L. 26, NO. 5

DECEMBER 1950

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

Increasing traffic needs many improvements
such as this one on U S 40 in California

BLISHED BY
E BUREAU OF
BLIC ROADS,
S. DEPARTMENT
COMMERCE,
SHINGTON

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

Vol. 26, No. 5 *December 195(*

Published Bimonthly

IN THIS ISSUE

BUREAU OF PUBLIC ROADS
Washington 25, D. C

REGIONAL HEADQUARTERS
180 New Montgomery St
San Francisco 5, Calif

DIVISION OFFICES

No. 1. 718 Standard Bldg., Albany 7, N. Y.
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, an Vermont.

No. 2. 2034 Alcott Hall, Washington 25, D. C.
Delaware, District of Columbia, Maryland, Ohio Pennsylvania, Virginia, and West Virginia.

No. 3. 504 Atlanta National Bldg., Atlanta 3, Ga
Alabama, Florida, Georgia, Mississippi, Nort Carolina, South Carolina, and Tennessee.

No. 4. South Chicago Post Office, Chicago 17, Il
Illinois, Indiana, Kentucky, and Michigan.

No. 5. (NORTH). Main Post Office, St. Paul 1, Minn
Minnesota, North Dakota, South Dakota, an Wisconsin.

No. 5. (SOUTH). Fidelity Bldg., Kansas City 6, Mo
Iowa, Kansas, Missouri, and Nebraska.

No. 6. 502 U. S. Courthouse, Fort Worth 2, Tex
Arkansas, Louisiana, Oklahoma, and Texas.

No. 7. 180 New Montgomery St., San Francisco Calif.
Arizona, California, Nevada, and Hawaii.

No. 8. 753 Morgan Bldg., Portland 8, Oreg.
Idaho, Montana, Oregon, and Washington.

No. 9. 254 New Customhouse, Denver 2, Colo.
Colorado, New Mexico, Utah, and Wyoming.

No. 10. Federal Bldg., Juneau, Alaska.
Alaska.

PUBLIC ROADS is sold by the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at $1 per year (foreign subscription $1.25) or 20 cents per single copy. Free distribution is limited to public officials actually engaged in planning or constructing highways, and to instructors of highway engineering. There are no vacancies in the free list at present.

The printing of this publication has been approved by the Director of the Bureau of the Budget January 7, 1949.

BUREAU OF PUBLIC ROAD

U. S. DEPARTMENT OF COMMERC

E. A. STROMBERG, Edit

Traffic Trends on Rural Roads in 1949

BY THE HIGHWAY TRANSPORT RESEARCH BRANCH
BUREAU OF PUBLIC ROADS

Reported by THOMAS B. DIMMICK, Head, Current Data Analysis Unit

[otal travel on rural roads in 1949 broke a records, exceeding the 1948 previous high b 7 percent and the prewar peak by 27 p·cent. On the 350,000 miles of main rural rads in the United States, travel in 1949 was o·r 159 billion vehicle-miles, of which 78 p·cent was by passenger cars, 1 percent by bsses, and 21 by freight-carrying vehicles. [rucks and combinations hauled 7 per-cit more ton-mileage of freight in 1949 tan in 1948 and 52 percent more than in 1(1, the increase resulting largely from g·ater use of heavier vehicles. Truck-com-bation travel was 10 percent higher than i 1948, 85 percent higher than in 1941, and 2(percent higher than in 1936. Compa-r·le figures for single-unit trucks were 5, 2 and 92 percent. The average carried ld for all trucks and combinations in 1949 ·s 2, 40, and 76 percent above the averages i 1948, 1941, and 1936, respectively.

[n 1949 more than 5 percent of all trucks ad combinations exceeded a State legal ·ight limit, and 16 percent of the combi-·tions were illegally overloaded in some ·rticular. In comparison with 1948, the ·rcentage of overweight vehicles decreased ·ghtly in 1949 except in the western States.

MOTOR-VEHICLE TRAVEL in 1949 broke all previous records for the fourth cnsecutive year. The 1949 traffic on all ral roads was 7 percent higher than in 1948, percent higher than in 1947, and about 27 rcent above the 1946 volume and the 1941 ewar peak. Geographically the increases er 1948 ranged from 4 percent in the western ates to 9 percent in the eastern States, with average increase in the central States of 7 rcent. The largest increase in any of the ited States census regions[1] was 12 percent the West North Central region and the allest increase was 1 percent in the Pacific gion. Records from about 800 automatic affic recorders, operated continuously roughout the year at permanent stations on ain and local roads in all States, were used nerally to establish these trends. More tensive traffic surveys, made by a number States, yielded valuable information con-rning the total volume of rural traffic within eir boundaries. Consideration has been ven to all such available data in this analysis. here States have prepared and submitted hicle-mile travel estimates of their own, ese have been employed rather than esti-ates made by applying trend factors.

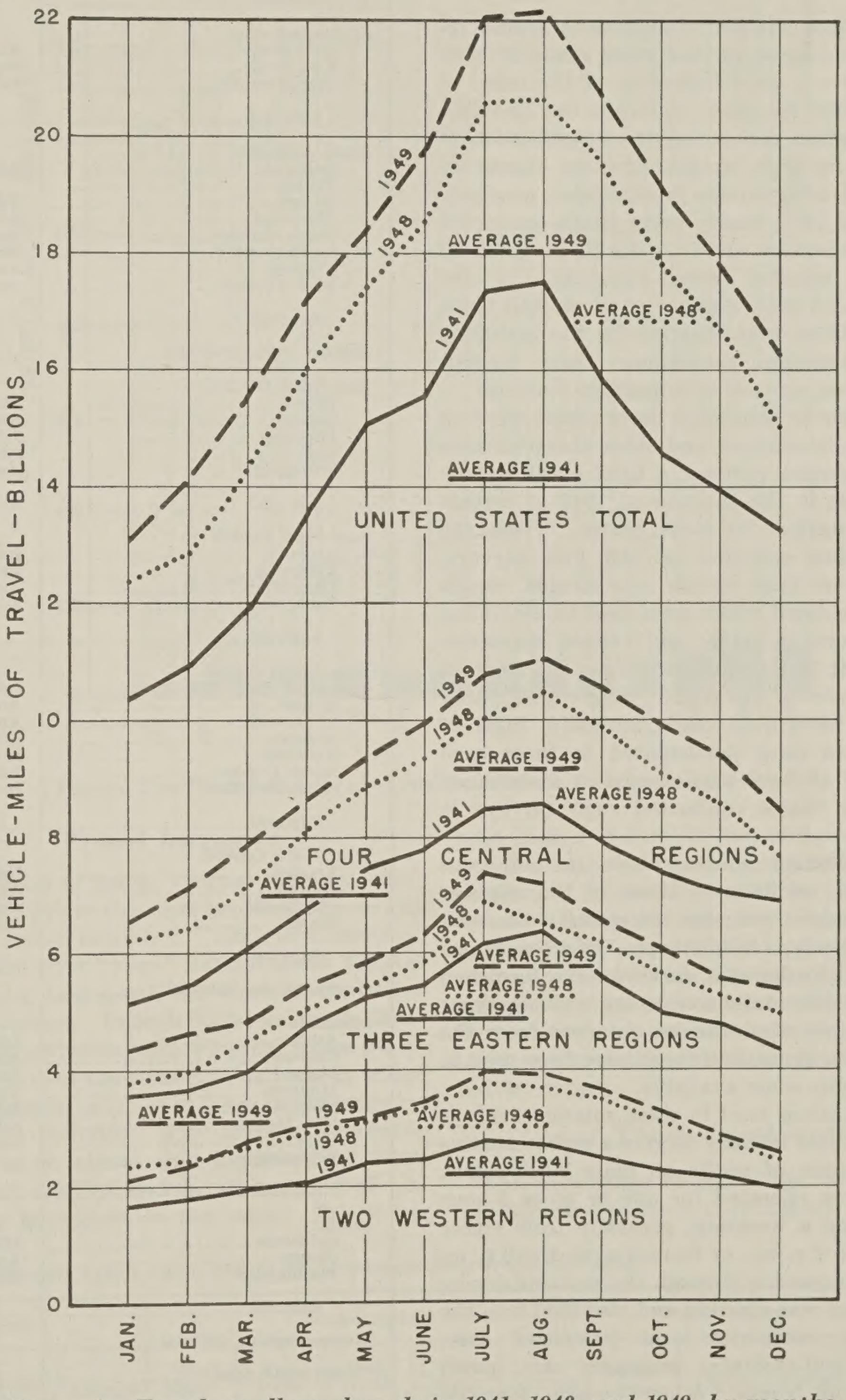

Figure 1.—Travel on all rural roads in 1941, 1948, and 1949, by months.

The variation in travel on rural roads in three main geographic divisions and in the United States as a whole is illustrated in figure 1 for the years 1949, 1948, and 1941, the latter being the prewar peak year. Travel in each month of 1949 in the eastern and central regions and in the United States as a whole was well above that of the corresponding month of the earlier years. The western regions, however, showed only a slight increase from 1948 to 1949.

Summer travel in 1949 reached its prewar importance for the first time since the end of hostilities in 1945. In the last two prewar years the average monthly travel in July and August was 23 percent above that of the

[1] The States comprising each census region are indicated table 1.

911058—50——1

average month of the year. Restrictions placed on nonessential driving in 1942 reduced travel in the summer months so that only 13 or 14 percent more traffic used the roads in the summer months than in the average month of the war years. Following the war this seasonal travel increased each succeeding year. Not until 1949, however, did vacation and other summer driving again reach the prewar level, 23 percent above the annual average.

1949 Summer Loadometer Survey

The large number of automatic traffic recorders operated on the rural roads of each State gives a good indication of the trend of total traffic on those highways but provides no indication concerning the classification of vehicles by type, weight, or other characteristics. During certain prewar years, generally 1936 and 1937, nearly every State conducted a comprehensive survey of traffic in which all vehicles counted were classified. At the same time a large number of trucks and truck combinations were stopped for the gathering of information concerning their weight, dimensions, and other important features.

In order to determine the wartime trend in weights, dimensions, and other characteristics of commercial vehicles, a brief check survey was made in the summer of 1942 at certain typical stations in most States. From the information collected in the two surveys, which were kept strictly comparable, trends were calculated which were used to determine the changes in traffic and vehicle characteristics that had taken place since the comprehensive survey was made. Since 1942, check surveys have been made annually; most of the States have participated in these each year and all have participated at some time.[2] Forty-six States conducted such surveys in 1949.

Classification counts made in numerous States, in addition to those of the summer survey, added valuable information concerning vehicle-type frequencies. In a few States expanded loadometer surveys have furnished more reliable data concerning vehicle types and weights than can be obtained from the trend data alone, and these have been used in the analysis when available.

The stations used in these summer surveys were selected initially to give a representative cross section of traffic on main rural roads. They were operated for one or more 8-hour periods on a weekday, generally from either 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 into the following categories: local passenger cars; foreign (out-of-State) passenger cars; panel and pickup trucks;[3] other two-axle, four-tire trucks; two-axle, six-tire trucks; three-axle trucks; truck-tractor and semitrailer combinations; truck and trailer combinations or truck-tractor semitrailer and trailer combinations; and busses. The combination-type vehicles were further subdivided according to the number of axles of each.

Most of the weight stations were operated during July, August, and September. Arizona completed its work in June; California started its survey on the last day in May and completed it in June; Texas operated its stations from June to September; Washington conducted its operations from June to October.

The survey period, number of stations operated, number of vehicles counted, and number weighed are shown for each State in table 1. Almost 1¼ million vehicles were counted at all stations during the period of the

Table 1.—*Survey period, number of stations operated, number of vehicles counted, and number weighed in each State in the special weight surveys, summer of 1949*

Region and State	Survey period	Number of stations	Total vehicles counted	Trucks and truck combinations	
				Counted	Weighed
New England:					
Connecticut	Aug. 1–12	10	32, 760	5, 817	2, 430
Maine	July 21–Aug. 5	10	24, 308	4, 252	2, 018
Massachusetts	Aug. 8–26	10	36, 083	5, 685	1, 925
New Hampshire	Aug. 8–12	5	15, 282	1, 814	496
Rhode Island	July 25–Aug. 1	5	14, 322	2, 400	1, 145
Vermont	Aug. 1–5	5	10, 002	651	651
Subtotal		45	132, 757	20, 619	8, 665
Middle Atlantic:					
New Jersey	Aug. 16–Sept. 8	10	79, 674	14, 873	1, 977
New York	Sept. 19–24	20	39, 380	10, 265	3, 464
Pennsylvania	July 26–Sept. 1	7	24, 066	4, 818	907
Subtotal		37	143, 120	29, 956	6, 34[illegible]
South Atlantic:					
Delaware	Aug. 11–25	9	26, 819	7, 922	1, 19[illegible]
Florida	(1)	--------	--------	--------	--------
Georgia	Aug. 1–30	12	17, 383	4, 384	3, 02[illegible]
Maryland	Aug. 8–15	10	39, 267	8, 001	1, 15[illegible]
North Carolina	Aug. 9–30	12	36, 228	6, 311	4, 32[illegible]
South Carolina	Sept. 12–26	10	17, 162	4, 659	2, 11[illegible]
Virginia	Aug. 3–19	10	22, 279	5, 099	3, 81[illegible]
West Virginia	Aug. 9–Sept. 2	9	13, 170	3, 134	1, 30[illegible]
Subtotal		72	172, 308	39, 510	16, 92[illegible]
Eastern regions, subtotal		154	448, 185	90, 085	31, 93[illegible]
East North Central:					
Illinois	Aug. 23–Sept. 7	47	85, 148	17, 143	6, 44[illegible]
Indiana	Aug. 3–31	20	44, 232	10, 375	4, 15[illegible]
Michigan	July 22–Aug. 4	8	21, 928	2, 930	1, 02[illegible]
Ohio	July 26–Aug. 11	10	26, 244	4, 891	1, 04[illegible]
Wisconsin	Aug. 4–25	10	24, 945	3, 755	1, 28[illegible]
Subtotal		95	202, 497	39, 094	13, 96[illegible]
East South Central:					
Alabama	July 13–29	10	11, 594	2, 910	1, 7[illegible]
Kentucky	June 20–July 6	10	12, 959	2, 925	1, 1[illegible]
Mississippi	Aug. 15–Sept. 2	15	24, 253	6, 633	2, 61[illegible]
Tennessee	Aug. 2–16	10	11, 336	3, 011	1, 71[illegible]
Subtotal		45	60, 142	15, 479	7, 2[illegible]
West North Central:					
Iowa	July 25–Aug. 5	10	13, 336	2, 427	2, 4[illegible]
Kansas	Aug. 11–24	10	10, 566	2, 141	1, 0[illegible]
Minnesota	Apr. 11–Aug. 3	10	29, 075	6, 492	2, 1[illegible]
Missouri	Aug. 12–Sept. 1	15	70, 079	14, 323	6, 9[illegible]
Nebraska	July 21–Aug. 17	20	22, 014	4, 744	4, 5[illegible]
North Dakota	July 21–Sept. 1	15	22, 960	5, 376	2, 0[illegible]
South Dakota	June 24–Sept. 21	11	8, 956	1, 391	1, 1[illegible]
Subtotal		91	176, 986	36, 894	20, 4[illegible]
West South Central:					
Arkansas	July 25–Aug. 5	10	16, 804	5, 519	1, 4[illegible]
Louisiana	July 18–27	10	10, 015	3, 019	1, 1[illegible]
Oklahoma	Aug. 15–29	10	14, 414	3, 139	3, 0[illegible]
Texas	June 15–Sept. 13	17	29, 982	6, 838	1, 6[illegible]
Subtotal		47	71, 215	18, 515	7, 2[illegible]
Central regions, subtotal		278	510, 840	109, 982	48, 8[illegible]
Mountain:					
Arizona	June 6–17	10	9, 010	1, 962	7[illegible]
Colorado	Aug. 11–29	10	25, 647	4, 161	4[illegible]
Idaho	July 25–Aug. 10	13	15, 429	2, 886	2, 7[illegible]
Montana	Aug. 3–Sept. 1	19	16, 344	3, 197	2, [illegible]
Nevada	July 25–Aug. 9	10	6, 693	1, 036	[illegible]
New Mexico	July 21–Aug. 4	10	12, 621	2, 739	1, [illegible]
Utah	July 18–Aug. 5	10	16, 112	3, 215	1, [illegible]
Wyoming	(1)	--------	--------	--------	--------
Subtotal		82	101, 856	19, 196	10, [illegible]
Pacific:					
California	May 31–June 30	20	[2] 71, 484	13, 153	4, [illegible]
Oregon	Aug. 9–19	8	15, 660	2, 893	1, [illegible]
Washington	June 7–Oct. 7	20	99, 978	18, 007	12, [illegible]
Subtotal		48	187, 122	34, 053	19, [illegible]
Western regions, subtotal		130	288, 978	53, 249	29, [illegible]
United States total		562	1, 248, 003	253, 316	110, [illegible]

[1] No survey made. [2] Passenger cars not counted; figure given is an estimate based on data from other reports.

[2] See *Traffic trends on rural roads*, by T. B. Dimmick, PUBLIC ROADS, vol. 25, No. 12, Feb. 1950; vol. 25, No. 7, Mar. 1949; vol. 25, No. 3, Mar. 1948; 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.

[3] Single-unit trucks with a carrying capacity of less than 1½ tons.

survey. About one-fifth of these were freight-carrying vehicles, of which almost one-half were weighed.

Wherever traffic volume permitted, every truck and truck combination was stopped and weighed. Where this procedure was impracticable all of the less common types were weighed and the common vehicle types were weighed in sufficient numbers to establish their characteristics from the sample. The type of vehicle, whether loaded or empty, the number of axles, and the weight of each axle were recorded. The axle-spacing and total wheelbase length of the heavier vehicles[4] were measured, and the commodity carried and the type of operation—private or for-hire—were recorded. Passenger cars and busses were counted but not stopped for weighing.

Prewar Travel Trend Maintained

Figure 2 shows in chart form the vehicle-mileage of travel on all rural roads, by type of vehicle, for each year from 1936 to 1949, inclusive. It is apparent that the effect of the drastic restriction of travel during the war period, 1942–45, has now been entirely overcome. A straight line from the top of the bar for 1936 to the top of the bar for 1949 passes through the tops of the bars for 1937, 1939, and 1940, and only slightly above the top of the bar for 1938 and slightly below that for 1941. The recession in business activity in 1938 probably accounts for the lessened volume of traffic in that year; and 1941 was a year of exceptional activity in preparation for the war that followed. Altogether, total traffic has recovered completely from the effect of the war and stands, as near as can be determined from the long-time trend, at a level which would have been reached had the war not occurred.

In the case of travel of trucks and truck combinations,[5] the 1949 value fits the 1936–40 trend, projected, almost exactly. For truck combinations alone, the 1936–48 line lies slightly above the tops of the bars for all intervening years. This and other trend data indicate an accelerating growth in traffic by vehicles of this type.

[4] Trucks and truck combinations weighing 13 tons or more or having an axle weighing 18,000 pounds or more.

[5] In this article, the term "truck" is used to indicate a single-unit vehicle; "truck combination" to indicate truck-tractor semitrailer (with or without full trailer) and truck with full trailer; and "trucks and truck combinations" to indicate all of these vehicles together.

