*B-1*	12.5	[2] 10.0
RT-3	*C-1*	32.5	32.5
RT-2	*D-1*	40.0	40.0
RT-3	*E-1*	35.0	32.5
RT-2	*1*	32.5	30.0
RT-2	*8*	27.5	25.0
RT-2	*10*	12.5	10.0
RT-3	*25*	7.5	7.5

[1] Residue from distillation to 270° C.
[2] Based on the point at which the viscosity begins to increase for additional Diesel oil.

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No. 296MP . . . Bibliography on Highway Safety.

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

Indexes to PUBLIC ROADS, volumes 17–23, inclusive.

Bibliography on Automobile Parking in the United States.

Express Highways in the United States: a Bibliography.

Bibliography on Land Acquisition for Public Roads.

REPORTS IN COOPERATION WITH UNIVERSITY OF ILLINOIS

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.

No. 345 . . . Ultimate Strength of Reinforced Concrete Beams as Related to the Plasticity Ratio of Concrete.

No. 346 . . . Highway Slab-Bridges with Curbs: Laboratory Tests and Proposed Design Method.

No. 363 . . . Study of Slab and Beam Highway Bridges.

No. 369 . . . Studies of Highway Skew Slab-Bridges with Curbs. Part I: Results of Analyses.

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.

STATUS OF FEDERAL-AID HIGHWAY PROGRAM

AS OF DECEMBER 31, 1947

(Thousand Dollars)