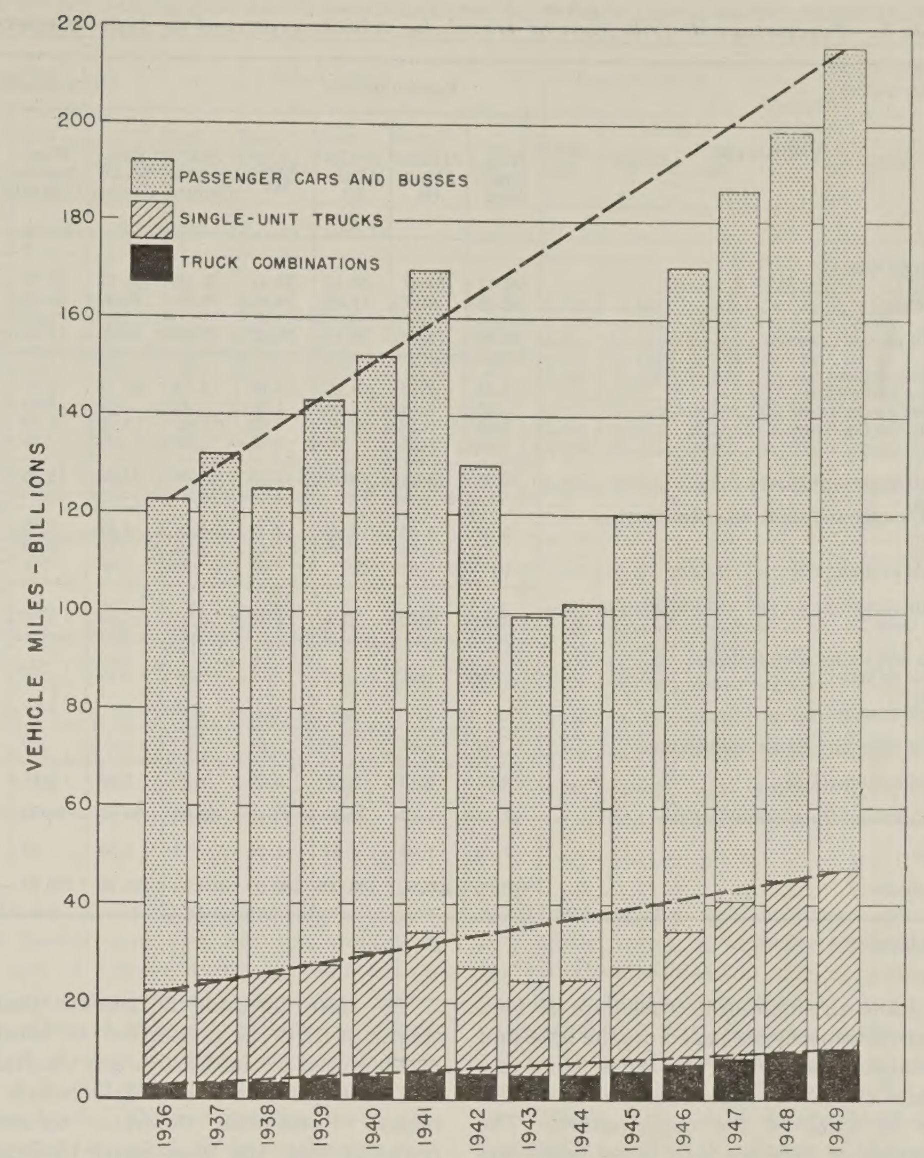

Figure 2.—Travel on all rural roads, 1936-49, by classes of vehicles.

Travel Increases

The ratio of traffic volumes on main rural roads in 1949 to the corresponding volumes in 1948 is shown in table 2. Highways classified under the term "main" include about 350,000 miles and, in general, are those of the entire State systems. In such States as North Carolina, Pennsylvania, and Virginia, where all or a large part of the rural-road mileage is under State control, only the mileage in the primary system is included. The consistent increase in travel on these main highways by most types of vehicles and in all sections of the country is evident in the table. Travel by both local and foreign (out-of-State) passenger cars increased in all regions, but travel by single-unit trucks decreased in the Middle Atlantic, South Atlantic, and Pacific regions and increased only slightly in the New England and West South Central regions. The increases in travel by truck combinations and the decreases by single-unit trucks appear to be a result of the continued shifting to the heavier types.

Use of Truck Combinations

The percentage of travel by vehicle types on main rural roads in 1949 is given in table 3.

Table 2.—*Ratio of 1949 traffic on main rural roads to corresponding traffic in 1948* [1]

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	Moun-tain	Pacific	Average	
Passenger cars:													
Local	1.09	1.15	1.08	1.11	1.07	1.01	1.09	1.10	1.08	1.08	1.04	1.05	1.08
Foreign	1.15	1.09	1.15	1.13	1.03	1.33	1.08	1.17	1.10	1.05	1.03	1.04	1.10
All passenger cars	1.11	1.13	1.10	1.12	1.06	1.10	1.09	1.12	1.09	1.07	1.04	1.05	1.09
Trucks and truck combinations:													
Single-unit trucks	1.01	.85	.99	.93	1.09	1.10	1.08	1.02	1.07	1.08	.84	.96	1.05
Truck combinations	1.10	1.17	1.31	1.22	1.02	1.11	1.06	1.05	1.04	1.30	1.26	1.27	1.10
All trucks and truck combinations	1.03	.93	1.06	1.01	1.06	1.10	1.07	1.03	1.06	1.12	.95	1.07	1.06
Busses	.75	.99	.99	.95	.87	1.06	.84	1.02	.94	.94	.97	.96	.95
All vehicles	1.09	1.09	1.09	1.09	1.06	1.10	1.08	1.09	1.08	1.08	1.02	1.06	1.08

[1] The ratios for "all vehicles" are based on year-round automatic recorder data, while those for the individual vehicle types are based principally on summer counts.

Table 3.—*Percentage distribution of travel, by vehicle type and by type of operation, on main rural roads in the summer of 1949*

Vehicle type	Eastern regions: New England	Eastern regions: Middle Atlantic	Eastern regions: South Atlantic	Eastern regions: Average	Central regions: East North Central	Central regions: East South Central	Central regions: West North Central	Central regions: West South Central	Central regions: Average	Western regions: Mountain	Western regions: Pacific	Western regions: Average	United States average	U. S. percentage distribution of trucks and truck combinations by type of operation: Private	U. S. percentage distribution of trucks and truck combinations by type of operation: For hire
Passenger cars:															
Local	56.11	63.31	57.15	59.61	58.56	45.37	59.79	58.84	57.13	41.75	76.14	63.83	59.12	------	------
Foreign	25.38	16.07	19.03	18.66	20.74	22.46	15.41	15.04	18.37	34.24	10.56	19.04	18.58	------	------
All passenger cars	81.49	79.38	76.18	78.27	79.30	67.83	75.20	73.88	75.50	75.99	86.70	82.87	77.70	------	------
Single-unit trucks:															
Panel and pickup	5.31	4.35	6.89	5.60	5.32	12.11	7.05	10.02	7.77	9.76	3.36	5.65	6.69	40.36	1.68
Other 2-axle, 4-tire	.65	1.18	1.04	1.04	.42	.57	1.02	.37	.57	.79	.52	.62	.73	4.38	.33
Other 2-axle, 6-tire	7.16	7.49	7.91	7.63	6.62	11.70	9.79	7.90	8.35	6.99	3.54	4.77	7.49	39.18	22.36
3-axle	.34	.42	.35	.38	.32	.22	.26	.18	.26	.36	.54	.48	.33	1.45	2.03
All single-unit trucks	13.46	13.44	16.19	14.65	12.68	24.60	18.12	18.47	16.95	17.90	7.96	11.52	15.24	85.37	26.40
Truck-tractor and semitrailer combinations:															
3-axle	3.58	5.05	4.89	4.77	4.58	4.85	3.33	4.65	4.34	1.74	.77	1.11	3.92	10.43	45.86
4-axle	.15	1.06	1.29	1.03	2.14	.80	2.09	1.67	1.83	1.34	.85	1.02	1.43	3.02	19.31
5-axle or more	(1)	.01	(1)	.01	.23	.02	.19	.04	.15	.86	1.36	1.19	.28	.40	4.46
All truck-tractor and semitrailer combinations	3.73	6.12	6.18	5.81	6.95	5.67	5.61	6.36	6.32	3.94	2.98	3.32	5.63	13.85	69.63
Truck and trailer combinations:															
4-axle or less	.02	.01	.01	.01	.05	(1)	.20	.17	.11	.23	.22	.22	.10	.39	.65
5-axle	----	----	----	----	.17	----	(1)	.01	.07	.34	.39	.38	.10	.18	1.46
6-axle or more	----	----	----	----	.11	----	(1)	----	.04	.32	.73	.58	.12	.21	1.86
All truck and trailer combinations	.02	.01	.01	.01	.33	(1)	.20	.18	.22	.89	1.34	1.18	.32	.78	3.97
All combinations	3.75	6.13	6.19	5.82	7.28	5.67	5.81	6.54	6.54	4.83	4.32	4.50	5.95	14.63	73.60
All trucks and truck combinations	17.21	19.57	22.38	20.47	19.96	30.27	23.93	25.01	23.49	22.73	12.28	16.02	21.19	100.00	100.00
Busses	1.30	1.05	1.44	1.26	.74	1.90	.87	1.11	1.01	1.28	1.02	1.11	1.11	------	------
All vehicles	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	------	------

[1] Less than 0.005 percent.

In this table all single-unit trucks are divided into classification types based on the axle and tire arrangements, while the truck combinations are classified according to the total number of axles of the combination. The classification of vehicles into these types has been used only in the last three annual surveys. It has several advantages over the old "light, medium, and heavy" grouping, among which are more homogeneous groupings and more positive identification of the types.

The data in table 3 indicate that truck travel in 1949 in proportion to total travel was heaviest in the East South Central region and next heaviest in the West South Central region. Somewhat different figures were found in 1948: the West South Central region then had the highest percentage of truck traffic, followed by the West North Central and South Atlantic regions. The percentage of truck traffic in the South Atlantic, East South Central, West North Central, West South Central, and Mountain regions exceeded 20 percent of the total traffic in both 1948 and 1949. More urbanized areas, such as the New England, Middle Atlantic, and Pacific regions, where total traffic is rather heavy, have the smallest percentage of truck travel. The table indicates that certain types of vehicles are popular in some sections. For instance, the truck and trailer combinations with six or more axles and the truck-tractor and semitrailer combinations with five or more

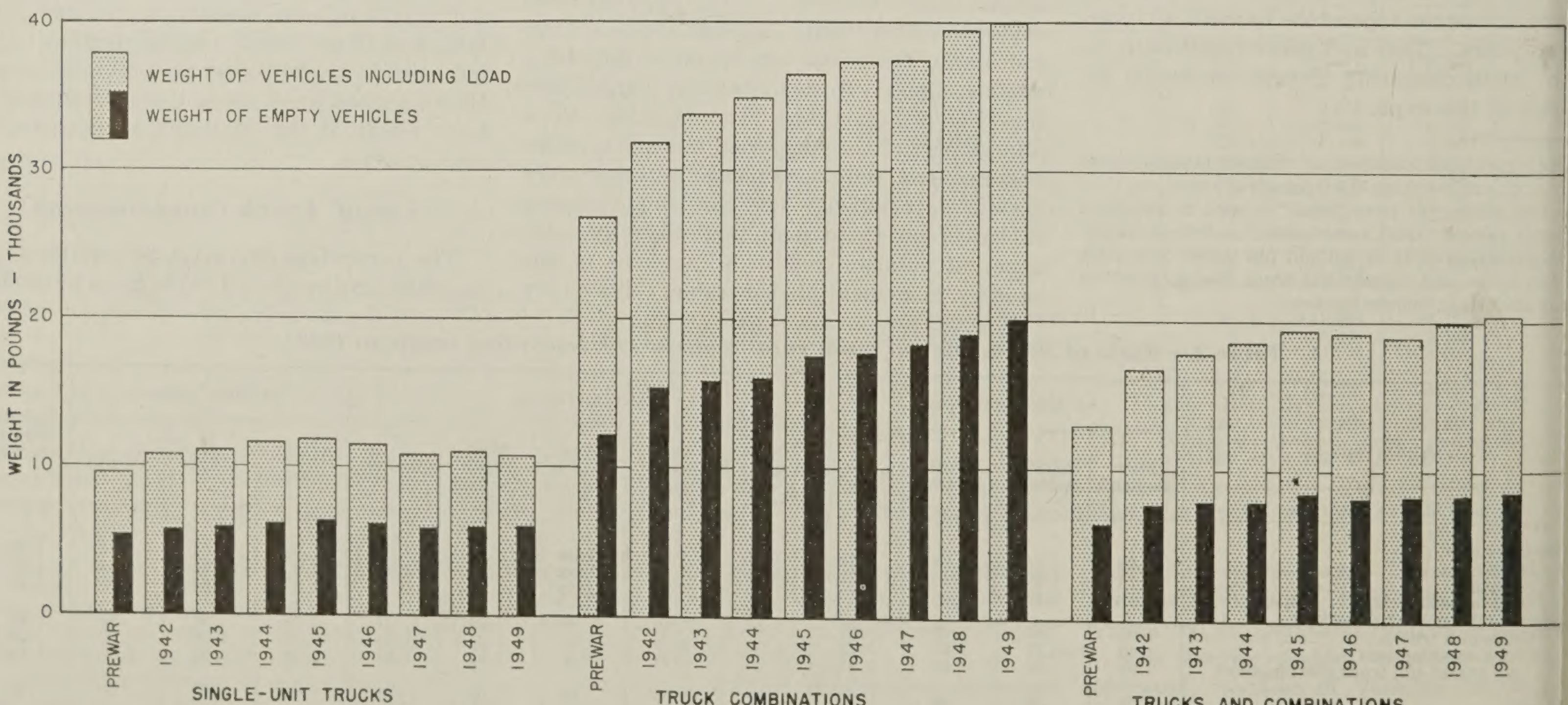

Figure 3.—Average weights of loaded and of empty trucks and truck combinations in the summers of 1942–49 and in a corresponding period of a prewar year.

ble 4.—*Average weights (in pounds) of loaded and empty trucks and truck combinations, by vehicle types, in the summer of 1949*

Vehicle type	Eastern regions				Central regions					Western regions			United States average	U. S. average by type of operation	
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average		Private	For-hire
AVERAGE WEIGHTS OF LOADED VEHICLES															
ingle-unit trucks:															
Panel and pickup	4, 901	5, 409	4, 756	5, 015	5, 041	5, 111	5, 154	5, 907	5, 362	5, 695	4, 524	5, 100	5, 242	5, 208	6, 702
Other 2-axle, 4-tire	6, 201	6, 278	6, 301	6, 281	6, 571	6, 974	6, 621	6, 883	6, 677	7, 133	5, 803	6, 302	6, 447	6, 358	10, 221
Other 2-axle, 6-tire	14, 343	15, 159	13, 307	14, 196	13, 007	13, 611	13, 674	12, 959	13, 294	14, 990	12, 262	13, 514	13, 614	13, 233	15, 789
3-axle	30, 595	33, 616	27, 675	30, 716	27, 734	28, 635	25, 951	28, 101	27, 433	26, 728	25, 635	25, 880	28, 128	27, 484	29, 081
Average	11, 352	12, 660	10, 716	11, 565	10, 339	10, 879	10, 920	9, 213	10, 310	11, 486	10, 380	10, 879	10, 765	10, 150	16, 222
'ruck combinations:															
Truck-tractor and semitrailer	37, 158	42, 105	37, 898	39, 629	37, 322	34, 364	39, 135	36, 211	37, 100	45, 621	48, 550	47, 405	39, 151	37, 255	40, 173
Truck and trailer	39, 471	60, 366	(1)	48, 506	69, 361	-------	18, 109	18, 495	47, 099	62, 642	58, 613	59, 451	55, 458	42, 182	64, 321
Average	37, 174	42, 158	37, 889	39, 653	38, 482	34, 364	38, 462	35, 719	37, 397	48, 009	51, 411	50, 227	39, 999	37, 543	41, 427
verage, all trucks and truck combinations	18, 062	23, 196	19, 152	20, 643	22, 638	17, 422	19, 589	16, 560	19, 774	22, 446	22, 781	22, 643	20, 432	14, 811	35, 374
AVERAGE WEIGHTS OF EMPTY VEHICLES															
ingle-unit trucks:															
Panel and pickup	4, 035	4, 383	3, 851	4, 039	3, 971	4, 078	4, 205	4, 446	4, 189	4, 141	3, 824	4, 038	4, 121	4, 099	4, 784
Other 2-axle, 4-tire	5, 074	4, 992	5, 126	5, 048	4, 836	5, 044	5, 271	5, 139	5, 102	5, 285	4, 585	4, 971	5, 057	5, 018	7, 131
Other 2-axle, 6-tire	8, 651	8, 966	7, 310	8, 182	7, 668	7, 728	8, 059	7, 692	7, 784	8, 285	7, 482	7, 978	7, 942	7, 828	8, 636
3-axle	17, 169	15, 230	13, 143	14, 609	14, 500	11, 953	13, 585	16, 187	14, 489	14, 377	14, 139	14, 225	14, 483	14, 519	13, 644
Average	6, 448	6, 895	5, 424	6, 108	5, 885	5, 529	6, 033	5, 991	5, 864	5, 553	5, 572	5, 560	5, 903	5, 724	8, 716
'ruck combinations:															
Truck-tractor and semitrailer	20, 672	20, 646	18, 787	19, 815	19, 588	16, 690	20, 250	18, 670	19, 094	23, 016	22, 103	22, 592	19, 610	19, 088	19, 945
Truck and trailer	--------	--------	(1)	(1)	31, 825	------	12, 393	15, 127	25, 124	29, 595	27, 837	28, 523	27, 142	23, 806	29, 630
Average	20, 672	20, 646	18, 784	19, 814	20, 389	16, 690	19, 906	18, 579	19, 330	24, 722	24, 296	24, 503	20, 019	19, 314	20, 546
verage, all trucks and truck combinations	8, 811	9, 782	7, 694	8, 655	10, 119	6, 781	8, 852	8, 673	8, 700	8, 142	8, 832	8, 406	8, 648	7, 252	16, 484

Data omitted because of insufficient sample.

es are used more frequently in the Pacific ion than in any other area. Combinations olving trailers are used much less in the st South Central region and in the three tern regions. The percentage of travel by combinations has increased steadily over t in the previous years' samples, this per- tage being 5.95 in 1949, 5.84 in 1948, 5.73 1947, and 5.26 in 1946.

Private and For-Hire Traffic

n the survey conducted in 1949 informa- n was gathered in most of the participating tes concerning the use-classification under ich each vehicle was being operated. Data re reported separately for private and for-hire vehicles of each type, showing the percentage loaded and the average weight of loaded and of empty vehicles. The operation-use classification of each of the heavy vehicles—those with one or more axles weighing 18,000 pounds or more, or with a gross weight of 26,000 pounds or more—generally was designated. This information made possible the calculating of vehicle-mileages, ton-mileages, and other data on the main rural roads by the various types of trucks and truck combinations privately operated and operated for-hire.

In the last two columns of table 3 are shown the percentage distribution of travel of all privately operated and for-hire trucks and combinations, by vehicle type. In general the lighter types of vehicles predominate in the private classification and, conversely, the heavier vehicles constitute a much higher proportion of the for-hire vehicles. This difference is very noticeable in the percentages for the light panel and pickup trucks and for the heavy three-axle truck-tractors with semitrailers. Over 40 percent of the privately operated truck travel was by the panel and pickup type, while less than 2 percent of the for-hire vehicle travel was by this type. On the other hand, less than 15 percent of the travel of all privately operated vehicles was by truck combinations, while of the for-hire travel almost 74 percent was by combinations.

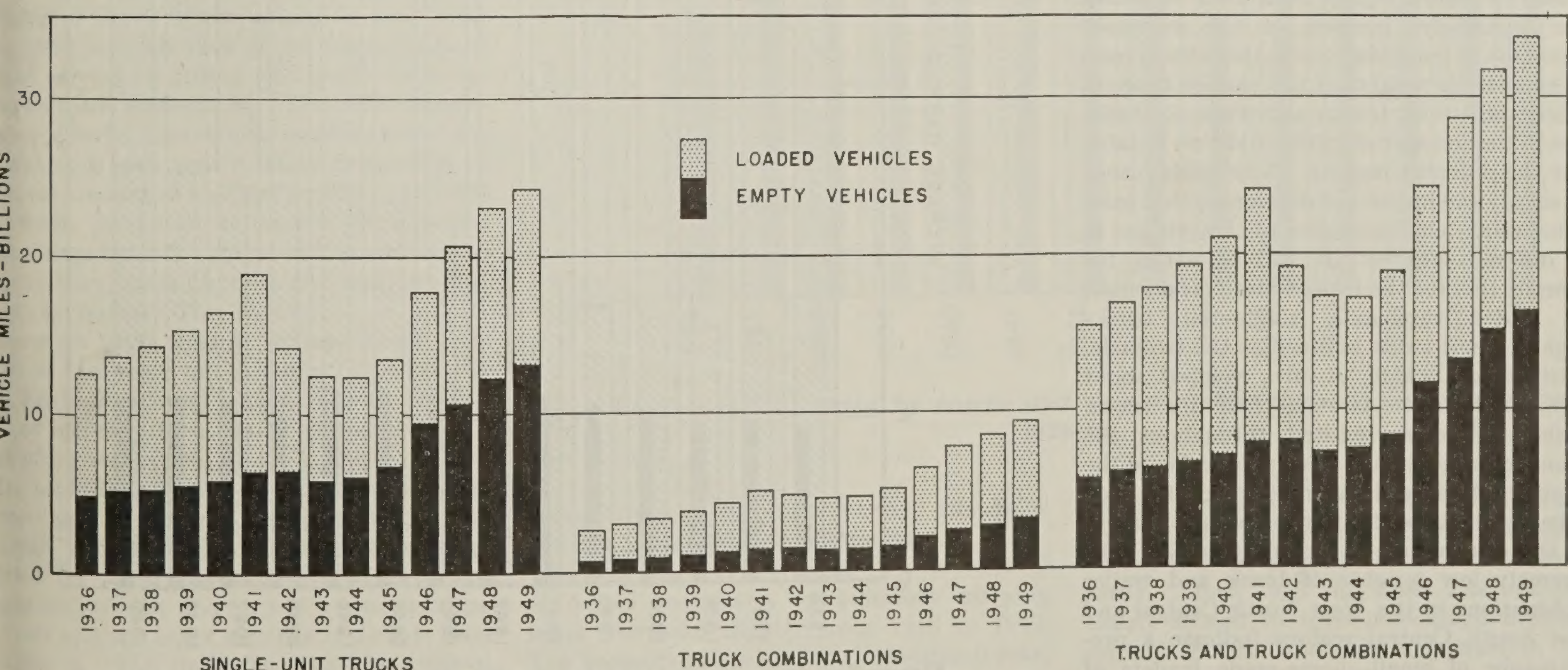

Figure 4.—Travel on main rural roads, 1936–49, by loaded and by empty trucks and truck combinations.

Table 5.—*Comparison of estimated vehicle-miles of travel on main rural roads in 1936, 1941, 1946, 1948, and 1949*

Year	All vehicles, vehicle-miles	Passenger cars and busses [1]		All trucks and truck combinations		Single-unit trucks		Truck combinations	
		Percentage of all vehicles	Vehicle-miles	Percentage of all vehicles	Vehicle-miles	Percentage of all trucks and truck combinations	Vehicle-miles	Percentage of all trucks and truck combinations	Vehicle-miles
	Millions		*Millions*		*Millions*		*Millions*		*Millions*
1936	88, 412	82. 6	73, 005	17. 4	15, 407	82. 1	12, 650	17. 9	2, 757
1941	122, 505	80. 3	98, 320	19. 7	24, 185	78. 8	19, 057	21. 2	5, 128
1941: 1936 ratio	*1. 39*	*. 97*	*1. 35*	*1. 13*	*1. 57*	*. 96*	*1. 51*	*1. 18*	*1. 86*
1946	124, 149	80. 4	99, 803	19. 6	24, 346	73. 3	17, 838	26. 7	6, 508
1946: 1941 ratio	*1. 01*	*1. 00*	*1. 02*	*. 99*	*1. 01*	*. 93*	*. 94*	*1. 26*	*1. 27*
1946: 1936 ratio	*1. 40*	*. 97*	*1. 37*	*1. 13*	*1. 58*	*. 89*	*1. 41*	*1. 49*	*2. 36*
1948	147, 597	78. 5	115, 837	21. 5	31, 760	72. 9	23, 138	27. 1	8, 622
1949	159, 379	78. 8	125, 602	21. 2	33, 777	71. 9	24, 295	28. 1	9, 482
1949: 1948 ratio	*1. 08*	*1. 00*	*1. 08*	*. 99*	*1. 06*	*. 99*	*1. 05*	*1. 04*	*1. 10*
1949: 1941 ratio	*1. 30*	*. 98*	*1. 28*	*1. 08*	*1. 40*	*. 91*	*1. 27*	*1. 33*	*1. 85*
1949: 1936 ratio	*1. 80*	*. 95*	*1. 72*	*1. 22*	*2. 19*	*. 88*	*1. 92*	*1. 57*	*3. 44*
COMPARISON FOR TRUCKS AND TRUCK COMBINATIONS, BY TYPE OF OPERATION									
Private:									
1936	--------	--------	--------	78. 8	12, 140	86. 7	10, 963	42. 7	1, 177
1949	--------	--------	--------	77. 2	26, 077	91. 6	22, 262	40. 2	3, 815
1949: 1936 ratio	--------	--------	--------	*. 98*	*2. 15*	*1. 06*	*2. 03*	*. 94*	*3. 24*
For-hire:									
1936	--------	--------	--------	21. 2	3, 267	13. 3	1, 687	57. 3	1, 580
1949	--------	--------	--------	22. 8	7, 700	8. 4	2, 033	59. 8	5, 667
1949: 1936 ratio	--------	--------	--------	*1. 08*	*2. 36*	*. 63*	*1. 21*	*1. 04*	*3. 59*

[1] Percentages of total 1949 travel by passenger cars and by busses are reported separately in table 3

Average Weights Increase

The average weights of loaded and empty trucks and truck combinations, separately and combined, are shown graphically in figure 3 for each year from 1942 to 1949, inclusive, and in a prewar year, generally 1936 or 1937. The weights of single-unit trucks, both loaded and empty, increased each year from the 1936–37 period through 1945, then leveled off or decreased slightly each succeeding year. At the same time weights of truck combinations, both loaded and empty, have increased each year during the period shown. The increase in average weight of loaded combinations from the 1936–37 period to 1949 was almost 50 percent, compared to only 12 percent for single-unit trucks. The increase for all trucks and truck combinations combined was 57 percent, a figure higher than that of either type separately, because of the increased proportion of combinations in the latter years.

The average weights of the various types of loaded and empty trucks and truck combinations in the summer of 1949 are shown in table 4 for the different regions. This table brings out clearly the important differences that exist in the weight characteristics of the vehicles in the different groups. It will be noted, for example, that for the United States as a whole, the loaded three-axle, single-unit trucks weighed about twice as much as the two-axle, six-tire trucks which, in turn, weighed about twice as much as the two-axle, four-tire trucks. Similar differences existed throughout the various classifications. On the other hand the regional differences in average weight for each of the vehicle types that are common throughout the country are surprisingly small. The extremely low weights of truck and trailer combinations in the West North Central and West South Central regions indicate a predominance of small, home-made trailers of low capacity.

The average weights of loaded and empty trucks and truck combinations operated privately and for-hire in the summer of 1949 are shown in the last two columns of table 4. The for-hire vehicles, when compared by types, are generally heavier than those operated privately, and the average of all ty of for-hire vehicles, either loaded or empty more than twice as heavy as the averag the privately operated vehicles. It was sh in table 3 that the largest portion of the vate vehicles consisted of the small sin unit trucks while the greater portion of for-hire vehicles consisted of the heavy tr combinations. This decided difference in distributions of sizes of vehicles in the operation classes accounts for the g difference between their average weights.

Truck Travel Again Increases

Figure 4 shows a comparison of the e mated vehicle-mileage of travel by loaded empty single-unit trucks and truck comb tions, separately and combined, on main r roads, for each year from 1936 to 1949, clusive. This chart demonstrates graphic the steady growth of truck traffic during prewar years, 1936–41, the temporary ef of wartime restrictions in the period 1942- and the remarkable increases in truck tr portation that have occurred since the en hostilities in 1945.

Table 5 shows a comparison of the e mated vehicle-mileage of travel by vehi of different types on all main rural road 1936, the earliest year for which compre sive weight data are available; in 1941, peak prewar year, 5 years after the begin of the surveys; in 1946, 10 years after beginning of the surveys; and in 1948

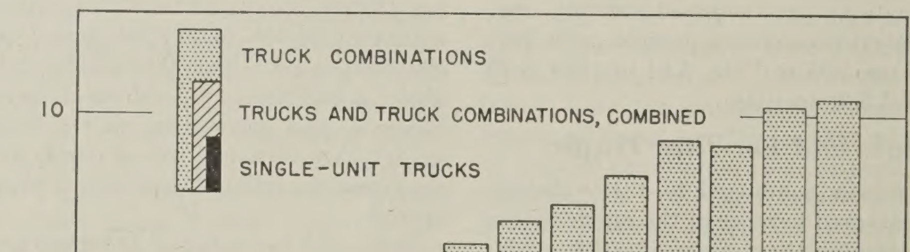

Figure 5.—Average load carried by trucks and truck combinations on main rural roads, 1936–49.

9. The ratios of 1949 travel to that of the [illegible]eding years indicate that increases for [illegible]ks and truck combinations generally [illegible] greater than for passenger cars, and that [illegible]eases for truck combinations were greater [illegible]i for single-unit trucks. In the 13 years [illegible]i 1936 to 1949, passenger-car and bus [illegible]el combined increased over 70 percent, [illegible]el by all trucks and combinations more [illegible]i doubled, and travel by truck combina[illegible]s (considered separately) more than tripled.

[illegible]he lower portion of table 5 shows a com[illegible]son of the estimated vehicle-mileage of [illegible]el in 1936 and in 1949 by privately oper[illegible]l trucks and combinations, and by those [illegible]rated for-hire. Travel by for-hire vehicles [illegible]eased somewhat more than travel by [illegible]ate vehicles, the 1949:1936 ratio being [illegible] in the case of for-hire vehicles and 2.15 [illegible]he case of private vehicles. Most of the [illegible]ease in for-hire vehicle travel was by truck [illegible]ubinations, there being only a 21-percent [illegible]ease in the for-hire vehicle-mileage by [illegible]gle-unit trucks compared to a 259-percent [illegible]ease by combinations. In the case of the [illegible]vate vehicles, on the other hand, there [illegible]e substantial increases in the vehicle-[illegible]eage by both types.

[illegible]n the lower portion of table 5, incidentally, [illegible] percentage figures refer to trucks and [illegible]ck combinations only; for example, of all [illegible]gle-unit trucks, in 1936, 86.7 percent were [illegible]rivate operation and 13.3 percent for-hire.

Volume of Highway Freight

[illegible]igure 5 gives a comparison of the average [illegible]d carried by single-unit trucks and truck [illegible]nbinations, separately and combined, in the [illegible] years that the planning surveys have been [illegible]erating. The general trend of load weights [illegible]s upward throughout the period. The [illegible]ght decline in the weights of loads carried by [illegible]gle-unit trucks since 1945 has been more [illegible]n offset by the increased use of combina[illegible]ns and the increased weights of loads carried [illegible] vehicles of this type.

Figure 6 shows a comparison for each year f[illegible]m 1936 through 1949 of the ton-mileage of f[illegible]ight carried by trucks and truck combina[illegible]ns on main rural roads. The chart demon[illegible]ates clearly that truck combinations are [illegible]nsporting each year a larger proportion of [illegible] total amount of highway freight. In 1936 [illegible]e truck combinations hauled slightly less [illegible]-mileage than the single-unit trucks, while [illegible] 1949 they hauled almost two and one-half [illegible]nes as much. The rapid rate of annual [illegible]crease in total freight carried, which took [illegible]ace in the years immediately following the [illegible]ar, has been reduced in the last two years to a [illegible]te of increase more nearly comparable with [illegible]at of prewar years.

In table 6 is shown a comparison of the [illegible]rcentage of vehicles carrying loads, the [illegible]erage carried load, and the ton-mileage [illegible]rried for all trucks and combinations, for [illegible]gle-unit trucks, and for truck combinations [illegible] 1949 and the other significant periods used [illegible] table 5. The trend from 1936 to 1949 of [illegible]erage weight carried, shown graphically in [illegible]ure 5, and that of the ton-mileage transported during the same period, shown in figure 6, have already been discussed.

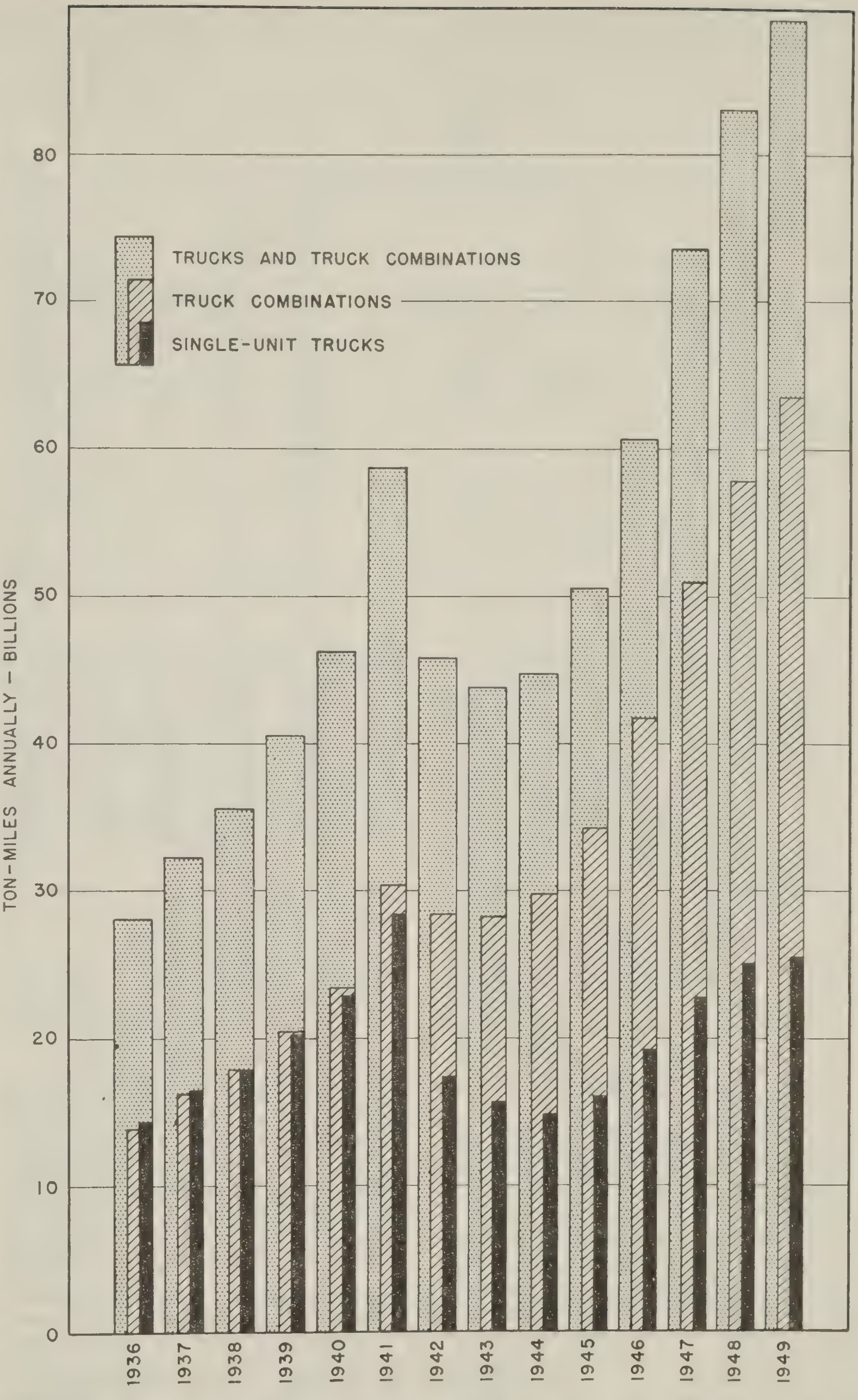

Figure 6.—Ton-miles carried by trucks and truck combinations on main rural roads, 1936–49.

In the country as a whole, the percentage of trucks and truck combinations carrying loads decreased slightly from 1948 to 1949. The percentage loaded for single-unit trucks, for truck combinations, and for the two types of vehicles combined was less than the comparable figures for 1946, when the downward trend in these figures that had been maintained during the war appeared to be halted temporarily. Since 1946 the trend has not been clearly defined, for these percentages increased slightly in 1947 and then decreased in 1948 and again in 1949. With these latest decreases the proportion of vehicles loaded

Table 6.—*Comparison of the estimated percentage of trucks and truck combinations loaded, average carried load, and ton-miles carried on main rural roads in 1936, 1941, 1946, 1948, and 1949, and similar data for privately operated and for-hire vehicles*

Year	All trucks and truck combinations			Single-unit trucks			Truck combinations		
	Percentage loaded	Average weight of carried load	Ton-miles carried	Percentage loaded	Average weight of carried load	Ton-miles carried	Percentage loaded	Average weight of carried load	Ton-miles carried
		Tons	*Millions*		*Tons*	*Millions*		*Tons*	*Millions*
1936	62.8	2.90	28,005	60.7	1.86	14,258	72.2	6.90	13,747
1941	66.7	3.64	58,737	65.4	2.29	28,487	71.6	8.23	30,250
1941:1936 ratio	*1.06*	*1.26*	*2.10*	*1.08*	*1.23*	*2.00*	*.99*	*1.19*	*2.20*
1946	51.7	4.84	60,892	46.4	2.31	19,101	66.2	9.70	41,791
1946:1941 ratio	*.78*	*1.33*	*1.04*	*.71*	*1.01*	*.67*	*.92*	*1.18*	*1.38*
1946:1936 ratio	*.82*	*1.67*	*2.17*	*.76*	*1.24*	*1.34*	*.92*	*1.41*	*3.04*
1948	52.2	5.02	83,119	46.8	2.33	25,219	66.5	10.10	57,900
1949	51.6	5.11	89,100	46.1	2.29	25,639	65.7	10.19	63,461
1949:1948 ratio	*.99*	*1.02*	*1.07*	*.99*	*.98*	*1.02*	*.99*	*1.01*	*1.10*
1949:1941 ratio	*.77*	*1.40*	*1.52*	*.70*	*1.00*	*.90*	*.92*	*1.24*	*2.10*
1949:1936 ratio	*.82*	*1.76*	*3.18*	*.76*	*1.23*	*1.80*	*.91*	*1.48*	*4.62*
Privately operated trucks and truck combinations:									
1936	60.3	2.20	16,094	59.8	1.71	11,180	65.5	6.37	4,914
1949	47.6	3.48	43,231	45.3	2.10	21,193	61.2	9.43	22,038
1949:1936 ratio	*.79*	*1.58*	*2.66*	*.76*	*1.23*	*1.90*	*.93*	*1.48*	*4.48*
For-hire trucks and truck combinations:									
1936	71.9	5.07	11,911	66.4	2.73	3,078	77.3	7.23	8,833
1949	65.1	9.16	45,869	55.1	3.97	4,446	68.7	10.65	41,423
1949:1936 ratio	*.91*	*1.81*	*3.85*	*.83*	*1.45*	*1.44*	*.89*	*1.47*	*5.03*

reached a new all-time low level, only 46 percent of the single-unit trucks and less than 66 percent of the truck combinations being loaded in 1949, compared to 61 percent and 72 percent, respectively, for these two types of vehicles in 1936.

The lower portion of table 6 shows a comparison of the percentage loaded, average carried load, and ton-mileage for single-unit trucks, truck combinations, and these two types of vehicles combined, when operated as private and as for-hire vehicles. An appreciably larger percentage of the for-hire vehicles are loaded; the loads carried by these vehicles are much heavier; and the average carried loads are increasing at a more rapid rate than for privately operated vehicles. Single-unit trucks transport an important part of the freight moved in privately operated vehicles, but only a minor part of the freight moved by for-hire trucks.

The first part of table 7 gives a detailed comparison of the percentage of vehicle-miles of travel, percentage of vehicles loaded, average carried load, and percentage of total ton-mileage carried by the various types of trucks and truck combinations traveling on main rural roads in 1948 and 1949. Many interesting comparisons can be made from this table showing the relative importance from a freight-carrying standpoint of different portions of the traffic stream. In 1949, for instance, while panel and pickup trucks traveled almost 32 percent of the vehicle-mileage, they accounted for less than 3 percent of the ton-mileage. The truck-tractor and semitrailer combinations traveled less than 27 percent of the vehicle-mileage, but they carried almost 66 percent of the ton-mileage.

From the columns in table 7 showing the percentage loaded, by types, it can be observed that the percentage of vehicles carrying loads increases directly as the size of the vehicle type, extending from the light panel and pickup trucks that are loaded 36 percent of the time, to the heavy combinations that are loaded over 65 percent of the time.

The right-hand portion of table 7 shows the percentage loaded, average carried load, and percentage of total ton-mileage carried by various types of privately operated trucks and truck combinations compared to those operated for-hire on the main rural roads in 1949. The percentage of travel (vehicle-mileage) by these types is given in table 3. A comparison of vehicle-mileage percentage with ton-mileage percentage, by operating classes, shows t panel and pickup trucks, privately operat travel over 40 percent of the vehicle-mile while transporting only about 5 percent of freight moved in privately operated vehic At the same time, for-hire panels and pick travel less than 2 percent of the total hire vehicle-mileage and carry only 0.2 perc of the total ton-mileage moved by the for-l vehicles. The heavy-vehicle combinatic privately operated, travel about 15 perc of the total mileage and carry almost 51 cent of the freight moved by privately o ated vehicles, while the for-hire combinati travel almost 74 percent of the total vehi mileage of all such vehicles and carry over percent of the freight transported by all for-hire trucks and combinations.