STATE	UNPROGRAMMED BALANCES	ACTIVE PROGRAM: PROGRAMMED ONLY			PLANS APPROVED, CONSTRUCTION NOT STARTED			CONSTRUCTION UNDER WAY			TOTAL		
		Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles
Alabama	$10,344	$13,587	$6,902	440.6	$5,597	$2,787	163.9	$8,735	$3,909	253.2	$27,919	$13,598	857.7
Arizona	1,754	8,041	5,290	92.9	744	524	9.4	4,110	2,838	61.0	12,895	8,652	163.3
Arkansas	5,065	9,618	4,981	222.2	6,511	3,149	163.8	11,062	5,859	259.4	27,191	13,989	645.4
California	2,858	33,428	14,957	315.7	10,252	5,244	37.8	66,662	32,805	340.6	110,342	53,006	694.1
Colorado	7,977	6,964	4,349	97.2	6,840	3,969	94.0	9,581	5,708	171.3	23,385	14,026	362.5
Connecticut	4,338	9,075	4,745	29.4	2,121	1,224	9.5	4,461	2,095	14.9	15,657	8,064	53.8
Delaware	4,160	1,436	872	18.0	1,872	1,050	23.1	761	380	12.0	4,069	2,302	53.1
Florida	8,388	8,700	4,193	185.0	4,230	2,250	80.8	12,074	5,500	264.3	25,004	11,943	530.1
Georgia	11,528	16,936	8,902	455.7	8,520	4,471	263.4	20,827	11,116	481.6	46,283	24,489	1,200.7
Idaho	5,349	3,092	1,949	197.0	4,306	2,655	114.9	2,637	1,659	41.6	10,035	6,263	353.5
Illinois	31,486	28,754	15,520	598.1	25,512	11,746	434.7	18,210	9,412	265.1	72,476	36,678	1,297.9
Indiana	14,281	13,162	7,175	148.6	10,071	5,049	93.6	15,246	7,844	119.0	38,479	20,068	361.2
Iowa	9,704	20,648	10,439	941.7	5,761	2,128	284.6	16,556	7,271	648.0	42,965	19,838	1,874.3
Kansas	5,934	18,639	9,573	1,684.8	7,405	3,258	781.4	28,268	14,674	1,091.9	54,312	27,505	3,558.1
Kentucky	2,555	15,981	7,877	199.4	9,059	4,644	155.2	13,581	6,785	211.0	38,621	19,306	565.6
Louisiana	9,613	17,541	8,660	283.0	10,925	4,933	68.2	9,802	5,148	117.2	38,268	18,741	468.4
Maine	5,339	4,595	2,362	36.1	945	484	10.5	5,284	2,957	57.1	10,824	5,803	103.7
Maryland	8,631	3,910	1,966	42.2	606	296	3.6	4,917	2,458	45.0	9,433	4,720	90.8
Massachusetts	18,969	17,068	8,588	47.6	3,520	1,936	9.6	8,934	5,319	27.4	29,522	15,843	84.6
Michigan	12,254	21,300	10,268	418.9	18,983	8,430	170.4	21,396	10,854	213.9	61,679	29,552	803.2
Minnesota	11,386	14,385	7,336	717.9	4,250	1,855	221.0	17,705	8,627	694.3	36,340	17,818	1,633.2
Mississippi	4,754	11,388	5,609	457.7	9,394	4,627	243.6	14,041	7,064	380.8	34,823	17,300	1,082.1
Missouri	18,484	24,147	11,342	603.1	9,125	4,296	313.6	18,106	9,147	469.5	51,378	24,785	1,386.2
Montana	12,429	9,264	5,433	370.3	3,009	1,695	98.3	6,105	3,829	160.1	18,378	10,957	628.7
Nebraska	5,787	18,307	9,659	713.1	3,659	1,708	200.3	10,407	5,172	473.5	32,373	16,539	1,386.9
Nevada	1,040	6,911	5,415	293.2	855	733	16.5	2,569	2,014	98.0	10,335	8,162	407.7
New Hampshire	3,327	2,602	1,428	22.8	1,318	691	12.4	3,733	1,954	12.2	7,653	4,073	47.4
New Jersey	8,192	13,201	6,208	63.3	4,458	2,194	14.3	18,812	9,707	15.5	36,471	18,109	93.1
New Mexico	5,024	8,393	5,380	241.4	2,406	1,539	61.7	3,459	2,204	111.2	14,258	9,123	414.3
New York	47,027	63,052	35,294	446.3	22,593	9,664	108.0	32,396	15,076	187.4	118,041	60,034	741.7
North Carolina	6,904	23,986	12,148	617.9	5,407	2,627	128.1	21,781	10,856	587.6	51,174	25,631	1,333.6
North Dakota	7,943	10,886	6,187	1,291.2	4,532	2,526	297.2	3,721	2,095	297.8	19,139	10,808	1,886.2
Ohio	24,810	24,167	11,815	267.4	20,950	10,457	115.2	25,548	12,953	93.6	70,665	35,225	476.2
Oklahoma	13,322	13,817	7,899	770.9	5,966	2,788	374.4	5,036	2,687	298.8	24,819	13,374	1,444.1
Oregon	1,475	10,444	5,712	190.1	3,145	1,664	70.5	10,327	5,696	202.9	23,916	13,072	463.5
Pennsylvania	5,364	59,164	30,437	138.7	24,427	12,977	77.9	46,546	24,269	231.8	130,137	67,683	448.4
Rhode Island	5,278	5,999	3,003	18.0	1,025	512	5.5	2,348	1,162	5.8	9,372	4,677	29.3
South Carolina	2,677	12,933	5,840	325.2	2,489	1,185	69.6	9,946	4,774	236.6	25,368	11,799	631.4
South Dakota	7,529	9,879	5,795	954.9	3,731	2,259	298.8	6,977	4,343	419.2	20,587	12,397	1,672.9
Tennessee	6,437	19,728	9,751	305.7	6,124	3,020	171.2	15,024	7,850	262.0	40,876	20,621	738.9
Texas	18,105	19,396	9,572	589.4	15,302	8,550	535.6	56,581	29,277	1,439.8	91,279	47,399	2,564.8
Utah	5,210	1,934	1,444	60.4	1,413	1,044	90.3	4,630	3,513	130.4	7,977	6,001	281.1
Vermont	2,091	2,959	1,462	60.9	861	420	23.1	3,800	1,916	37.2	7,620	3,798	121.2
Virginia	8,489	16,570	8,329	296.4	4,493	2,236	82.4	15,377	7,467	211.3	36,445	18,032	590.1
Washington	2,951	15,376	6,478	339.2	5,383	2,600	62.2	8,289	4,541	125.3	29,048	13,619	526.7
West Virginia	5,184	8,760	4,214	262.1	3,135	1,663	27.0	6,245	3,229	63.9	18,140	9,106	353.0
Wisconsin	18,785	19,371	9,343	464.7	8,617	3,307	123.2	12,585	4,749	375.8	40,573	17,399	963.7
Wyoming	4,449	1,936	1,277	91.8	2,026	1,324	62.8	6,707	4,423	214.3	10,669	7,024	368.9
District of Columbia	91	1,564	907	2.5	4,264	2,115	1.8	8,743	4,459	4.4	14,571	7,481	8.7
Hawaii	2,481	4,829	2,562	17.0	3,871	1,666	4.0	2,196	1,093	15.3	10,896	5,321	36.3
Puerto Rico	4,066	5,145	2,338	32.1	6,792	2,329	27.2	1,844	867	19.0	13,781	5,534	78.3
TOTAL	451,618	732,968	379,185	17,479.7	338,305	166,498	6,910.1	684,688	351,604	12,570.8	1,756,461	897,287	36,960.6