Gross Weights Increasing Slightl

Figure 7 shows for the United States a whole the frequency of gross weights by ye from the prewar years (generally 1936 or 19 to 1949, of 30,000 pounds or more, of 40, pounds or more, and of 50,000 pounds or m The trend of frequency of heavy loads c tinues upward although the frequency 50,000-pound weights was slightly less in 1 than in the previous year. The frequency these heaviest loads was 12 times greate 1949 than in the prewar year, the weight 40,000 pounds or more were 7 times as quent, and those of 30,000 pounds or n were 3½ times as frequent as in the earl years of the surveys. Vehicles weigh 30,000 pounds or more and 40,000 pound more appear in greater numbers than e before, whereas the number of those in heaviest group declined slightly.

The 1949 gross-weight frequency data vehicle type and region are presented in t 8. No panels, pickups, or other two-a four-tire, single-unit trucks were found in survey weighing as much as 30,000 pounds there is no entry for these vehicles in table, though they are included in the t number of vehicles weighed in computing frequencies for all trucks and combinati Heavy gross weights are much more frequ in the Pacific region than in other parts of country. In this region 99 of each 1 trucks and truck combinations on the n rural highways in 1949, empties inclu weighed 50,000 pounds or more. This

Table 7.—*Percentage of vehicle-miles of travel, percentage loaded, average carried load, and percentage of total ton-miles carried various types of trucks and truck combinations on main rural roads in 1949 compared to that in corresponding months of 1948*

Vehicle type	Percentage of vehicle-miles of travel		Percentage loaded		Average carried load		Percentage of ton-miles carried		Distribution by type of operation in 1949					
									Percentage loaded		Average carried load		Percentage of to miles carried	
	1949	1948	1949	1948	1949	1948	1949	1948	Private	For-hire	Private	For-hire	Private	For-h
Single-unit trucks:					*Tons*	*Tons*					*Tons*	*Tons*		
Panel and pickup	31.55	28.90	35.9	36.7	0.64	0.64	2.75	2.60	35.72	48.13	0.63	1.42	5.45	0.
Other 2-axle, 4 tire	3.46	3.59	49.4	51.9	.78	1.24	.50	.88	49.39	47.75	.74	2.76	.96	.
Other 2-axle, 6-tire	35.34	38.66	54.5	53.6	3.17	3.10	23.15	24.51	54.40	55.40	3.06	3.82	39.28	7.
3-axle	1.58	1.70	54.8	55.2	7.23	6.57	2.38	2.35	53.44	58.09	7.11	7.52	3.33	1.
All single-unit trucks	71.93	72.85	46.1	46.8	2.29	2.33	28.78	30.34	45.30	55.05	2.10	3.97	49.02	9.
Truck combinations:														
Truck-tractor and semitrailer	26.57	25.35	65.8	66.2	9.95	9.83	65.91	63.09	61.11	68.98	9.39	10.27	47.98	82.
Truck and trailer	1.50	1.80	63.4	70.2	14.69	13.64	5.31	6.57	63.60	63.24	10.08	17.75	3.00	7.
All truck combinations	28.07	27.15	65.7	66.5	10.19	10.10	71.22	69.66	61.24	68.67	9.43	10.65	50.98	90.
All trucks and truck combinations	100.00	100.00	51.6	52.2	5.11	5.02	100.00	100.00	47.63	65.07	3.48	9.16	100.00	100.

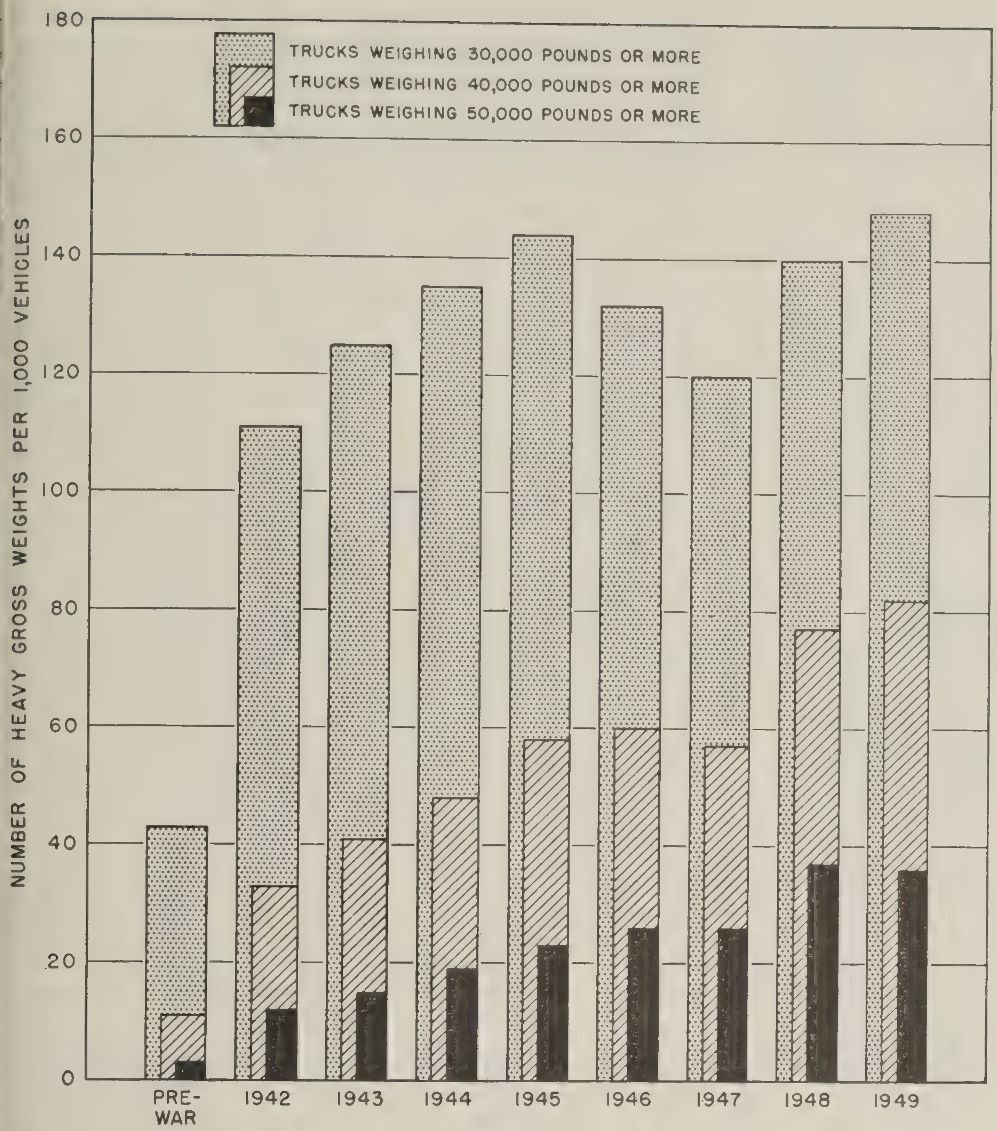

Figure 7.—Number of heavy gross weights per 1,000 trucks and truck combinations (empties included) in the summers of 1942–49 and a prewar year.

ency is the same as was found in 1948 but slightly lower than the 1946 figure of 104 each 1,000 in this heavy category. These heavy vehicles are almost entirely of the combination type, approximately 40 percent of all combinations observed, or about 52 percent of the loaded ones, weighing 50,000 pounds or more. In the East South Central region these heavy gross weights were about one-fifteenth as frequent as in the Pacific region, while in the New England, South Atlantic, and West South Central regions the heavy weights were one-fifth as frequent as in the Pacific region.

Frequency of Heavy Axle Loads

Figure 8 shows the frequency of axle loads of 18,000 pounds or more, of 20,000 pounds or more, and of 22,000 pounds or more, by years from the prewar years (1936–37) to 1949. The frequency of heavy axle loads increased year by year from the prewar period through 1948. The frequencies for 1949 are slightly lower than those found in the previous year, yet are higher than in any other previous period and fit very closely the long-time trend from 1942 through 1947. Axle loads in excess of 22,000 pounds increased in frequency from per 1,000 vehicles in the prewar period to per 1,000 vehicles in 1949, an increase of 750 percent. Somewhat lesser increases occurred in the frequencies of axle loads from 18,000 to 20,000 pounds. The decline in heavy axle loads in all the categories from 1948 to 1949, coupled with the decline in frequency of the heaviest gross loads shown in figure 7, may possibly indicate that increased enforcement activity is being reflected in better law observance. One year's reversal in trend is insufficient to warrant conclusions. The 1950 survey results should show whether the trend will continue downward from 1948 or resume the steady upward course followed prior to that year.

Table 9 gives data concerning the number of heavy axle loads per 1,000 loaded and empty trucks and truck combinations of various types on the main rural roads in the summer of 1949. Since no panel or pickup trucks were found with axles weighing 18,000 pounds or more, there is no entry for these in the table, though they are included in figuring the frequencies for all trucks and truck combinations.

Though the greatest frequency of heavy gross weights is in the Pacific region, as shown in table 8, the lowest frequency of heavy axle loads is in this same region. The greatest frequency is in the Middle Atlantic region and the next greatest in New England. In these two regions the relatively high frequency is attributable mainly to the large number of two-axle truck-tractors pulling one-axle or two-axle semitrailers. The relative infrequency of heavy axles in the Pacific region, in the presence of a large proportion of heavy gross loads, indicates a better distribution of the loads over a larger number of axles.

Loads Above Legal Limits

Table 10 [6] shows the number of trucks and truck combinations of each type, per 1,000 such vehicles counted, empties included, that exceeded the permissible axle, axle-group, or gross-weight legal limits in effect in the individual States in the summer of 1949, and the number per 1,000 that exceeded these limits by various percentages. Loads in excess of the State legal limits were most frequent, as in 1948, in the East North Central region where it was found that 63 of each 1,000 vehicles exceeded a State weight limit. The Middle Atlantic region stood second in frequency of violations, with 59 vehicles out of each 1,000 exceeding a load limit, followed closely by the Mountain region with 58 violations per 1,000 vehicles.

A comparison of the frequency of loads exceeding State legal limits in 1949, shown in table 10, with similar data collected in the previous year, indicates that these excessive loads have decreased in all areas except the Mountain and Pacific regions. In the Mountain region the frequency increased 45 percent, while in the Pacific region the increase was about 9 percent. For the country as a whole, excessive loads in 1949 were slightly less frequent than in 1948 but slightly more than in 1947. No panel or pickup truck was weighed that exceeded any of the State weight regulations and this classification is omitted from the tables although the number of such vehicles counted is included in the calculations.

Recommended Weight Limits

Uniform regulations concerning maximum allowable gross weights, axle weights, and axle-group weights have been adopted as a policy by the American Association of State Highway Officials and recommended to the State governments for adoption.[7] This policy recommends that no axle shall carry a load in excess of 18,000 pounds and no group of axles shall carry a load in excess of amounts specified in a table of permissible weights based on the distance between the extremes of any group of axles.

In table 11 is shown the number of axles per 1,000 vehicles of various types that exceeded the axle-load limit of 18,000 pounds recommended by the A.A.S.H.O. and the number exceeding these limits by various percentages.

[6] Tables 10–14 are on pages 96–98.

[7] *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 in 1946.

Table 8.—*Heavy gross weights per 1,000 loaded and empty trucks and truck combinations on main rural roads, summer of 1949*

Vehicle type [1]	Eastern regions: New England	Eastern regions: Middle Atlantic	Eastern regions: South Atlantic	Eastern regions: Average	Central regions: East North Central	Central regions: East South Central	Central regions: West North Central	Central regions: West South Central	Central regions: Average	Western regions: Mountain	Western regions: Pacific	Western regions: Average	United States average
Number Per 1,000 Weighing 30,000 Pounds or More													
Single-unit trucks:													
2-axle, 6-tire	16	19	3	11	(2)	(2)	(2)	2	1	6	(2)	4	5
3-axle	286	371	245	309	221	298	212	231	229	206	208	207	253
Average	16	22	8	14	6	3	3	3	4	7	14	10	8
Truck combinations:													
Truck-tractor and semitrailer	475	595	498	539	521	458	517	434	492	569	644	612	520
Truck and trailer	(3)	(3)	(3)	--------	789	0	82	53	495	783	722	739	657
Average	476	596	498	540	534	457	502	424	492	613	668	647	528
Average, all trucks and truck combinations	117	191	130	153	208	87	139	107	144	118	176	147	148
Number Per 1,000 Weighing 40,000 Pounds or More													
Single-unit trucks:													
2-axle, 6-tire	1	1	0	(2)	0	0	(2)	0	(2)	(2)	0	(2)	(2)
3-axle	137	157	40	107	34	0	14	112	38	69	12	28	61
Average	4	5	1	3	1	0	(2)	1	1	1	1	1	1
Truck combinations:													
Truck-tractor and semitrailer	287	390	285	332	262	189	293	221	250	380	481	438	297
Truck and trailer	(3)	(3)	(3)	--------	512	0	67	31	323	461	523	506	448
Average	289	391	285	333	274	189	285	215	252	397	494	456	305
Average, all trucks and truck combinations	66	120	71	90	105	36	77	54	73	75	121	97	82
Number Per 1,000 Weighing 50,000 Pounds or More													
Single-unit trucks:													
2-axle, 6-tire	0	0	0	0	0	0	0	0	0	(2)	0	(2)	(2)
3-axle	6	15	4	9	21	0	0	0	10	14	2	5	9
Average	(2)	1	(2)	(2)	1	0	0	0	(2)	(2)	(2)	(2)	(2)
Truck combinations:													
Truck-tractor and semitrailer	69	170	87	122	109	28	124	75	94	243	382	323	127
Truck and trailer	0	(3)	(3)	--------	455	0	31	10	278	381	470	446	392
Average	69	171	87	123	125	28	120	74	100	271	409	356	141
Average, all trucks and truck combinations	15	52	21	33	48	6	32	18	29	51	99	75	36

[1] No two-axle, four-tire trucks weighing as much as 30,000 pounds were reported.
[2] Less than 5 per 10,000.
[3] Data omitted because of insufficient sample.

Table 9.—*Heavy axle loads per 1,000 loaded and empty trucks and truck combinations on main rural roads in the summer of 1949*

Vehicle type [1]	Eastern regions: New England	Eastern regions: Middle Atlantic	Eastern regions: South Atlantic	Eastern regions: Average	Central regions: East North Central	Central regions: East South Central	Central regions: West North Central	Central regions: West South Central	Central regions: Average	Western regions: Mountain	Western regions: Pacific	Western regions: Average	United States average
Number Per 1,000 Weighing 18,000 Pounds or More													
Single-unit trucks:													
2-axle, 4-tire	0	2	2	2	0	0	0	0	0	0	0	0	1
2-axle, 6-tire	46	58	23	40	10	18	10	11	12	34	14	24	23
3-axle	116	169	55	116	67	33	11	56	48	71	4	23	67
Average	27	38	13	24	7	9	5	5	6	15	7	11	13
Truck combinations:													
Truck-tractor and semitrailer	471	566	361	462	206	238	179	198	203	252	147	192	290
Truck and trailer	0	(2)	0	--------	578	0	50	10	355	188	106	128	210
Average	468	567	361	462	223	237	175	193	208	239	135	175	286
Average, all trucks and truck combinations	124	195	99	140	89	50	50	51	63	57	37	48	86
Number Per 1,000 Weighing 20,000 Pounds or More													
Single-unit trucks:													
2-axle, 4-tire	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
2-axle, 6-tire	27	36	9	23	4	6	2	3	3	18	3	10	11
3-axle	40	69	27	48	32	0	0	0	15	58	0	16	[illegible]
Average	15	22	5	13	3	3	1	1	2	8	1	5	[illegible]
Truck combinations:													
Truck-tractor and semitrailer	281	341	172	257	60	86	42	72	62	113	28	64	[illegible]
Truck and trailer	0	(2)	0	--------	211	0	14	0	128	44	8	18	61
Average	280	342	172	257	67	86	41	70	64	99	22	52	[illegible]
Average, all trucks and truck combinations	73	118	46	78	27	18	12	18	20	26	6	16	[illegible]
Number Per 1,000 Weighing 22,000 Pounds or More													
Single-unit trucks:													
2-axle, 4-tire	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
2-axle, 6-tire	16	17	4	11	1	2	1	1	1	9	1	5	[illegible]
3-axle	0	29	8	17	29	0	0	0	14	24	0	7	[illegible]
Average	9	11	2	6	1	1	(3)	(3)	1	4	(3)	2	[illegible]
Truck combinations:													
Truck-tractor and semitrailer	120	193	66	127	19	22	8	24	18	46	5	22	[illegible]
Truck and trailer	0	0	0	0	91	0	12	0	57	23	4	9	[illegible]
Average	120	192	66	127	22	22	8	23	20	41	5	19	[illegible]
Average, all trucks and truck combinations	33	65	18	39	9	5	3	6	6	11	2	6	[illegible]

[1] No panel or pick-up trucks with an 18,000-pound axle load were reported.
[2] Data omitted because of insufficient sample.
[3] Less than 5 per 10,000.

This table emphasizes again the high frequency of heavy axle loads in the Middle Atlantic and New England regions. The number of axles per 1,000 vehicles weighing more than the recommended limits was 175 in the Middle Atlantic and 109 in the New England regions, while only 31 such axles for each 1,000 vehicles were found in the Pacific region. For the United States as a whole axle loads heavier than 18,000 pounds were about 12 percent less frequent in 1949 than in 1948, although almost 14 percent more frequent than in 1947.

Table 12 shows the number of vehicles of various types per 1,000 with an axle-group load in excess of the limits recommended by the A.A.S.H.O. and in excess of these limits by various percentages. For the country as a whole, of each 1,000 loaded and empty trucks and truck combinations, 28 had axle-group loads [8] weighing in excess of the recommended limits, 7 of which exceeded the limits by more than 20 percent. Of each 1,000 combinations weighed, 98 had axle-group loads weighing more than the recommended limits, of which 24 exceeded the limits by more than 20 percent. The frequency of the excessive axle-group loads in 1949 was about 7 percent less than in 1948 and 12 percent above the 1947 frequency.

As might be expected, many vehicles were so loaded that they exceeded more than one recommended weight limit, and some vehicles had more than one axle loaded in excess of the recommended limit. Counting each vehicle only once, regardless of the number of ways in which it exceeded any of the A.A.S.H.O. recommended limits, table 13 was derived to show the number of vehicles per 1,000 of each type, both loaded and empty, that exceeded the limits by various percentages. Those vehicles which exceeded more than one provision of the recommended restrictions were tabulated in the column showing the highest percentage excess only of any item.

In the United States as a whole, 68 vehicles out of every 1,000 were overloaded to some degree, and 19 out of every 1,000 exceeded some one of the provisions by more than 20 percent. The frequency of vehicles exceeding the recommendations by any amount in 1949 was 7 percent less than in 1948 and about 15 percent greater than in 1947.

In considering the data concerning the frequencies of axles or vehicles exceeding the State legal limits and the A.A.S.H.O. recommendations, especially the frequencies in the Middle Atlantic and New England regions, the fact should be recognized that higher limits generally are permissible under the State laws in this area than are recommended by the Association. Axles exceeding the recommended limits by 25 percent may be within the legal limits of certain States, particularly in these two regions. Some States have no axle limits or axle-group limits in their motor-vehicle restrictions, a fact that complicates direct comparison of excess weights based on law and those based on the recommendations. Comparison of the frequency data given in table 13 with those in table 10 shows that from one-third to one-half of the vehicles exceeding one or more of the Association recommendations actually exceeded a State legal limit.

[8] The frequency of 28 vehicles of each 1,000 weighed that exceeded the A.A.S.H.O. axle-group recommendation, found in the final analysis of these data as shown in table 12, is slightly larger than the frequency of 2.56 percent (or 26 per 1,000) found in the preliminary analysis reported to the Subcommittee of the Senate Committee on Interstate and Foreign Commerce.

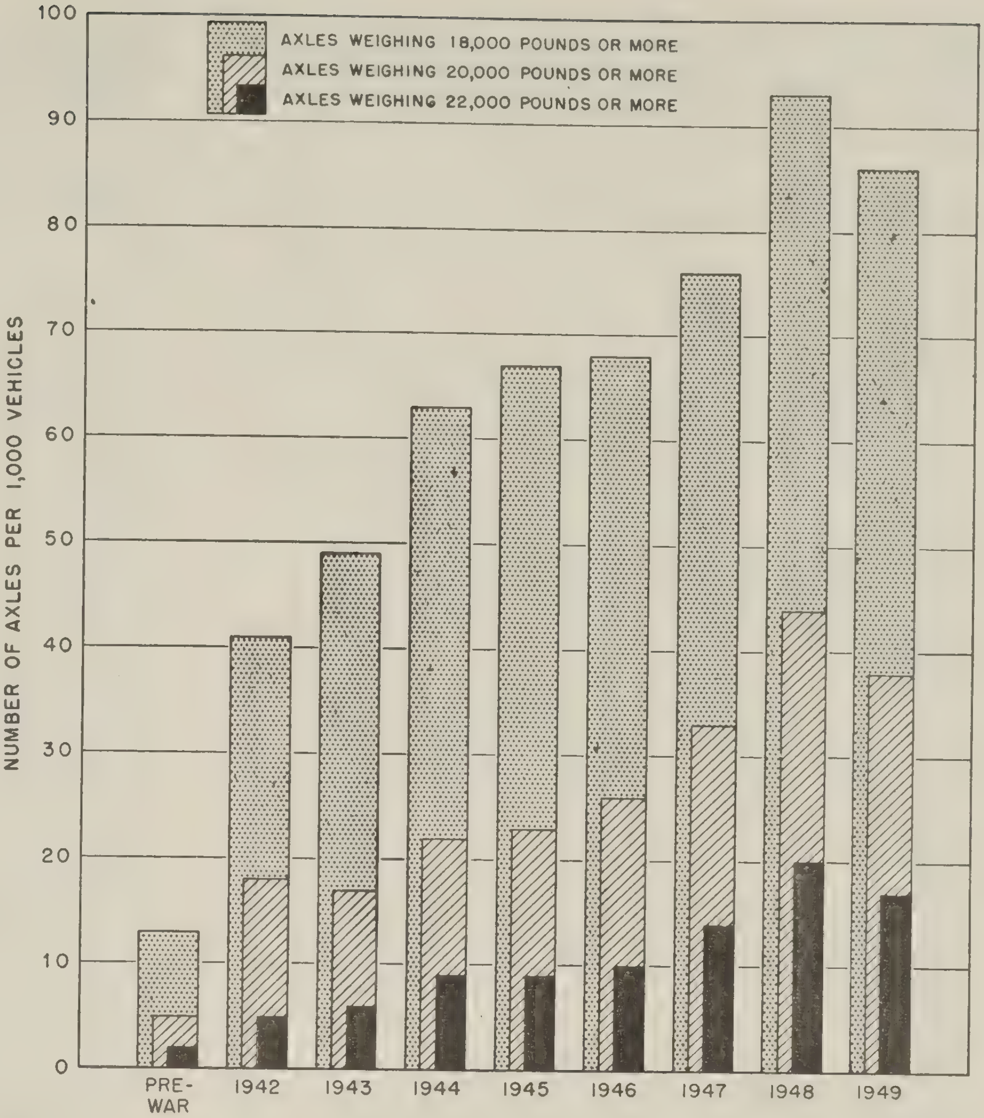

Figure 8.—Number of heavy axle loads per 1,000 trucks and truck combinations (empties included) in the summers of 1942–49 and a prewar year.

For-Hire Vehicles More Frequently Overloaded

The first part of table 14 shows the number of privately operated trucks and truck combinations and those operated for-hire, for each 1,000 such loaded and empty vehicles, on main rural roads of the United States, that exceeded some State legal weight limit in 1949. A comparison of the frequency of the excessively loaded vehicles in the two operation classifications shows, in a striking manner, that type by type, the for-hire vehicles generally are more frequently overloaded than are the privately operated ones. For instance, 6 of each 1,000 private single-unit trucks exceeded a State weight limit while 27 of each 1,000 for-hire trucks exceeded the same limits. Likewise, 146 of each 1,000 private truck combinations exceeded State weight limits, while 168 of each 1,000 for-hire combinations exceeded the same limits.

Of each 1,000 vehicles, the frequencies of all private and all for-hire trucks and truck combinations exceeding the State limits were 26 and 131, respectively. In other words, there were five times as many excess loads among the for-hire vehicles as among the privately operated ones. This is as would be expected, because the heavier vehicles are operated more frequently for-hire and the lighter ones for private transportation.

The following parts of table 14 show frequencies of private and for-hire trucks and truck combinations exceeding the A.A.S.H.O. recommended limits for axle loads, for maximum axle-group loads, or for any of the recommended maximum loads. This table shows, in general, that the relation of the frequency of overload of privately operated and of for-hire vehicles is the same when based on A.A.S.H.O. recommendations or on State legal limits.

Table 10.—*Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded the permissible axle, axle-group, or gross-weight legal limits in effect in the States by various percentages (maximum) of overload, summer of 1949*

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 over-loaded	Number per 1,000 overloaded more than—				
		5 per-cent	10 per-cent	20 per-cent	30 per-cent	50 per-cent
New England:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	15	12	7	4	1	(1)
3-axle	85	76	57	11	6	---
Average, single-unit trucks	10	8	5	2	1	(1)
Truck-tractor and semitrailer	91	53	34	12	5	1
Truck and trailer	---	---	---	---	---	---
Average, truck combinations	91	53	34	12	5	1
Average, all trucks and combinations	28	18	11	4	2	(1)
Middle Atlantic:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	21	13	9	3	1	(1)
3-axle	209	178	115	66	28	---
Average, single-unit trucks	18	13	9	4	1	(1)
Truck-tractor and semitrailer	147	102	73	38	24	6
Truck and trailer	(2)	(2)	(2)	---	---	---
Average, truck combinations	149	104	75	38	24	6
Average, all trucks and combinations	59	42	30	15	8	2
South Atlantic:						
2-axle, 4-tire	1	1	1	1	---	---
2-axle, 6-tire	14	10	7	2	1	(1)
3-axle	41	27	11	8	---	---
Average, single-unit trucks	8	6	4	1	(1)	(1)
Truck-tractor and semitrailer	169	110	70	24	11	1
Truck and trailer	---	---	---	---	---	---
Average, truck combinations	169	110	70	24	11	1
Average, all trucks and combinations	53	35	22	7	7	(1)
East North Central:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	7	5	3	1	(1)	---
3-axle	72	69	66	43	29	20
Average, single-unit trucks	5	4	3	2	1	(1)
Truck-tractor and semitrailer	156	106	65	28	13	2
Truck and trailer	316	226	117	98	40	25
Average, truck combinations	163	112	70	31	14	3
Average, all trucks and combinations	63	43	27	13	6	1
East South Central:						
2-axle, 4-tire	9	9	4	4	4	---
2-axle, 6-tire	13	7	4	2	1	---
3-axle	66	43	11	---	---	---
Average, single-unit trucks	7	4	2	1	1	---
Truck-tractor and semitrailer	162	118	81	26	9	1
Truck and trailer	---	---	---	---	---	---
Average, truck combinations	162	118	81	26	9	1
Average, all trucks and combinations	36	25	17	6	2	(1)
West North Central:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	7	2	1	1	---	---
3-axle	56	37	24	8	---	---
Average, single-unit trucks	5	2	1	1	---	---
Truck-tractor and semitrailer	179	123	76	29	12	1
Truck and trailer	20	16	8	6	---	---
Average, truck combinations	173	119	74	28	12	1
Average, all trucks and combinations	46	30	19	8	3	(1)
West South Central:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	10	7	4	1	---	---
3-axle	---	---	---	---	---	---
Average, single-unit trucks	4	3	2	(1)	---	---
Truck-tractor and semitrailer	153	115	76	31	11	5
Truck and trailer	10	10	---	---	---	---
Average, truck combinations	149	112	74	30	11	5
Average, all trucks and combinations	42	31	21	8	3	1
Mountain:						
2-axle, 4-tire	2	2	2	2	2	---
2-axle, 6-tire	34	31	19	11	7	(-)
3-axle	63	55	48	38	34	---
Average, single-unit trucks	15	13	8	5	4	(1)
Truck-tractor and semitrailer	215	167	120	64	27	5
Truck and trailer	233	179	121	69	25	15
Average, truck combinations	218	169	120	65	27	7
Average, all trucks and combinations	58	46	32	18	9	1
Pacific:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	6	4	2	1	1	1
3-axle	18	7	1	(1)	---	---
Average, single-unit trucks	4	2	1	(1)	(1)	(1)
Truck-tractor and semitrailer	116	63	36	9	3	(1)
Truck and trailer	171	50	16	2	(1)	---
Average, truck combinations	133	59	30	7	2	(1)
Average, all trucks and combinations	49	22	11	2	1	(1)
United States average:						
2-axle, 4-tire	1	1	1	(1)	(1)	---
2-axle, 6-tire	13	9	6	2	1	(1)
3-axle	75	61	42	24	13	4
Average, single-unit trucks	8	6	4	2	1	(1)
Truck-tractor and semitrailer	158	109	71	29	13	3
Truck and trailer	193	107	70	33	12	8
Average, truck combinations	160	109	71	29	13	3
Average, all trucks and combinations	51	35	23	10	4	1
Average, 1948	55	38	26	12	6	1
Average, 1947	46	34	23	10	4	1

[1] Less than 5 per 10,000. [2] Data omitted because of insufficient sample.

Table 11.—*Number of axles, per 1,000 loaded and empty tru and truck combinations, that exceeded the permissible a load limit of 18,000 pounds recommended by the A.A.S.H.O. various percentages of overload in the summer of 1949*

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 over-loaded	Number per 1,000 overloaded more than—				
		5 per-cent	10 per-cent	20 per-cent	30 per-cent	50 per-cent
New England:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	44	35	30	19	11	3
3-axle	91	46	33	---	---	---
Average, single-unit trucks	26	20	17	10	6	2
Truck-tractor and semitrailer	403	337	259	118	44	4
Truck and trailer	(1)	(1)	(1)	---	---	---
Average, truck combinations	408	343	261	117	44	4
Average, all trucks and combinations	109	90	70	33	14	2
Middle Atlantic:						
2-axle, 4-tire	1	1	---	---	---	---
2-axle, 6-tire	54	47	40	21	9	2
3-axle	175	129	70	35	21	7
Average, single-unit trucks	36	30	24	13	6	1
Truck-tractor and semitrailer	480	384	312	177	89	24
Truck and trailer	(1)	(1)	(1)	(1)	---	---
Average, truck combinations	481	385	313	177	89	24
Average, all trucks and combinations	175	141	115	64	32	8
South Atlantic:						
2-axle, 4-tire	1	1	1	---	---	---
2-axle, 6-tire	17	13	9	3	2	(2)
3-axle	55	41	27	8	---	---
Average, single-unit trucks	10	7	5	2	1	(2)
Truck-tractor and semitrailer	299	229	160	62	21	3
Truck and trailer	---	---	---	---	---	---
Average, truck combinations	299	229	160	62	21	3
Average, all trucks and combinations	90	68	48	19	7	1
East North Central:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	7	5	3	1	---	---
3-axle	34	34	31	28	20	---
Average, single-unit trucks	5	3	2	1	1	---
Truck-tractor and semitrailer	165	104	60	22	8	1
Truck and trailer	406	247	151	63	17	---
Average, truck combinations	176	111	64	24	8	1
Average, all trucks and combinations	67	42	25	9	4	(2)
East South Central:						
2-axle, 4-tire	9	9	4	4	4	---
2-axle, 6-tire	13	7	4	2	1	---
3-axle	33	11	---	---	---	---
Average, single-unit trucks	7	4	2	1	1	---
Truck-tractor and semitrailer	191	131	79	22	7	1
Truck and trailer	---	---	---	---	---	---
Average, truck combinations	191	131	79	22	7	1
Average, all trucks and combinations	41	28	16	5	2	(2)
West North Central:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	7	2	1	(2)	---	---
3-axle	21	10	2	2	---	---
Average, single-unit trucks	4	1	1	(2)	---	---
Truck-tractor and semitrailer	168	94	51	14	5	1
Truck and trailer	9	9	5	4	---	---
Average, truck combinations	162	91	49	14	5	1
Average, all trucks and combinations	42	23	13	3	1	(2)
West South Central:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	10	7	4	1	---	---
3-axle	---	---	---	---	---	---
Average, single-unit trucks	4	3	2	(2)	---	---
Truck-tractor and semitrailer	180	122	73	27	11	2
Truck and trailer	10	10	---	---	---	---
Average, truck combinations	175	119	71	26	11	2
Average, all trucks and combinations	49	33	20	7	3	1
Mountain:						
2-axle, 4-tire	2	2	2	2	2	---
2-axle, 6-tire	33	31	19	11	7	(2)
3-axle	67	67	67	27	13	---
Average, single-unit trucks	14	14	9	5	3	(2)
Truck-tractor and semitrailer	216	158	112	51	21	4
Truck and trailer	132	75	39	15	7	2
Average, truck combinations	201	143	99	44	18	4
Average, all trucks and combinations	54	41	28	13	6	1
Pacific:						
2-axle, 4-tire	---	---	---	---	---	---
2-axle, 6-tire	6	4	2	1	1	1
3-axle	2	---	---	---	---	---
Average, single-unit trucks	3	2	1	(2)	(2)	(2)
Truck-tractor and semitrailer	70	37	16	3	1	(2)
Truck and trailer	113	40	12	2	(2)	---
Average, truck combinations	83	38	14	3	1	(2)
Average, all trucks and combinations	31	15	6	1	(2)	(2)
United States average:						
2-axle, 4-tire	1	1	1	(2)	(2)	---
2-axle, 6-tire	19	15	11	5	3	(2)
3-axle	57	43	28	14	8	1
Average, single-unit trucks	11	8	6	3	2	(2)
Truck-tractor and semitrailer	242	175	122	55	24	5
Truck and trailer	168	92	50	17	4	(2)
Average, truck combinations	238	171	118	53	23	5
Average, all trucks and combinations	75	54	37	17	8	1
Average, 1948	85	63	45	23	11	2
Average, 1947	66	49	33	15	7	1

[1] Data omitted because of insufficient sample. [2] Less than 5 per 10,000.

Table 12.—*Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded the permissible axle-group loads recommended by the A.A.S.H.O. by various percentages of overload in the summer of 1949*

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 overloaded	Number per 1,000 overloaded more than—				
		5 percent	10 percent	20 percent	30 percent	50 percent
New England:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	1	1	1	(1)	---	----
3-axle	106	81	48	24	6	----
Average, single-unit trucks	3	3	2	1	(1)	----
Truck-tractor and semitrailer	68	42	24	10	4	(1)
Truck and trailer	(2)	(2)	(2)	(2)	(2)	----
Average, truck combinations	71	45	27	14	8	(1)
Average, all trucks and combinations	18	12	7	4	2	(1)
Middle Atlantic:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	1	---	---	---	---	----
3-axle	157	129	112	45	14	7
Average, single-unit trucks	5	4	3	1	(1)	(1)
Truck-tractor and semitrailer	142	102	73	41	25	5
Truck and trailer	(2)	(2)	(2)	---	---	----
Average, truck combinations	144	104	75	41	25	5
Average, all trucks and combinations	49	35	26	14	8	2
South Atlantic:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	-----	---	---	---	---	----
3-axle	62	34	21	14	8	----
Average, single-unit trucks	1	1	(1)	(1)	(1)	----
Truck-tractor and semitrailer	54	39	29	16	9	1
Truck and trailer	-----	---	---	---	---	----
Average, truck combinations	54	39	29	16	9	1
Average, all trucks and combinations	16	12	8	4	3	(1)
East North Central:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	-----	---	---	---	---	----
3-axle	48	35	35	29	29	10
Average, single-unit trucks	1	1	1	1	1	(1)
Truck-tractor and semitrailer	98	75	50	25	11	3
Truck and trailer	425	407	374	293	191	56
Average, truck combinations	113	90	65	37	19	6
Average, all trucks and combinations	42	33	24	14	8	2
East South Central:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	-----	---	---	---	---	----
3-axle	11	---	---	---	---	----
Average, single-unit trucks	(1)	---	---	---	---	----
Truck-tractor and semitrailer	25	15	9	2	1	(1)
Truck and trailer	-----	---	---	---	---	----
Average, truck combinations	25	15	9	2	1	(1)
Average, all trucks and combinations	5	3	2	(1)	(1)	(1)
West North Central:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	-----	---	---	---	---	----
3-axle	15	8	8	---	---	----
Average, single-unit trucks	(1)	(1)	(1)	---	---	----
Truck-tractor and semitrailer	83	58	36	11	4	(1)
Truck and trailer	16	6	6	2	---	------
Average, truck combinations	81	56	35	11	4	(1)
Average, all trucks and combinations	20	14	9	3	1	(1)
West South Central:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	-----	---	---	---	---	----
3-axle	-----	---	---	---	---	----
Average, single-unit trucks	-----	---	---	---	---	----
Truck-tractor and semitrailer	52	36	22	11	6	2
Truck and trailer	10	10	10	10	10	----
Average, truck combinations	51	35	22	11	6	2
Average, all trucks and combinations	13	9	6	3	2	1
Mountain:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	(1)	(1)	(1)	---	---	----
3-axle	53	50	38	33	15	----
Average, single-unit trucks	1	1	1	1	(1)	----
Truck-tractor and semitrailer	160	122	92	43	19	3
Truck and trailer	246	185	126	47	29	12
Average, truck combinations	176	134	98	44	21	5
Average, all trucks and combinations	38	29	22	10	4	1
Pacific:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	-----	---	---	---	---	----
3-axle	11	5	---	---	---	----
Average, single-unit trucks	1	(1)	---	---	---	----
Truck-tractor and semitrailer	143	111	71	22	5	(1)
Truck and trailer	258	178	74	5	(1)	----
Average, truck combinations	179	132	72	17	3	(1)
Average, all trucks and combinations	64	46	25	6	1	(1)
United States average:						
2-axle, 4-tire	-----	---	---	---	---	----
2-axle, 6-tire	(1)	(1)	(1)	(1)	---	----
3-axle	58	43	34	19	10	3
Average, single-unit trucks	1	1	1	(1)	(1)	(1)
Truck-tractor and semitrailer	89	65	44	21	10	2
Truck and trailer	260	207	140	72	46	13
Average, truck combinations	98	73	49	24	12	3
Average, all trucks and combinations	28	21	14	7	3	1
Average, 1948	30	22	16	7	3	1
Average, 1947	25	19	12	5	2	1

[1] Less than 5 per 10,000.

[2] Data omitted because of insufficient sample.

Table 13.—*Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded any of the permissible load limits recommended by the A.A.S.H.O. by various percentages (maximum) of overload in the summer of 1949*

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 overloaded	Number per 1,000 overloaded more than—				
		5 percent	10 percent	20 percent	30 percent	50 percent
New England:						
2-axle, 4-tire	-------	-----	-----	-----	-----	-----
2-axle, 6-tire	44	36	30	19	11	3
3-axle	119	86	57	24	6	-----
Average, single-unit trucks	26	21	17	11	6	2
Truck-tractor and semitrailer	288	250	203	108	45	4
Truck and trailer	(1)	(1)	(1)	(1)	(1)	-----
Average, truck combinations	290	252	206	111	48	4
Average, all trucks and combinations	84	71	58	33	15	2
Middle Atlantic:						
2-axle, 4-tire	1	1	-----	-----	-----	-----
2-axle, 6-tire	54	47	40	21	9	2
3-axle	181	149	112	53	21	7
Average, single-unit trucks	36	31	26	13	6	1
Truck-tractor and semitrailer	345	284	244	153	85	26
Truck and trailer	(1)	(1)	(1)	(1)	-----	-----
Average, truck combinations	346	285	245	153	85	26
Average, all trucks and combinations	133	111	95	57	31	9
South Atlantic:						
2-axle, 4-tire	1	1	1	-----	-----	-----
2-axle, 6-tire	17	13	9	3	2	(2)
3-axle	66	37	24	14	8	-----
Average, single-unit trucks	10	7	5	2	1	(2)
Truck-tractor and semitrailer	229	182	138	64	26	4
Truck and trailer	-------	-----	-----	-----	-----	-----
Average, truck combinations	229	182	138	64	26	4
Average, all trucks and combinations	71	55	42	19	8	1
East North Central:						
2-axle, 4-tire	-------	-----	-----	-----	-----	-----
2-axle, 6-tire	7	5	3	1	-----	-----
3-axle	56	43	43	38	29	10
Average, single-unit trucks	5	4	3	1	1	(2)
Truck-tractor and semitrailer	180	133	86	39	18	3
Truck and trailer	425	414	381	293	191	56
Average, truck combinations	191	146	100	51	26	6
Average, all trucks and combinations	73	56	38	19	10	2
East South Central:						
2-axle, 4-tire	9	9	4	4	4	-----
2-axle, 6-tire	13	7	4	2	1	-----
3-axle	33	11	-----	-----	-----	-----
Average, single-unit trucks	7	4	2	1	1	-----
Truck-tractor and semitrailer	151	111	74	22	8	1
Truck and trailer	-------	-----	-----	-----	-----	-----
Average, truck combinations	151	111	74	22	8	1
Average, all trucks and combinations	35	24	15	5	2	(2)
West North Central:						
2-axle, 4-tire	-------	-----	-----	-----	-----	-----
2-axle, 6-tire	7	2	1	1	-----	-----
3-axle	36	17	10	2	-----	-----
Average, single-unit trucks	4	1	1	1	-----	-----
Truck-tractor and semitrailer	172	112	65	20	8	1
Truck and trailer	16	8	8	6	-----	-----
Average, truck combinations	167	108	63	20	8	1
Average, all trucks and combinations	44	27	16	6	2	(2)
West South Central:						
2-axle, 4-tire	-------	-----	-----	-----	-----	-----
2-axle, 6-tire	10	7	4	1	-----	-----
3-axle	-------	-----	-----	-----	-----	-----
Average, single-unit trucks	4	3	2	(2)	-----	-----
Truck-tractor and semitrailer	149	113	73	30	12	3
Truck and trailer	10	10	10	10	10	----
Average, truck combinations	145	110	72	29	12	3
Average, all trucks and combinations	41	31	20	8	3	1
Mountain:						
2-axle, 4-tire	2	2	2	2	2	------
2-axle, 6-tire	34	31	19	11	7	(2)
3-axle	63	60	48	34	24	-----
Average, single-unit trucks	15	13	8	5	3	(2)
Truck-tractor and semitrailer	233	185	139	74	35	6
Truck and trailer	258	198	136	55	29	15
Average, truck combinations	238	187	138	71	34	8
Average, all trucks and combinations	62	50	36	19	10	2
Pacific:						
2-axle, 4-tire	-------	-----	-----	-----	-----	-----
2-axle, 6-tire	6	4	2	1	1	1
3-axle	13	5	(2)	-----	-----	-----
Average, single-unit trucks	4	2	1	(2)	(2)	(2)
Truck-tractor and semitrailer	166	127	80	22	6	1
Truck and trailer	299	212	83	7	(2)	--------
Average, truck combinations	207	153	81	17	4	1
Average, all trucks and combinations	75	55	29	6	1	(2)
United States average:						
2-axle, 4-tire	1	1	1	(2)	(2)	-----
2-axle, 6-tire	19	15	11	6	3	(2)
3-axle	68	50	38	22	12	3
Average, single-unit truck	11	9	6	3	2	(2)
Truck-tractor and semitrailer	210	162	119	58	28	6
Truck and trailer	281	227	148	75	46	14
Average, truck combinations	214	165	121	59	29	6
Average, all trucks and combinations	68	53	38	19	10	2
Average, 1948	73	56	42	23	11	3
Average, 1947	59	45	32	15	7	1

[1] Data omitted because of insufficient sample.

[2] Less than 5 per 10,000.

Table 14.—*Number of trucks and truck combinations per 1,000 loaded and empty vehicles, in private and in for-hire operation, t exceeded various load limits by various percentages of overload in the summer of 1949 (U. S. average)*

Type of vehicle	Private operation						For-hire operation					
	Number per 1,000 over-loaded	Number per 1,000 overloaded more than—					Number per 1,000 over-loaded	Number per 1,000 overloaded more than—				
		5 percent	10 percent	20 percent	30 percent	50 percent		5 percent	10 percent	20 percent	30 percent	50 percen
NUMBER OF TRUCKS AND TRUCK COMBINATIONS PER 1,000 EXCEEDING PERMISSIBLE AXLE, AXLE-GROUP, OR GROSS-WEIGHT LEGAL LIMITS OF THE SEVERAL STATES												
2-axle, 4-tire	1	1	1	1	(1)	------	------	------	------	------	------	----
2-axle, 6-tire	11	7	5	2	1	------	23	16	10	6	3	(1)
3-axle	65	53	39	24	14	5	99	82	51	27	10	----
Average, single-unit trucks	6	4	3	1	1	(1)	27	20	12	7	3	(1)
Truck-tractor and semitrailer	148	103	70	29	12	3	164	112	71	29	14	3
Truck and trailer	111	61	42	25	20	15	247	140	88	38	6	3
Average, truck combinations	146	101	69	29	12	4	168	114	72	29	14	3
Average, all trucks and combinations	26	18	13	5	3	1	131	89	56	23	11	2
NUMBER OF AXLES PER 1,000 TRUCKS AND TRUCK COMBINATIONS EXCEEDING THE 18,000-POUND LIMIT RECOMMENDED BY THE A. A. S. H. O.												
2-axle, 4-tire	1	1	1	(1)	(1)	------	12	12	------	------	------	----
2-axle, 6-tire	17	12	9	4	2	(1)	36	29	23	14	6	2
3-axle	40	29	20	9	5	------	97	76	47	27	15	4
Average, single-unit trucks	9	6	5	2	1	(1)	38	31	23	14	6	2
Truck-tractor and semitrailer	222	159	110	45	18	4	255	186	130	61	28	6
Truck and trailer	136	82	50	20	6	1	190	97	50	14	3	----
Average, truck combinations	217	155	107	44	17	4	251	181	126	58	27	6
Average, all trucks and combinations	39	28	20	8	3	1	195	141	99	46	21	5
NUMBER OF TRUCKS AND TRUCK COMBINATIONS PER 1,000 EXCEEDING THE MAXIMUM AXLE-GROUP LOADS RECOMMENDED BY TH E A. A. S. H. O.												
2-axle, 6-tire	(1)	(1)	(1)	(1)	------	------	1	(1)	(1)	------	------	----
3-axle	43	28	24	14	9	3	92	77	60	28	12	4
Average, single-unit trucks	1	(1)	(1)	(1)	(1)	(1)	8	6	5	2	1	(1)
Truck-tractor and semitrailer	71	54	36	18	9	2	102	74	50	23	11	3
Truck and trailer	135	113	89	54	45	20	341	270	175	87	50	11
Average, truck combinations	74	57	39	20	11	3	115	85	57	26	13	3
Average, all trucks and combinations	12	8	6	3	2	(1)	87	64	43	20	10	2
NUMBER OF TRUCKS AND TRUCK COMBINATIONS PER 1,000 EXCEEDING ANY OF THE MAXIMUM MOTOR-VEHICLE LOADS RECOMMENDED B Y THE A. A. S. H. O.												
2-axle, 4-tire	1	1	1	(1)	(1)	------	12	12	------	------	------	----
2-axle, 6-tire	16	12	9	4	2	(1)	36	29	23	16	6	2
3-axle	53	36	25	14	9	3	99	80	63	36	18	4
Average, single-unit trucks	8	6	5	2	1	(1)	38	31	24	16	6	2
Truck-tractor and semitrailer	185	142	104	50	21	5	228	177	129	64	31	7
Truck and trailer	140	121	95	51	41	17	372	296	182	90	49	11
Average, truck combinations	183	141	104	50	22	6	236	183	132	65	32	7
Average, all trucks and combinations	34	26	19	9	4	1	184	143	103	52	25	6

[1] Less than 5 per 10,000.

Report of Trends in Motor-Vehicle Travel Discontinued

For several years past, PUBLIC ROADS has annually carried a companion article, *Trends in motor-vehicle travel,* which provided estimates of total urban and rural travel and average unit travel and fuel consumption of each of the major classes of motor vehicles.

In making these estimates it has been necessary to predicate the estimates of a given year on the sequence of values obtained for previous years, with the 1936–37 period of the comprehensive State-wide traffic surveys as a base. As this base period has become more and more remote the hazards of the procedure have multiplied.[1]

The interval of nearly 15 years and the changes in circumstances affecting travel are so great that the estimates can no longer be published with confidence. It is hoped that they can be resumed when the States have accumulated a sufficient body of current basic data.

[1] A fuller explanation will be found in *Trends in motor-vehicle travel, 1947,* PUBLIC ROADS, vol. 25, No. 3, Mar. 1949, p. 160.

(*Continued from page 104*)

described here is applicable to such hydr materials as pozzolanic, slag, and na cements which cannot be analyzed accur by the tentative method for portland cem

A further application of this method w be for limestone or other calcareous mat even though certain types may be pletely soluble in mineral acid. By using J. Lawrence Smith fusion on such mate the eventual calcium in solution would b same as that obtained for the siliceous sam Thus, no previous knowledge of the ca content of the sample would be required the same correction curves would be applic

lame-Photometer Determination of odium and Potassium in Soils nd Other Siliceous Materials

THE PHYSICAL
SEARCH BRANCH
REAU OF PUBLIC ROADS

Reported by W. J. HALSTEAD, Chemist, and BERNARD CHAIKEN, Associate Chemist

RAVIMETRIC METHODS for determining the alkalies—sodium, lithium, and ıssium—are long and tedious. The lengthy ·ations required may introduce serious er- unless meticulous care is observed ughout the entire procedure. For this on, there has long been much effort di- ed toward developing an alternate pro- ıre for the determination of these ele- ıts. This has been accomplished by the nt developments in flame photometry. cessful and rapid flame photometric hods for the determination of sodium and ıssium in such complex materials as whole ɔd, serum, urine, fertilizers, portland ents (*1, 4, 7*),[1] plant tissues (*10, 11*), soil acts, and cation-exchange capacity of ; (*8, 9*), have been described elsewhere.

'he fundamental basis of flame photometry ı the long-known fact that all elements, n heated to a sufficiently high tempera- ɔ, will emit characteristic light waves of nite wave lengths. The intensity of these ssions varies directly with the quantity of element present. The temperature nec- .ry to cause the emissions for the various nents ranges from the extremely high ıe which may be obtained with an electric to the comparatively low temperature of as flame. The flame photometer is ap- able to those elements which emit radia- ıs at the temperature of an acetylene or pane flame. Essentially, it is an instru- ıt by which the desired element is intro- ed into a gas flame under carefully con- led conditions, and the characteristic wave gth of the element is isolated and its nsity is measured photoelectrically.

'he alkali metals—lithium, sodium, and assium—emit characteristic radiations at temperature of the propane flame and gas is generally used for the determina- ı of these elements. The flame photometer lso applicable to the determination of cal- m, strontium, barium, magnesium, man- ese, and chromium, provided a higher perature flame, such as that of acetylene, ısed.

---

[1] talic numbers in parentheses refer to the bibliographic ence list on page 104.

This article presents a method for using a flame photometer to determine the alkalies—sodium and potassium oxides—in soil and other siliceous material which cannot easily be decomposed by mineral acids. The method is much more rapid than existing gravimetric procedures, and yields results which are equally accurate.

The sample is decomposed by fusion and the melt is leached with hot water in order to bring the alkalies into solution as chlorides. The concentration of alkalies in the resulting solution is then determined by means of a flame photometer, using the direct-intensity method.

A wide variety of materials can be analyzed by the method, including soils, sands, rocks, various minerals, ceramic clays, fly ash, and pozzolanic, slag, and natural cements. The method is also applicable to the determination of the alkalies in limestones and other calcareous materials.

Summary

This article describes a method for using the flame photometer to determine sodium and potassium in various siliceous materials which cannot easily be decomposed by acids. These include such materials as soils, sands, rocks, various minerals, ceramic clays, fly ash, pozzolanic cement, natural cement, and slag cement. The alkalies are brought into solution by the J. Lawrence Smith fusion method with calcium carbonate, and the melt leached with hot water as is customary. The concentrations of the sodium and potassium oxides in the resulting solution are then determined with a flame photometer, using the direct-intensity procedure. Tests show that calcium is the only interfering ion present. By careful quantitative control of the reagents and control of the amount of washings, concentration of the calcium ion can be held substantially constant at 1,700 parts per million as calcium oxide. Correction can then be made for the effect of this constituent by the use of correction curves. This makes possible the calibration against standard solutions containing only sodium and potassium chlorides, which is advantageous since such solutions are used in a large number of other analyses.

In addition to soils, sands, various minerals, ceramic clays, fly ash, and similar siliceous materials, the flame-photometer method is applicable to the determination of the alkalies in the nonportland type cements such as pozzolanic, slag, and natural cements. While actual tests were not made, the method is indicated as also applicable to limestone and other calcareous materials. The advantage of the method for this type of material is that a neutral solution of a definite concentration of calcium oxide is obtained regardless of the calcium content of the limestone or calcareous material being analyzed.

Comparisons of the results obtained with the flame-photometer method and the results of gravimetric methods show the average differences in percentage to be less than 0.1 when 0.5-gram samples are used. This is of the same order as differences between two gravimetric results on the same sample. The time saved by the flame-photometer method is considerable. Comparative records show that for the same number of analyses only one-fourth the time is required for the flame-photometer method (including the time for calibration) as is required by the usual gravimetric procedure.

Many features of the given flame-photometer method follow well-established procedures. However, the quantitative evaluation of the interferences from other elements and the technique of the detailed operations as given in this article should be of considerable value to those engaged in analyzing such materials or to those who may be seeking further applications of the flame photometer.

Direct-Intensity Procedure

The instrument used in this study was a model 52A Perkin–Elmer flame photometer, which has been described in a number of publications (*1, 7*). This flame photometer can be used in either of two ways, both of which require careful calibration against standard solutions having a range of concentrations of the desired element overlapping that to be expected in the unknown samples.

These two procedures are known as the internal-standard method and the direct-intensity method.

In the internal-standard method, the emitted light-intensity ratio of the element sought and another element added in known amount (the internal standard) is measured. This is done by amplifying the photoelectric current resulting from the unknown until it equals that from the internal standard, the amount of amplification required being indicated by the reading of the gain-control dial. A basic requirement of the internal-standard method is that the element chosen as the internal standard be absent from the sample to be analyzed. The flame photometer used in this work is so equipped as to require the use of a lithium salt exclusively as the internal standard. However, this element is often present in materials of mineral origin (*5*, page 517) or highly sodic rocks (*12*). Thus, in analyzing a wide variety of siliceous materials, the use of the internal-standard method is not desirable.

In the direct-intensity method, a measure of the absolute light-intensity of the element sought is obtained directly by the meter reading and there is no interference from lithium when present.

Method of Analysis

The method described in this article is directly concerned with those materials which are not easily or completely decomposed by mineral acids, and thus require fusion or special digestion in order to bring the alkalies completely into solution.

The familiar J. L. Smith method of fusion with calcium carbonate, as described by Hillebrand and Lundell (*5*, page 787), was chosen, since its use limits the metals which go into solution. After the fusion the melt is extracted with water in the usual manner and the resulting solution is used for the determinations of the alkalies by means of the flame photometer. The adjustment and calibration of the apparatus follow closely the directions given in the tentative method of test for sodium oxide and potassium oxide in portland cement by flame photometry of the American Society for Testing Materials (*1*), the chief differences being that the standard solutions used in this method contain only sodium and potassium chloride, and the zero adjustment is made with distilled water.

By careful control of the weights of the sample and the reagents, and of the volume of wash water used, it was found that the amount of calcium in solution could be held substantially constant, and thus the results could be corrected for any interference resulting from this element.

In order to present a complete picture, the method of test, including the calibration of the instrument, the determination of the correction curve, and the preparation of the sample, is given here in detailed step-by-step procedure.

1. Reagents

(*a*) Calcium carbonate: A.C.S. "low-alkali" $CaCO_3$, limited to 0.02 percent total alkalies as sulfate.

(*b*) Sodium chloride: A.C.S. NaCl with a maximum limit of 0.01 percent potassium.

(*c*) Potassium chloride: A.C.S. KCl with a maximum limit of 0.02 percent sodium.

(*d*) Ammonium chloride: Reagent grade A.C.S. NH_4Cl.

(*e*) Brom-thymol blue indicator: 0.04 percent solution in water.

(*f*) Water: Distilled water.

2. Solutions

(*a*) *Sodium-potassium chloride stock solution.*—Prepare a solution containing 1.8858 gm. of NaCl and 1.5830 gm. of KCl (previously dried at 105° C. for several hours) dissolved in water and diluted to 1 liter in a volumetric flask. This solution contains the equivalent of 1,000 p.p.m. (parts per million) each of Na_2O and K_2O.

(*b*) *Calcium chloride stock solution.*—Prepare a solution containing 6.068 gm. of $CaCO_3$ per liter as follows: Weigh the $CaCO_3$ into a large beaker. Add sufficient water to form a slurry and then add concentrated HCl cautiously until the $CaCO_3$ is dissolved. Avoid any excess of HCl by adding the acid drop by drop with vigorous stirring until the solution just clears. Cool the solution to room temperature and filter into a 1,000-ml. volumetric flask. Dilute to the mark and mix thoroughly. This solution contains the equivalent of 3,400 p.p.m. of CaO.

(*c*) *Standard sodium-potassium chloride solutions.*—Using the NaCl-KCl stock solution, prepare standard solutions containing the equivalent of 5, 20, 40, 60, 80, and 100 p.p.m. each of Na_2O and K_2O. Store these solutions in acid-resistant glass bottles with ground-glass or rubber stoppers.

(*d*) *Correction solutions.*—Using the $CaCl_2$ stock solution and the NaCl-KCl stock solution, prepare solutions containing the equivalent of 0, 5, 20, 40, 60, 80, and 100 p.p.m. of Na_2O and K_2O, respectively, and each containing the equivalent of 1,700 p.p.m. of CaO.

3. Calibration of flame photometer

(*a*) Turn on the instrument, adjust the air pressure to 10 p.s.i. and the propane gas pressure to 5 p.s.i. Adjust the burner so as to give a faintly visible flame 5 to 6 inches high and with ⅛-inch cones over the burner grid. These cones should be uniform, quiet, and of a blue or greenish-blue color. Allow the system to warm up for approximately 30 minutes after the current and gas are turned on.

(*b*) Set the internal-standard dial at zero and adjust the meter reading to zero with the zero adjustment knob.

(*c*) Find the correct position on the wave-length dial for the element to be determined by pouring into the atomizer a portion of the 100-p.p.m. standard solution of Na_2O–K_2O and moving the selector slowly back and forth on each side of the indicated wave length for the element until the point of maximum deflection is noted. Set the wave-length selector at this point. The coarse and fine gain controls are used to adjust the deflections to the range of 90 to 100.

(*d*) Pour the 100-p.p.m. standard solution into the atomizer and adjust the controls until the meter reading is 100. Then pour in distilled water and adjust the zero-adjustment knob until the meter reads zero. I peat these two operations until no adjustme is necessary in going from one to the other.

(*e*) Next pour into the atomizer the 8 p.p.m. standard solution and note the me reading to the nearest whole division.[2] Che the zero reading with distilled water and t 100 reading with the 100-p.p.m. standa solution. If these readings are exactly ze and within one scale division of 100, resp tively, the reading for the 80-p.p.m. soluti can be considered correct. If the zero readi is not exact, or the 100-p.p.m. reading is n within one scale division of 100, repeat t adjustments in step 3 (*d*) and take anoth reading for the 80-p.p.m. solution. Contir until no adjustment of the zero and 100 poi is necessary after securing the reading for t 80-p.p.m. standard solution.

(*f*) In a similar manner, determine readings[2] for the 60, 40, 20, and 5-p.p. standard solutions of Na_2O–K_2O.

(*g*) Plot calibration curves for each oxi using cross-section paper of such type th each division on the ordinate represents meter reading of one unit and each divis on the abscissa represents a concentration 1 p.p.m. (see fig. 1, page 101).

4. Correction curves

(*a*) Using the correction solutions, termine the apparent Na_2O and K_2O conc tration in parts per million as directed for analysis of the samples in steps 6 and 7, w the application of the calibration curve determined in accordance with step 3 (*g*).

(*b*) To determine the reagent impurit make a blank determination, following procedure outlined in step 5 for the prepa tion of the sample and in steps 6 and 7 for determination of Na_2O and K_2O. The me readings obtained are converted to parts million (see step 3 *g*) and the latter val represent the effect of the 1,700-p.p.m. C in addition to the reagent impurities. S tract from the value for each oxide the va obtained for the correction solution contair no added NaCl or KCl. These values repres the effect of the reagent impurities alone.

(*c*) Add the effect of the reagent impuri as obtained in step 4 (*b*) to the appar sodium and potassium concentration obtai in step 4 (*a*). Plot the resulting appar concentrations as abscissas and the kn true value for the alkali oxide as ordina This gives a correction curve which inclu the reagent blank. Once obtained, it not necessary to recheck the curve exc when the reagents are changed or when so change is made in the instrument.

5. Preparation of sample

(*a*) Place 0.5000±0.0005 gm. of fi ground sample (passing No. 100 sieve) t an agate mortar, add 0.500 gm. NH_4Cl, grind until completely mixed.[3] Add 4.0 $CaCO_3$ to the mixture, grind until well mi and transfer the mixture to a J. Lawre

[2] For meter readings of all solutions in the lower half of scale, the apparatus is sufficiently stable and sensiti that readings may be made to the nearest half divisi less.

[3] Close control of the quantity of NH_4Cl is necessary it directly affects the amount of calcium which goes solution as the chloride.

th platinum crucible containing approxi-ely 0.5 gm. $CaCO_3$ in the bottom. Rinse mortar and pestle with approximately 0.5 $CaCO_3$ and add to the crucible. Cap the cible, tap it gently to cause the powder to le, and place it in a slightly inclined position refractory cylinder provided with a suit- hole to receive the crucible.

5) Heat the portion of the crucible within cylinder by means of a fish-tail flame ced well below the crucible for about 15 nutes or until the odor of ammonia is no ger perceptible. The heat should not be ong enough to cause vapors of NH_4Cl to ape. The crucible should be rotated at ervals during the early stages of the ignition. adually increase the heat until the crucible bright red and maintain this temperature 40 to 60 minutes.[4] Allow the crucible to l and transfer the sintered mass to a 250-ml. serole. Pour hot water into the crucible l digest until all remaining matter can be shed out into the casserole or until it is roughly extracted. Slake the sintered e in the casserole by adding cautiously a milliliters of water, then add approxi-tely 50 ml. more and digest on the steam h until the cake is thoroughly disintegrated o 8 hours). Disintegration may be aided grinding with an agate pestle during the estion period.

c) After the cake has completely disin-rated, adjust the volume of liquid in the serole to approximately 50 ml., evaporating necessary. Heat the covered casserole to ling on a hot plate, let the solids settle, l rapidly filter into a 250-ml. volumetric k made of acid-resistant glass. Add 30 of hot water to the casserole, break up lumps by gentle pressure with a pestle glass stirring rod, heat to boiling, let settle, l filter. Repeat the extraction with 30 of water three more times (a total of r 30-ml. washings). Transfer the bulk of residue to the filter paper with a minimum ount of hot water, and wash the residue the paper once or twice with hot water so to bring the filtrate level to within several timeters of the neck of the flask.[5]

Add three or four drops of brom-thymol e indicator to the flask and then add con-trated HCl drop by drop until one drop ses the indicator to change color. Cool flask and its contents to room temperature, l sufficient water to bring the liquid level the calibration mark, and mix well. This ution is then used for the flame-photometer alysis.

Determination of sodium oxide

(a) Warm up the apparatus and calibrate the sodium determination, following the tructions given in step 3.

(b) Add a portion of the sample solution the atomizer and record the meter reading the nearest whole division.[6] Then select standard solution which gives a meter ding closest to the unknown and record its reading. This latter value should agree to within one division on the meter scale with the average value established during the calibration of the apparatus. If it does not, reset the meter needle to the original calibration point by use of the fine-gain control. Check the zero and 100 division points with the appropriate standard solutions. Finally, alternate the use of the unknown solution and the closest standard until readings for the unknown agree to within one division on the meter scale and the reading for the standard similarly agrees with the calibration point. Record the average of the last two meter readings obtained with the unknown solution.

7. Determination of Potassium Oxide

Follow the same procedure as for Na_2O (step 6) except that the instrument is calibrated with the wave-length selector set at the point of maximum response to K_2O by use of the 100-p.p.m. standard solution.

8. Calculation of results [7]

(*a*) From the recorded averages of the meter readings for Na_2O and K_2O read the concentration to the nearest half division from the calibration curve (step 3*g*). This is the apparent concentration of the alkali oxide in parts per million. Convert this value to the corrected or true concentration by use of the correction curve obtained in step 4.

(*b*) Calculate the percentage of alkali oxide to the nearest 0.02 percent as follows:

$$\text{Alkali oxide, percent} = \frac{C}{20}$$

Where C = true concentration in p.p.m. (from correction curve), and

$$20 = \frac{0.5 \text{ (weight of sample)}}{250 \text{ (volume of solution)}} \times \frac{1{,}000{,}000}{100}$$

Constant Calibration Check Needed

Careful calibration and a constant check on the calibration of the flame photometer are essential for accurate results. The calibration depends on the constancy of a large number of the system components, such as voltage, tube sensitivity, gain control, gas pressure, air pressure, atomizer efficiency, and burner adjustment. The calibration must be made before each run and certain calibration points checked during a run as directed. However, with the instrument operating normally when the zero and 100-p.p.m. points are properly set, the balance of the calibration points

[4] In order to obtain a bright red heat, it may be necessary eplace the fish-tail burner with one of the Meker type.

[5] The final volume of the filtrate must be as nearly constant possible in order to insure a uniform calcium concentration.

[6] See footnote 2, p. 100.

[7] These calculations are based on a 0.500-gm. sample. For samples containing greater than 5 percent of either alkali oxide a smaller sample must be used and the calculations varied accordingly.

Table 1.—*Example of data obtained in calibrating the flame photometer with standard solution* [1]

Concentration of Na_2O or K_2O in standard solution	Meter reading (in divisions) for—							
	Na_2O determination				K_2O determination			
	Test 1	Test 2	Test 3	Avg.	Test 1	Test 2	Test 3	Avg.
P.p.m.								
5	5	5	4.5	5	3	3	3	3
20	22	21	21	21	18	17	17	17
40	46.5	46.5	45.5	46	39.5	38.5	39.5	39
60	70.5	70	70	70	64	63.5	64	64
80	87	87	87.5	87	84	83	83	83
100	[2] 100	------	------	[2] 100	[2] 100	------	------	[2] 100

[1] The standard solutions were prepared as given in step 2(*c*) of the method of analysis, page 100.

[2] Apparatus was adjusted to give a full-scale deflection of 100 divisions with the standard solution containing 100 p.p.m. of the alkali oxide.

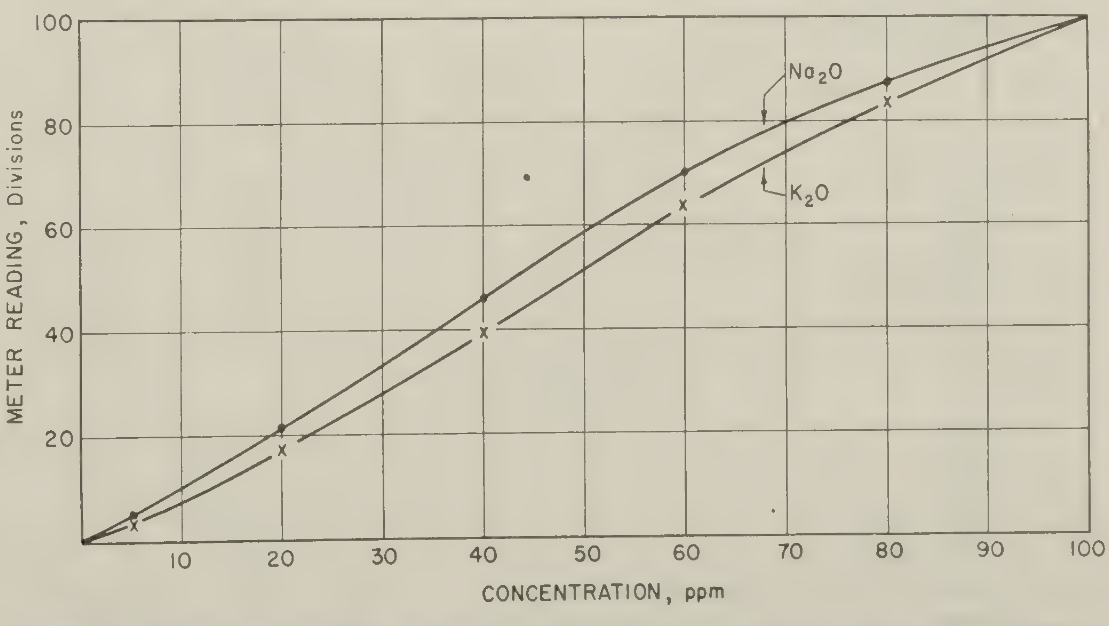

Figure 1.—Typical calibration curves for determination of sodium oxide and potassium oxide with the flame photometer, using the direct-intensity method.

Table 2.—*Suggested form for recording test data in flame-photometer analyses*

Sample identification	Na_2O determination (a similar table is used for K_2O determination)						
	Meter reading (in divisions) of—				Concentration		
	Nearest standard	Unknown			Apparent	True	On basis of sample
		Test 1	Test 2	Average			
					P.p.m.	*P.p.m.*	*Percent*

usually remain essentially constant so that it may not be necessary to draw a new calibration curve for each run. Also, during the course of a run there is usually very little change in the calibration unless the atomizer is clogged or the burner flooded, in which cases the trouble is immediately apparent. Thus, the practical accomplishment of the conditions necessary for accurate results is not difficult.

Table 1 shows an example of the data obtained in calibrating the instrument. These data are plotted in figure 1. Table 2 presents a convenient form for recording the test data obtained in analyzing unknown samples.

Calcium Interference

The effects of the interference of other constituents on the alkali determination by flame photometry have been described (*3*, *6*) for instruments using color filters to isolate the wave lengths. However, the instrument used in this study employs a two-prism monochrometer for wave-length separation and, therefore, it is likely that the interferences may be different than when color filters are used.

The elements to be concerned with are sodium, potassium, and calcium. The other elements which may occur in natural silicates—iron, aluminum, barium, lithium, magnesium, manganese, strontium, and chromium—have a negligible effect. Furthermore, because of the method of decomposition employed, these constituents will not be present in solution except in very small amounts. Mineral and organic acids will not be present as such to interfere with the results.

Table 3 shows the effects of varying amounts of sodium, potassium, and calcium oxides on the determinations of Na_2O and K_2O. For these tests the instrument was calibrated and the apparent concentration of the alkali in the solution was determined as described in the method of analysis. The results indicate that for the type of solutions employed sodium and potassium do not interfere with each other within the range of concentration studied. However, the calcium ion (shown as CaO), when present in considerable amounts, has a significant inhibiting effect on determinations of both sodium and potassium.

A study was made to determine the concentration of calcium to be expected in test solutions. Aliquot portions were taken f[...] a group of solutions prepared for the de[...]mination of the alkalies by the flame phot[...]eter. The amount of calcium in each s[...]tion was determined by a standard volume[...] method. The results of these tests are gi[...] in table 4, the calcium being expressed as [...] equivalent amount of CaO. The rang[...] these results was from approximately 1[...] to 1,800 p.p.m. with the average being 1,[...] Thus, 1,700 p.p.m. of CaO was taken as b[...] a suitable expression of the expected calc[...] concentration in all test solutions. Since [...] data shown in table 3 indicate that the ef[...] of calcium does not change greatly [...] concentration, deviations from this ave[...] value which normally may be obtained [...] not be sufficient to make a measurable cha[...] in the interference of the calcium ion.

Table 3.—*Effect of certain constituents on the sodium oxide and potassium oxide determinations with the flame photometer*

[parts per million]

Interfering constituent and its concentration	Amount added: None		Amount added: 5 p.p.m.		Amount added: 80 p.p.m.	
	Amount found	Error	Amount found	Error	Amount found	Error
SODIUM OXIDE [1] DETERMINATION						
K_2O: [1]						
5	0	0	5	0	80	0
80	0	0	5	0	80	0
CaO: [2]						
50	0	0	5	0	80	0
300	0	0	5	0	79	−1
700	2	+2	5	0	75	−5
1,200	1	+1	6	+1	75	−5
1,700	2	+2	7	+2	75	−5
2,200	2	+2	7	+2	76	−4
POTASSIUM OXIDE [1] DETERMINATION						
Na_2O: [1]						
5	0	0	5	0	80	0
80	0	0	5	0	80	0
CaO: [2]						
50	0	0	5	0	77	−3
300	0	0	5	0	75	−5
700	0	0	5	0	74	−6
1,200	0	0	4	−1	73	−7
1,700	0	0	5	0	72	−8
2,200	0	0	4	−1	71	−9

[1] The proper amount of A.C.S. NaCl or KCl was dissolved in water to give the indicated oxide concentration.
[2] Present in solution as $CaCl_2$. The proper amount of A.C.S. "low-alkali" $CaCO_3$ was neutralized with just sufficient concentrated HCl to give the indicated oxide concentration.

Table 4.—*Concentration of calcium as* [...] *in test solutions of silicates prepared* [...] *flame-photometer analysis*

Sample identification	Type of material	Conc[...] tratio[...] of Ca[...] in te[...] soluti[...]
		P. p.
19	Trap rock	1,60[...]
20	Diorite	1,62[...]
21	Fly ash	1,81[...]
22	do	1,71[...]
Blank *A*		1,70[...]
Blank *B*		1,73[...]
Average		1,70[...]

[1] Volumetric determination with standard $KMnO_4$ [...] on aliquot portion.

A more complete study was made to s[...] the effect of 1,700 p.p.m. of CaO on [...] sodium and potassium determination for [...] range of concentrations usually encounte[...] These analyses were made as before, u[...] the calibration curve obtained with pure s[...] tions of NaCl and KCl. The results [...] shown in table 5. These data further [...] firmed the conclusion drawn from the [...] in table 3 that, for this type of solution [...] within the range studied, the alkalies did [...] affect each other. Also, the interference [...] the calcium ion for a definite concentra[...] of one alkali metal is the same regardless [...] the concentration of the other alkali. [...] inhibiting effect of the calcium ion increase[...] the concentration of the alkali increases. [...] should be noted that for the lower concen[...]tions of Na_2O, 1,700 p.p.m. of CaO prod[...] a positive error (see tables 3 and 5).

Correction Curve for Calcium

The use of a correction curve to correct [...] the effect of the calcium ion is a depart[...] from the usual practice in flame-photome[...] applications. In the usual procedure, cor[...]tions would be made by using as standards [...] correction solutions, each of which conta[...] 1,700 p.p.m. of CaO with different amou[...] of Na_2O and K_2O. A calibration curve c[...]structed from data obtained with these so[...]tions would then automatically correct for [...] interference. For laboratories concerned w[...] the analysis of this type of silicate mater[...]

Table 5.—*Effect of alkali oxides and 1,700 p.p.m. calcium oxide on the alkali determinations with the flame photometer*

[parts per million]

Na₂O determination								K₂O determination							
Amount of Na_2O in sample [1]	Apparent Na_2O determined when amount of K_2O added [1] (and 1,700 p.p.m. of CaO also added [2] in each case) was—						Average apparent Na_2O determined	Amount of K_2O in sample [1]	Apparent K_2O determined when amount of Na_2O added [1] (and 1,700 p.p.m. of CaO also added [2] in each case) was—						Average apparent K_2O determined
	0 p.p.m.	5 p.p.m.	20 p.p.m.	60 p.p.m.	80 p.p.m.	100 p.p.m.			0 p.p.m.	5 p.p.m.	20 p.p.m.	60 p.p.m.	80 p.p.m.	100 p.p.m.	
0	2	2	1.5	2	1	--------	1.7	0	1	0	1	0	0	--------	0.4
5	6	6	6	7.5	7.5	--------	6.6	5	5	5	5	5	5	--------	5.0
20	20	20	[3] 18.5	21	21	--------	20.5	20	15.5	16	15.5	17.5	17.5	--------	16.4
60	56.5	55	[3] 52.5	57	56	--------	56.1	60	52	52	52.5	[3] 55.5	51	--------	51.9
80	73	74.5	76	77.5	74.5	--------	75.1	80	73	72	[3] 68.5	72	72	--------	72.2
100	------	------	------	------	------	95, 95.5, 95.5	95.3	100	------	------	------	------	------	90.5, 90.5, 90	90.3

[1] Added to solution as A.C.S. NaCl or KCl in calculated amounts to give indicated oxide concentrations.
[2] In solution as A.C.S. $CaCl_2$, "low-alkali" $CaCO_3$ was dissolved with concentrated HCl, care being taken to avoid excess HCl.
[3] Not included in average.

y, this is obviously the simpler procedure. the Public Roads laboratory, however— l it is believed the same condition will be e in most other laboratories—it is necessary analyze a variety of materials such as soil cement extracts with water, water analysis, ., which require the pure NaCl–KCl standl solutions. Thus, these standard solutions readily available. Inasmuch as the thod for determining the alkalies in portd cement by flame photometry already quires a special set of standard solutions (*1*), was considered advisable to limit the numr of different types of standard solutions. addition, once the correction curve is tained for a particular instrument, there is need of repeating this work unless a change made in the reagents or in the instrument. hus, while the use of a correction curve may em to be at first glance an unnecessary step, r practical laboratory applications it is connient and economical.

Since the alkali impurities in the reagents ed also must be accounted for, the data tained with the correction solutions alone nnot be used directly as the basis of the rrection curve. Blank determinations were ade using the method as shown. These gave parent values of the sodium and potassium ncentrations which include the effects of the 700 p.p.m. of CaO, in addition to the alkali purities. Thus it is necessary to subtract om the blank determinations the effect of the lcium ion for zero concentration of the kali. The resulting value represents the kali impurities in the reagents, and an overl effect is calculated by adding the value of e blank to each of the values obtained with e correction solution. A curve is then nstructed using these apparent values as bscissas and the corrected or true values as rdinates.

For example, the correction curves used for the eterminations reported in this article were conructed as follows: The averages for each concenation shown in table 5 are equivalent to the ata normally obtained with the correction olutions. Blank determinations showed an verage apparent value of 2.5 p.p.m. for Na_2O nd 2.0 p.p.m. for K_20. Table 5 showed the ffect of the calcium ion alone (zero concentraion of alkali) to be +1.7 p.p.m. for the sodium etermination, and +0.4 p.p.m. for the potasium determination. The respective differences, 0.8 p.p.m. for sodium and 1.6 p.p.m. for potassium, represent the concentration of the alkali resulting from the reagent impurities. The combined effect is obtained by adding these values to the respective average values shown in table 5. These data, given in table 6, were then used to plot the correction curves shown in figure 2.

Comparison with Gravimetric Method

Table 7 shows a comparison between results obtained by an accepted gravimetric procedure and by the flame-photometer method described in this article. A variety of silicates were analyzed, including a large number of soils, in order to obtain as wide a range of alkali content as possible. For most samples there is very good agreement between the flame-photometer and the gravimetric results. For Na_2O, out of 24 samples only 3 showed differences in percentage greater than 0.10. For K_2O, 9 samples showed differences in percentage greater than 0.10, but only 1 of these differences was greater than 0.15. The average difference in percentage for sodium was 0.054 while that for potassium was 0.076. Since in most cases the gravimetric result represents only one determination, there is no assurance that this result is more accurate than that obtained with the flame photometer.

Table 6.—*Combined effect of 1,700 p.p.m. calcium oxide and reagent impurities on the alkali determinations with the flame photometer*

[parts per million]

Na_2O added [1]	Na_2O determined [2]	K_2O added [1]	K_2O determined [2]
0	2.5	0	2.0
5	7.4	5	6.6
20	21.3	20	18.0
60	56.9	60	53.5
80	75.9	80	73.8
100	96.1	100	91.9

[1] True concentration.
[2] Apparent concentration.

While data on the reproducibility of gravimetric results are limited, table 8 shows a comparison of duplicate gravimetric results for a few materials. These analyses were made in a routine manner, employing the usual technique with the average amount of care. It is noted that the differences between the results of duplicate tests by the gravimetric method are of the same order as differences between results of the gravimetric and flame-photometer methods.

The differences between gravimetric and flame-photometer test results found in this

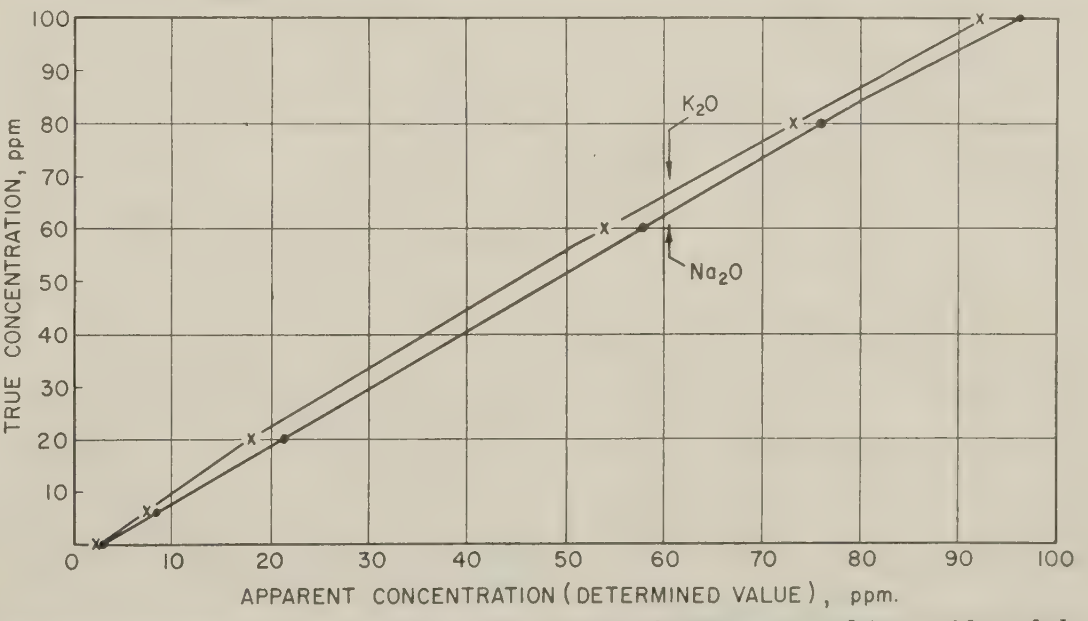

Figure 2.—Correction curves for the combined effect of 1,700 p.p.m. calcium oxide and the reagent blank on the sodium oxide and potassium oxide determinations with the flame photometer.

paper compare favorably with differences reported for other applications of the flame photometer. Barnes and others (2) recently described a method involving the use of an internal standard (lithium) in an instrument using filters to isolate the desired wave length. While their data for clays gave only the total alkali (Na_2O+K_2O) determined by chemical means, their differences are of the same order or slightly higher in most cases than the differences shown in this work.

For portland cement analyses the concentration of the test solution is such that 1 p.p.m. is equivalent to 0.01-percent alkali oxide. Results obtained in the Public Roads laboratory, as well as those which appear in various unpublished reports and in a report by Eubank and Bogue (4), show an average difference in percentage between gravimetric and flame-photometer results of from 0.01 to 0.03 for Na_2O and from 0.02 to 0.03 for K_2O. In the method for siliceous materials the concentration of the test solution is such that 1 p.p.m. is equivalent to 0.05 percent. Thus, while the actual difference reported for portland cement is less, the difference in terms of concentration of test solution in parts per million is approximately the same.

Application to Non-Portland Hydraulic Cements

An interesting observation may be made in connection with the pozzolanic cements shown in table 7. Flame-photometer results for these same cements by the tentative A.S.T.M. method for portland cements (1) gave, for sample 23, 0.09 percent Na_2O and 0.39 percent K_2O, and for sample 24, 0.13 percent Na_2O and 0.59 percent K_2O. These values are considerably less than those obtained by gravimetric means or by the method given here. These and similar cements have alkalies associated with the acid-insoluble residue which are not brought into solution by the tentative A.S.T.M. method for portland cements. Thus, the proposed procedure

(*Continued on page 98, third column*)

Table 7.—*Comparison of results obtained by gravimetric and flame-photometer metho[ds]*

Sample identification	Material	Amount of Na_2O			Amount of K_2O		
		Gravimetric [1]	Flame photometer	Difference [2]	Gravimetric [1]	Flame photometer	Difference [2]
		Percent	*Percent*		*Percent*	*Percent*	
1	Soil	0.15	0.14	−0.01	4.08	4.20	+0.12
2	do	.07	.08	+.01	3.76	3.87	+.11
3	do	.11	.15	+.04	.40	.34	−.06
4	do	.43	.45	+.02	1.50	1.61	+.11
5	do	.84	.82	−.02	2.22	2.18	−.04
6	do	1.03	1.01	−.02	2.14	2.21	+.07
7	do	.72	.82	+.10	2.06	2.18	+.12
8	do	.39	.42	+.03	1.57	1.56	−.01
9	do	.50	.52	+.02	1.38	1.41	+.03
10	do	.73	.77	+.04	2.88	2.94	+.06
11	do	.49	.58	+.09	1.59	1.73	+.14
12	do	.92	.93	+.01	2.00	2.24	+.24
13	do	.84	.90	+.06	2.08	2.18	+.10
14	do	.10	.10	.00	.21	.16	−.05
15	do	.15	.06	−.09	.53	.51	−.02
16	do	.31	.18	−.13	1.32	1.31	−.01
17	Slag	.19	.15	−.04	.68	.75	+.07
18	Trap rock	2.52	2.77	+.25	.76	.77	+.01
19	do	2.64	2.69	+.05	.79	.90	+.11
20	Diorite	3.90	4.08	+.18	3.08	3.23	+.15
21	Fly ash	.25	.25	.00	2.34	2.34	.00
22	do	2.74	2.69	−.05	.81	.96	+.15
23	Pozzolanic cement	.21	.19	−.02	1.23	1.24	+.01
24	do	.16	.15	−.01	.86	.89	+.03
Average		------	------	.054	------	------	.076

[1] Analyses made by J. Lawrence Smith method of fusion, with potassium being determined as K_2PtCl_6 and sodium [ob]tained by difference from the weight of the combined sulfates.
[2] Calculated by subtracting the gravimetric from the flame photometer result.

Table 8.—*Comparison of results obtained in duplicate tests by the gravimetric determin[a]tion of sodium and potassium oxide* [1]

Sample identification	Material	Amount of Na_2O found			Amount of K_2O found		
		Test 1	Test 2	Difference	Test 1	Test 2	Difference
		Percent	*Percent*		*Percent*	*Percent*	
1	Soil	0.14	0.16	0.02	4.08	4.08	0.00
3	do	.09	.14	.05	.38	.43	.05
4	do	.51	.36	.15	1.55	1.45	.10
17	Slag	.21	.17	.04	.66	.48	.18
18	Trap rock	2.55	2.50	.05	.76	.76	.00
19	do	2.65	2.64	.01	.81	.77	.04
20	Diorite	3.83	3.98	.15	3.17	3.00	.17
21	Fly ash	.23	.27	.04	2.29	2.38	.09
23	Pozzolanic cement	.21	.21	.00	1.17	1.29	.12
24	do	.17	.15	.02	.85	.88	.03
Average				.053			.078

[1] Samples analyzed by J. L. Smith method of fusion with $CaCO_3$. Potassium determined as K_2PtCl_6 and sodium det[er]mined by difference from the weight of the combined sulfates.

Bibliographic Reference List

(1) AMERICAN SOCIETY FOR TESTING MATERIALS

Tentative method of test for sodium oxide and potassium oxide in portland cement by flame photometry. Designation: C 228–49T; 1949 Book of A. S. T. M. Standards, Part 3, p. 133.

(2) BARNES, R. B.; BERRY, J. W.; and HILL, W. B.

The flame photometer. Engineering and Mining Journal, Sept. 1948, vol. 149, No. 9, p. 92.

(3) BERRY, J. W.; CHAPPELL, D. G.; and BARNES, R. B.

Improved method of flame photometry. Industrial and Engineering Chemistry (Anal. Ed.), Jan. 1946, vol. 18, No. 1, p. 19.

(4) EUBANK, W. R., and BOGUE, R. H.

Studies on the flame photometer for the determination of Na_2O and K_2O in portland cement. National Bureau of Standards: Journal of Research, Aug. 1949, vol. 43, No. 2, p. 173.

(5) HILLEBRAND, W. F., and LUNDELL, G. E. F.

Applied inorganic analysis. John Wiley & Sons, 1929.

(6) PARKS, T. D.; JOHNSON, H. O.; and LYKKEN, LOUIS

Errors in the use of a model 18 Perkin-Elmer flame photometer for the determination of alkali metals. Analytical Chemistry, Sept. 1948, vol. 20, No. 9, p. 822.

(7) PRITCHARD, L. R.

Application of flame photometer to portland cement analysis. Pit and Quarry, July 1948, vol. 41, No. 1, p. 83.

(8) RIEHM, H.

Determination of potassium in lactate extracts with the flame photometer without precipitation of calcium. Bodenkunde und Pflanzene[r]nahrung, 1945, vol. 36, p. 109.

(9) TOTH, S. J., and PRINCE, A. L.

Estimation of cation-exchange capaci[ty] and exchangeable calcium, potassium and sodiu[m] contents of soils by flame photometer technique[s]. Soil Science, June 1949, vol. 67, No. 6, p. 43[9].

(10) TOTH, S. J.; PRINCE, A. L.; WALLACE, A[.] and MIKKELSEN, D. S.

Rapid quantitative determination [of] eight mineral elements in plant tissue by [a] systematic procedure involving use of a flam[e] photometer. Soil Science, Dec. 1948, vol. 6[6], No. 6, p. 459.

(11) WALLACE, A.; TOTH, S. J.; and BEA[R], F. E.

Sodium content of some New Jerse[y] plants. Soil Science, Mar. 1948, vol. 65, N[o.] 3, p. 249.

(12) WASHINGTON, H. S.

Manual of the chemical analysis [of] rocks. John Wiley & Sons, 1919, p. 19.

A complete list of the publications of the Bureau of Public Roads, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to Bureau of Public Roads, Washington 25, D. C.

PUBLICATIONS of the Bureau of Public Roads

The following publications are sold by the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Orders should be sent direct to the Superintendent of Documents. Prepayment is required.

ANNUAL REPORTS

(See also adjacent column)

Reports of the Chief of the Bureau of Public Roads:
1937, 10 cents. 1938, 10 cents. 1939, 10 cents.

Work of the Public Roads Administration:
1940, 10 cents. 1942, 10 cents. 1948, 20 cents.
1941, 15 cents. 1946, 20 cents. 1949, 25 cents.
1947, 20 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.
Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.
Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.
Part 4 . . . Official Inspection of Vehicles. 10 cents.
Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.
Part 6 . . . The Accident-Prone Driver. 10 cents.

UNIFORM VEHICLE CODE

Act I.—Uniform Motor-Vehicle Administration, Registration, Certificate of Title, and Antitheft Act. 10 cents.
Act II.—Uniform Motor-Vehicle Operators' and Chauffeurs' License Act. 10 cents.
Act III.—Uniform Motor-Vehicle Civil Liability Act. 10 cents.
Act IV.—Uniform Motor-Vehicle Safety Responsibility Act. 10 cents.
Act V.—Uniform Act Regulating Traffic on Highways. 20 cents.
Model Traffic Ordinance. 15 cents.

MISCELLANEOUS PUBLICATIONS

Bibliography of Highway Planning Reports. 30 cents.
Construction of Private Driveways (No. 272MP). 10 cents.
Economic and Statistical Analysis of Highway Construction Expenditures. 15 cents.
Electrical Equipment on Movable Bridges (No. 265T). 40 cents.
Federal Legislation and Regulations Relating to Highway Construction. 40 cents.
Financing of Highways by Counties and Local Rural Governments, 1931–41. 45 cents.
Guides to Traffic Safety. 10 cents.
Highway Accidents. 10 cents.
Highway Bond Calculations. 10 cents.
Highway Bridge Location (No. 1486D). 15 cents.
Highway Capacity Manual. 65 cents.
Highway Needs of the National Defense (House Document No. 249). 50 cents.
Highway Practice in the United States of America. 50 cents.
Highway Statistics, 1945. 35 cents.
Highway Statistics, 1946. 50 cents.
Highway Statistics, 1947. 45 cents.
Highway Statistics, 1948. 65 cents.
Highway Statistics, Summary to 1945. 40 cents.
Highways of History. 25 cents.
Identification of Rock Types. 10 cents.
Interregional Highways (House Document No. 379). 75 cents.
Legal Aspects of Controlling Highway Access. 15 cents.
Manual on Uniform Traffic Control Devices for Streets and Highways. 50 cents.
Principles of Highway Construction as Applied to Airports, Flight Strips, and Other Landing Areas for Aircraft. $1.75.
Public Control of Highway Access and Roadside Development. 35 cents.
Public Land Acquisition for Highway Purposes. 10 cents.
Roadside Improvement (No. 191MP). 10 cents.
Specifications for Construction of Roads and Bridges in National Forests and National Parks (FP–41). $1.50.
Taxation of Motor Vehicles in 1932. 35 cents.
The Local Rural Road Problem. 20 cents.
Tire Wear and Tire Failures on Various Road Surfaces. 10 cents.
Transition Curves for Highways. $1.25.

Single copies of the following publications are available to highway engineers and administrators for official use, and may be obtained by those so qualified upon request addressed to the Bureau of Public Roads. They are not sold by the Superintendent of Documents.

ANNUAL REPORTS

(See also adjacent column)

Public Roads Administration Annual Reports:
1943. 1944. 1945.

MISCELLANEOUS PUBLICATIONS

Bibliography on Automobile Parking in the United States.
Bibliography on Highway Lighting.
Bibliography on Highway Safety.
Bibliography on Land Acquisition for Public Roads.
Bibliography on Roadside Control.
Express Highways in the United States: a Bibliography.
Indexes to PUBLIC ROADS, volumes 17–19, 22, and 23.
Road Work on Farm Outlets Needs Skill and Right Equipment.

STATUS OF FEDERAL-AID HIGHWAY PROGRAM

AS OF OCTOBER 31, 1950

(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	$11,813	$12,354	$6,333	282.7	$4,954	$2,354	155.7	$13,921	$6,249	306.1	$31,229	$14,936	744.5
Arizona	392	1,923	1,374	44.5	1,897	1,265	26.2	5,793	4,137	120.3	9,613	6,776	191.0
Arkansas	1,531	9,168	5,234	227.0	3,152	1,538	83.6	17,763	8,759	462.7	30,083	15,531	773.3
California	2,655	23,715	9,088	177.8	4,847	2,363	22.6	44,665	21,994	277.2	73,227	33,445	477.6
Colorado	1,559	4,189	2,261	74.0	2,097	1,177	61.2	15,203	8,824	316.0	21,489	12,262	451.2
Connecticut	1,373	10,322	4,752	23.4	2,212	1,274	2.4	5,379	3,080	10.2	17,913	9,106	36.0
Delaware	1,345	618	318	21.3	1,409	703	4.5	5,471	2,620	41.6	7,498	3,641	67.4
Florida	2,366	14,424	7,325	387.0	8,936	4,422	225.1	12,901	6,452	256.3	36,261	18,199	868.4
Georgia	574	17,922	9,173	398.2	9,971	4,035	115.5	27,933	13,778	664.3	55,826	26,986	1,178.0
Idaho	3,707	8,959	5,642	292.2	915	561	60.9	7,058	3,835	141.4	16,932	10,038	494.5
Illinois	20,376	39,092	20,932	324.8	10,758	5,385	76.6	51,108	25,029	365.3	100,958	51,346	766.7
Indiana	6,648	32,943	16,004	165.3	6,142	3,655	24.5	16,009	7,948	94.1	55,094	27,607	283.9
Iowa	2,951	8,903	3,409	222.7	3,349	1,182	110.9	17,455	8,254	572.0	29,707	12,845	905.6
Kansas	3,434	9,520	3,903	968.7	3,700	1,878	449.5	12,762	6,385	620.1	25,982	12,166	2,038.3
Kentucky	1,491	11,512	5,565	103.7	6,034	2,978	107.9	17,675	8,703	321.1	35,221	17,246	532.7
Louisiana	3,294	20,827	9,227	165.7	5,659	2,594	60.9	20,296	10,744	261.4	46,782	22,565	488.0
Maine	1,290	7,302	3,866	84.2	789	398	11.1	6,348	3,359	61.1	14,439	7,623	156.4
Maryland	1,313	6,714	3,192	18.7	2,889	1,165	15.5	13,234	6,175	48.1	22,837	10,532	82.3
Massachusetts	2,476	3,390	896	.7	7,018	3,602	6.0	67,871	33,078	69.7	78,279	37,576	76.4
Michigan	2,431	17,043	8,775	454.1	7,484	3,922	134.9	41,014	16,889	409.7	65,541	29,586	998.7
Minnesota	1,757	7,329	4,361	752.6	1,935	954	215.5	22,180	12,009	677.9	31,444	17,324	1,646.0
Mississippi	3,882	14,804	7,791	529.3	3,828	1,839	127.2	6,932	3,546	237.8	25,564	13,176	894.3
Missouri	5,226	29,582	16,228	871.3	6,806	2,898	214.8	30,020	14,561	481.3	66,408	33,687	1,567.4
Montana	4,572	14,853	7,673	505.1	2,301	1,389	13.4	10,577	6,418	296.7	27,731	15,480	815.2
Nebraska	4,505	16,152	8,446	533.0	4,531	2,048	98.9	10,388	5,648	285.6	31,071	16,142	917.5
Nevada	1,644	3,423	2,819	117.3	925	765	29.6	3,868	3,184	105.1	8,216	6,768	252.0
New Hampshire	1,727	3,404	1,880	28.4	1,065	486	7.7	4,350	2,081	37.6	8,819	4,447	73.7
New Jersey	2,526	3,288	1,532	6.5	2,970	1,331	5.1	18,087	8,578	27.6	24,345	11,441	39.2
New Mexico	987	3,754	2,398	115.1	5,207	3,331	143.6	6,465	4,226	185.6	15,426	9,955	444.3
New York	24,816	63,536	31,347	180.0	29,461	11,369	69.5	103,468	49,045	187.5	196,465	91,761	437.0
North Carolina	991	18,123	8,686	458.4	5,072	2,485	88.0	23,506	11,116	583.3	46,701	22,287	1,129.7
North Dakota	2,224	7,642	3,949	1,052.1	3,694	1,692	323.3	4,917	2,456	519.9	16,253	8,097	1,895.3
Ohio	8,500	26,531	12,913	281.5	20,677	11,482	156.5	53,280	25,302	280.3	100,488	49,697	718.3
Oklahoma	2,415	10,431	6,088	96.4	10,015	5,266	199.4	18,733	8,734	451.1	39,179	20,088	746.9
Oregon	639	3,597	2,024	54.2	2,123	1,218	30.0	8,485	4,929	123.8	14,205	8,171	208.0
Pennsylvania	4,330	17,729	8,775	25.5	10,309	5,154	49.9	73,509	36,284	193.6	101,547	50,213	269.0
Rhode Island	248	6,159	3,079	49.6	1,853	989	3.9	12,155	6,149	10.1	20,167	10,217	63.6
South Carolina	1,919	9,717	4,937	227.8	1,523	643	66.7	8,767	4,604	292.2	20,007	10,184	586.7
South Dakota	1,028	7,153	4,051	673.3	1,747	1,028	162.1	10,621	6,451	789.1	19,521	11,530	1,624.5
Tennessee	1,116	12,713	6,162	268.0	6,493	3,030	105.0	18,594	8,485	362.9	37,800	17,677	735.9
Texas	2,175	3,269	1,678	216.0	12,964	6,918	318.7	48,473	22,707	1,219.2	64,706	31,303	1,753.9
Utah	1,417	3,946	2,888	92.3	675	500	24.3	5,968	4,358	183.4	10,589	7,746	300.0
Vermont	933	2,284	1,268	38.4	581	292	6.4	5,575	2,609	51.6	8,440	4,169	96.4
Virginia	4,272	21,455	10,628	488.1	6,793	3,340	186.2	13,253	6,477	194.5	41,501	20,445	868.8
Washington	402	11,975	4,941	74.8	2,714	1,327	36.8	18,652	9,030	171.7	33,341	15,298	283.3
West Virginia	722	16,952	7,084	135.0	2,330	1,193	45.0	8,950	4,543	77.7	28,232	12,820	257.7
Wisconsin	7,856	17,556	9,234	262.9	1,923	983	91.1	16,278	8,204	384.9	35,757	18,421	738.9
Wyoming	399	1,846	1,223	34.5	939	610	12.0	5,596	3,404	163.7	8,381	5,237	210.2
Hawaii	665	8,228	3,648	19.9	3,158	1,417	7.6	3,342	1,642	15.8	14,728	6,707	43.3
District of Columbia	1,487	4,150	2,075	4.1	899	662	1.8	1,240	619	1.8	6,289	3,356	7.7
Puerto Rico	848	13,157	6,023	66.2	2,077	870	6.1	10,024	4,220	37.7	25,258	11,113	110.0
TOTAL	169,247	645,578	323,098	12,694.3	251,800	123,960	4,601.6	1,006,112	497,911	14,049.7	1,903,490	944,969	31,345.6

U. S. GOVERNMENT PRINTING OFFICE 72190